Lazell E W (1915) Hydrated Lime: History, Manufacture and Uses in Plaster, Mortar, Concrete; a Manual for the Architect, Engineer, Contractor and Builder. Jackson-Remlinger Pittsburgh.

*The thrust of Lazell's treatise is clear and unambiguously promotes the use of dry hydrated lime for all building purposes, and for plastering. Advances in the industrialised production of reliable, good quality dry hydrate – both of high calcium and magnesian – lime indicated to him that this was the most convenient, most economic and most reliable form of slaked lime, obviating the need to either slake to powder or stiff putty or to dry powder by traditional methods, which he considered more time consuming; more vulnerable to the inexperience or inattention of the masons or plasterers who carried out the operation and with more variable and less reliably burned lump lime. At no point does he entertain the notion that this may be an inferior product, whether used as the only binder, or in combination with Portland cement. He includes images of a number of high-rise and high status buildings the masonry of which was built using dry hydrated lime and Portland cement, as well as having been plastered within with dry hydrated lime mortars. He quotes historic Italian sources, including Vitruvius, to argue that slaking lime to a dry hydrate, to be laid down for later use, was the best way to achieve mortar of the highest quality but then bemoans the unreliability of traditional methods of dry-slaking and disapproving of "the modern method of slaking the lime in the middle of a ring of sand and almost immediately hoeing in the sand. In the present practice, more often than not, the plaster is placed on the wall or the mortar laid between the bricks within a few hours." (pp39-40), a rare confirmation of Millar's earlier assertion that this was, indeed, general craft practice, although Millar suggests that hot mixed plasters be subsequently laid down for up to 3 months. For Lazell, industrially produced dry hydrate solved all of the inconveniences of traditional forms of lime, slaked by traditional means and is flagging up a definite shift in lime use not only in the USA but in Europe also; a shift that ran in parallel with the rise in the use of Portland cement and saw increasing combination of dry hydrates of lime and Portland cement for all uses in the Construction industry.*

Chapter III Classification of Lime.

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TYPES OF LIME. Classification of lime based upon chemical composition:

a) *High Calcium Lime* – containing at least 90% of calcium oxide
b) *Calcium Lime* – containing from 85% to 90% of calcium oxide
c) *Magnesian Lime* – containing from 85% to 90% of calcium and magnesian oxides, 10% to 25% being magnesian oxide
d) *High Magnesian Lime* – containing not less than 85% of calcium and magnesian oxides, not less than 25% being magnesian oxide
e) *Hydraulic Lime* – which contains as large a percentage of lime silicate, aluminate or ferrate as to give the material the property of hardening under water, but which at the same time contains so much free lime that the burned mass will slake upon the addition of water.

BUILDING TRADES CLASSIFICATION OF LIME.

Classification of lime and lime products based upon the form in which they are supplied the trade:

a) *Run of Kiln Lime* – the product as it comes from the kiln, without any sorting or further preparation
b) *Selected Lump Lime* – a well burned lime which has been freed from core, ashes and cinder by sorting
c) *Ground or Pulverised Lime* – lime which has been reduced in size to pass a ¼ inch screen
d) *Hydrated Lime* – a dry flocculent powder resulting from the treatment of quicklime with sufficient water to satisfy chemically all the calcium oxide present.

The various kinds of lime mentioned under the chemical classification may be brought into the market in any of the above four forms….

Chapter V

SLAKING LIME

QUICK OR SLOW SLAKING LIMES

…in order to render lime as it comes from the kiln suitable for use in mortar, it is necessary to slake it. This is **generally accomplished by adding sufficient water to the lime to produce a thick paste**….The high calcium limes are quick slaking and give off the greater amount of heat because these limes consist principally of calcium oxide, this being the material which, by combining with water, generates the heat. As the amount of impurities (silica, alumina and iron oxide), increases, the lime contains less calcium oxide and is therefore slower slaking. Such slow slaking limes are generally called 'lean' limes.

The dolomitic quick limes are slower slaking and generate less heat because they contain less calcium oxide (a part of this being replaced by magnesian oxide), which does not combine with water under the ordinary conditions of slaking….(Impurities make the process slower again).

METHOD OF SLAKING

The ordinary method of slaking quicklime is to add sufficient water to produce a thick paste after the reaction of slaking is completed….Sufficient water should be used in order that it may come into contact with all parts of the lime. If insufficient water is used some parts of the mass of lime become dry and are 'burned' in slaking. 'Burned' lime works tough and non-plastic in the mortar. If an excess of water is used, the slaking proceeds slowly and the resulting paste is thin and watery. Such lime paste is spoken of as 'drowned'.

Since various kinds of lime differ greatly in their behavior in slaking, some requiring more water and some a longer time to become reduced to a proper paste, it is necessary to exercise great care in slaking. **A quick slaking lime will require a large amount of water and this must be added quickly, also the lime must be turned over rapidly, so that the water has access to all parts and no 'burning' takes place during slaking.** On the contrary, the slower slaking limes…require less water, and care is necessary to see that these limes are not 'drowned'….Too often the slaking is left to inefficient and ignorant labor, with the result that the mass of lime is not thoroughly slaked, being either 'burned' or 'drowned'….

AGING LIME PASTE.

(Lazell supports the view that lime paste should be well-aged before use to allow full slaking to occur),

The necessity of aging lime paste before using was recognized by the Romans *[but contradicted by the experiments of French and US military engineers some decades before Lazell's work].* Vitruvius gives the following directions for the preparation of lime paste to be used in plastering.* "This will be all right if the best lime, taken in lumps, is slaked a good while before it is to be used, so that, if any lump has not been burned long enough in the kiln, it will be forced to throw off its heat during the long course of slaking in the water, and will his be thoroughly burned to the same consistency. When it is taken not thoroughly slaked but fresh, it has little crude bits concealed in it, and so, when applied, it blisters. When such bits complete their slaking after they are on the building, they break up and spoil the smooth polish of the **stucco.** *{Vitruvius is here describing the preparation of lime for fine stucco-work, not for building].*
"But when the proper attention has been paid to the slaking, and greater pains have thus been employed in the preparation for the work, take a hoe, and apply it to the slaked lime in the mortar bed just as you hew wood. If it sticks to the hoe in bits, the lime is not yet tempered; and when the iron is drawn out dry and clean, it will show that the lime is weak and thirsty; but when the lime is rich and properly slaked, it will stick to the tool like glue, proving that it is completely tempered."
"Vitruvius, translated by Morris Hicky Morgan, Cambridge, Mass., 1914, page 204. 38

The art of preparing lime mortar of the finest quality has survived in Italy *[again, for fine stucco finishes, and particularly, for repair and conservation of the same, and some 60 years before Lazell was writing]:*

"So late as 1851 an English architect, when sketching in the Campo Santo at Pisa, found a plasterer busy in lovingly repairing portions of its old plaster work, which time and neglect had treated badly, and to whom he applied himself to learn the nature of the lime he used. So soft and free from caustic qualities was it that the painter could work on it in true fresco painting a few days or hours after it was repaired, and the modeler used it like clay. But until the very day the architect was leaving no definite information could he extract. At last, at a farewell dinner, when a bottle of wine had softened the way to the old man's heart, the plasterer exclaimed, 'And now, signor will show you my secret!* And immediately rising from the table, the two went off into the back streets of the town, when, taking a key from his pocket, the old man unlocked a door, and the two descended into a large vaulted basement, the remnant of an old palace. There amongst the planks and barrows, the architect dimly saw a row of large vats or barrels. Going to one of them, the old man tapped it with his key; it gave a hollow sound until the key nearly reached the bottom. There, signor! There is my grandfather! He is nearly done for.' Proceeding to the next, he repeated the action, saying, 'There, signor, there is my father! There is half of him left.' The next barrel was nearly full. 'That's me!' exclaimed he; and at the last barrel he chuckled at finding it more than half full; 'That's for the little ones, signor!' Astonished at this barely understood explanation, the architect learned that it was the custom of the old plasterers, whose trade descended from father to son from many successive generations, to **carefully preserve any fine white lime produced by burning fragments of pure statuary**, and to each fill a barrel for his successors. This they turned over from time to time, and let it air- slake in the moist air of the vault, and so provide pure old lime for the future by which to **preserve and repair the old works they venerated.** After inquiries showed that this was a common practice in many an old town, and thus the value of old air-slaked lime, such as had been written about eighteen hundred years before, was preserved as a secret of the trade in Italy, whilst the rest of Europe was advocating the exclusive use of newly burnt and hot slaked lime." (quoted in Hodgson, Concrete, Cement, Mortar, Plaster and Stucco, pages 22 to 25).

NECESSITY FOR HYDRATED LIME

If a good, sound, smooth working lime paste is to be HYDRATED LIME made from lump lime, it is absolutely necessary that the lime be slaked some considerable time before

using. Compare the method of slaking recommended by Vitruvius and that of the skilled Italian plasterer with the **modern method of slaking the lime in the middle of a ring of sand and almost immediately hoeing in the sand. In the present practice more often than not, the plaster is placed on the wall or the mortar laid between the bricks within a few hours.** Such mortar must contain free lime that has not had time or opportunity to slake. This lime later takes up water causing the mortar to be crumbly or the plaster to crack and pop.

In spite of improvements in the method of producing lime with better and more economical kilns, the material is brought into the market in the same manner as it was centuries ago. Further, the method of slaking lime has changed only for the worse, in that our rapid modern practice does not admit of the slow action of slaking lime thoroughly on the operation.
The only improvement in the form of the **merchantable** lime, known to the author, is that of hydrated lime.

CHAPTER VI

MANUFACTURE OF HYDRATED LIME

Within recent years, a method has been introduced of treating lime with water in a suitable apparatus in which the lime combines with sufficient water to satisfy the chemical requirements of the calcium oxide, forming a dry, finely divided flour, the so-called Hydrated Lime. *Hydrated Lime can be defined as the dry, flocculent powder resulting from the treatment of quicklime with sufficient water to satisfy the calcium oxide.* This material comes into the market in bags…and is ready for use, requiring only **guaging with water and mixing with sand** in much the same way as cement is used. The fact that lime could be slaked to the form of a dry powder has long been known, and three methods have been used in the past to produce this powder.

METHODS OF SLAKING

1. Lime, in comparatively small pieces about the size of an egg, is placed in a basket and immersed in water for a minute or two, until hydration has commenced, when it is withdrawn. The wet lime is generally put in heaps or silos in order to conserve the heat and prevent the escape of vapour. The material swells, cracks and becomes reduced to a dry powder.
2. Lumps of lime are placed in a heap and wetted at intervals so that the mass is equally moistened throughout. The slaking proceeds as in the first instance.
3. Small pieces of lime are exposed to the air for a number of months. The material absorbs both water and carbon dioxide from the atmosphere, falling to a dry powder. The powdered form consists of a **hydrated sub-carbonate of lime** containing about 10% to 11% of water.

The methods of dry-slaking lime are crude, and unless the greatest care is exercised, the resulting dry product will contain particles of unslaked lime. Further, the hydrates produced by these methods **generally work short and possess poor sand carrying capacities.** In fact, hydrated lime produced by any of the above methods is **only suitable for use on the soil,** and such hydrate should not be confounded with hydrated lime manufactured by modern methods, (which are much more controlled and exact. Lazell details a number of modern, industrial processes)….

CHAPTER VIII

USE OF HYDRATED LIME IN SAND MORTARS.

It may be stated that hydrated lime is suitable for any use in the building trade to which lump lime can be put…

A mortar made with hydrated lime often does not trowel quite so easily as a mortar made from lime putty. The smooth working qualities of the hydrate can be greatly improved by proper method of manufacturing and by **allowing the mortar or paste to soak overnight so that the gauging water becomes thoroughly incorporated.** The great ease of handling hydrate and the thoroughness with which it has been slaked make up to a great extent for any lack of plasticity.

The use of hydrated lime does away with the necessity of slaking lime to a paste, thus saving the cost of slaking…Hydrated lime comes into the market in convenient packages of a definite weight. This makes it possible to proportion the mortar (exactly)…which is always appreciated both by architects and engineers. It is much more difficult to obtain accurate proportions of lime and sand when lump lime is used, especially as it is a **general custom to add as much sand as possible, with the result that the mortar is often over-sanded and possesses little strength.**

ADVANTAGES OF HYDRATED LIME

(LAZELL PRESENTED RESULTS OF TESTS ON BOTH HYDRATED AND LUMP LIME MORTARS TO AMRICAN SOCIETY FOR TESTING MATERIALS IN 1910…) One of the most important conclusions …**was that mortar produced from hydrated lime was stronger than that produced by lump lime slaked to a paste** ( - expected because hydrate fully and properly slaked)…The user in dealing with hydrated lime is handling a product **which can be definitely proportioned and will produce known results.** ….With lump lime the user is dependent upon the thoroughness of slaking and it is well known that unless paste is run off and stored for some considerable time, there is **no assurance of complete and thorough slaking.**

Practically all those who investigated the strength of lime mortars have recommended the use of hydrated lime rather than lump lime.

In Circular No.30, 1911, of the Bureau of Standards:

“The proportion of impurities in hydrated lime is generally less than that in the lime from which it is made. **In building operations, hydrated lime may be used for any purpose in place of lump lime, with precisely similar results** The consumer must pay the freight on a large amount of water, but the **time and labour required for the slaking is eliminated** and there is no danger of spoiling it either by burning or incomplete slaking…**For all building purposes hydrated lime is to be preferred to lump lime.** By its use the time and labor involved in slaking may be saved **and the experience of the labourer is eliminated as a factor in the problem.**

In plastering (the need to lay down lime or coarse stuff is removed, causing potential delay). Moreover, plaster made from lime does not set quite so rapidly or in the same manner as gypsum plaster…(leading people to think that hydrated lime will also cause delay)…By the use of hydrated lime the delay due to slaking and seasoning is done away with, and by a proper method of planning and rotating the work, the job can be completed without delay *[does hydrated lime carbonate faster than other forms?]….*

…Sand for use in lime mortars should be clean, free from dirt and loam, and as coarse as is **consistent with the character of surface required.** Investigations of sands have shown that coarse sand yields a stronger mortar than fine sand *[Treussart and Totten showed the opposite].* …

…(asserts that sand-carrying capacity of hydrated lime is very good)….It would require 264 pounds of hydrate to carry the same amount of sand as 200 pounds of lump lime….

Hydrated lime is especially adapted for use in the mortar mixer because the material comes on the work in a convenient form and in packages of known weight.
On a recent job with which the author is familiar, all the mortar used in the brick work was mixed in this manner. The mixer machine was operated only during the last few hours in the afternoon, enough mortar being prepared for next day's requirements. The mortar mixed in the machine was dumped into the basement in a pile and was **allowed to age overnight.** When used, the mortar was entirely satisfactory and worked free and smooth.

PREPARATIONS FOR HYDRATED LIME PLASTER.

WOOD LATH - THREE COAT WORK

Scratch Coat 1:3.5 + hair (by weight)

Brown Coat: 1: 4 + hair (by weight)

Finish Coat, White: lime putty properly gauged with Plaster of Paris.

Sand Float Coat 1:2.75 (by weight)

WOOD LATH – TWO COAT WORK

First Coat: 1: 3.5 + hair (by weight)

Finish Coat, white: as above

Sand Float finish: as above.

BRICK OR TILE, THREE COAT WORK (all by weight)

Scratch Coat: 1:4 + hair

Brown Coat: 1:4

Finish or sand float finish, as above.

TWO COAT WORK – as above, without brown coat.

ON CONCRETE:

8 LIME: 2.5 CALCINED PLASTER (GYPSUM): 1 SAND.

HAND-MIXED MORTARS.

(Best by mortar mixer but two methods if perforce by hand):

FIRST: soak the hydrate with water so as to produce a thick paste, and allow to stand over night, then add the desired amount of sand and sufficient water to give the required consistency to the mortar. It is generally conceded that **this method produces the more plastic mortar.**

SECOND: Mix the hydrate and sand dry, the same as with cement mortar, then add the water to produce the required consistency.

When hair is used, it should always be well soaked and beaten before mixing with the mortar. Thorough hoeing and mixing always improves the plasticity and working qualities of a mortar.

LIME-CEMENT MORTARS

In many cases where a mortar having a greater strength is required, or it is advisable to have considerable strength produced quickly, it is advantageous to use Portland cement in the mixture.

Investigations by various authorities have proven that hydrated lime and Portland cement can be mixed in any proportion, from an addition of 10% of hydrate to the Portland cement for making a cement mortar, to an addition of 10% Portland cement to the hydrate for making a hydrated lime mortar. The addition of hydrated lime to a cement mortar improves the **plasticity and water tightness,** and the addition of Portland cement to a hydrated lime mortar increases the early time strength.

ADVANTAGES OF HYDRATED LIME OVER OTHER FORMS OF LIME

- Hydrated lime is generally purer than the quicklime from which it is made
- Hydrated lime is easily subjected to inspection and tests, and the same material is used as is tested
- The use of hydrated lime does away with the slaking of lump lime, hence saves the cost and the space required for this operation
- Hydrated lime is thoroughly slaked and this fact can be determined by tests
- By the use of hydrated lime mortar definite proportions can be maintained. This is a difficult matter with lump lime
- The putty or mortar made with hydrated lime requires no aging to be assured of thorough slaking…In the south of Europe at the present time, it is the custom to slake lime the season before it is used.
- Hydrated lime can be economically mixed by means of a mortar mixer.
- Mortars made from hydrated lime are stronger than mortars made from lump lime slaked to a paste.
- Hydrated lime can be mixed with cement mortar or concrete in any desired proportions. It is a very difficult matter to mix lime paste with cement thoroughly.
- Hydrated lime can be stored without danger of fire. No heat is generated when water comes into contact with hydrate.
- Hydrated lime is not apt to be spoiled by air slaking, as is the case with lump lime. Often large amounts of lime are lost in this manner.
- Hydrated lime comes to the market in packages of definite weight and convenient size.
- The paper sacks generally used cost less than half as much as the barrels required to hold an equal weight of lump lime
- The paste made from hydrated lime requires no screening.
- There is no loss in the form of ‘core’ when hydrated lime is used.

Against all these advantages only two objections are obvious. One, the mortar made from hydrated lime often works harder and is less plastic than that made from lump lime. This

difficulty is generally greatly exaggerated. Second, hydrated lime will not carry so much sand as a corresponding weight of lump lime….

The second objection is dependable on the first, because the larger sand carrying capacity of lump lime paste is due to its plasticity, or buttery, easy-working quality. This quality of lump lime *[and especially of hot-mixed quicklime]* usually results in the addition of too much sand *[as during the 20th C as putty lime was more used, and during the Lime Revival].* The over-sanding of lime mortar is very generally practiced, since it is the custom to add as much sand as possible, in order to cheapen the cost of the mortar. **This results in a lean, over-sanded mortar possessing little strength.** The manufacturers of lime are not blameless in this respect, since they have educated the public to believe that the greater the yield of paste from a barrel of lime, the more sand it will carry, overlooking the fact that that a leaner lime, or one which does not yield as great a volume of paste, produces a stronger mortar [*though here Lazell is comparing meagre, feebly hydraulic limes].*

The increase in bulk when lime is slaked is mostly due to the water mechanically absorbed. When the lime mortar hardens, this water evaporates, causing it to shrink and the excess water is therefore a source of weakness and not strength. The greater the amount of water held mechanically, the greater the volume of the paste, and therefore, the less the amount of binding ingredient or lime contained in a volume of paste.

It has been proven by many experiments that the poorer limes make the stronger mortars. These poor, or lean limes contain clay, which unites with the lime during the process of burning, and the presence of this clay imparts some hydraulic or hardening properties to the mortar. These hydraulic limes are largely used in Europe, but, unfortunately, little of this material has been manufactured in this country. Practically the same results can be obtained by the use of a mixture of hydrated lime and Portland cement.

From all the advantages possessed by hydrated lime it would appear to be the **best form** of lime to be used. It is perfectly logical that the process of slaking **should be taken away from the haphazard manner used on the work and done at the point of manufacturer of the lime, where skilful supervision is possible. (80)**

Elis Warren Lazell (1915). Hydrated Lime: History, Manufacture and Uses in Plaster, Mortar, Concrete; A Manual for the Architect, Engineer, Contractor and Builder. Jackson-Remlinger, Pittsburgh. Facsimile by Filiquarian Publishing LLC.