Traité théorique et pratique de l'art de calciner la pierre calcaire et de fabriquer toutes sortes de mortiers. M. Hassenfratz 1825

SECOND PART : USE OF LIME
Preliminary stages we subject the lime to and the differences of various limes

p129 There exist, in many countries, monuments which have resisted the destructive action of time. The mortars in almost all these antique ruins have acquired such hardness that sometimes the stones themselves break before the mortars do. Observers believe this hardness in the mortars is the result of the way they were made and **particularly of how the lime was slaked.**

So everyone rushed to consult the works of the Ancients, **in which a few details were given**, whether on lime slaking or on the preparation of mortars. We noticed, attentively, the small differences in the description of these preparations and we may think these differences explain the (good) quality we observe in those mortars and the hardness they attained.

Pliny, Vitruvius, Saint Augustin and others reported two methods of slaking, the first, **by immersion, fusion and marceration and the second by aspersion, imbibition, air slaking and natural pulverisation.** We thought to attribute to this second method to prepare lime, which is not usually (p131) employed, the good quality mortar we obtain, and Loriot expressly recommends this method of slaking in his mortar compositions.

(A paragraph on what Vicat says are the three ways to slake lime then talks about Ancient buildings erected without mortar).

Some observers doubt, with reason, the superiority we attribute to the Roman mortars over the ones we employ today. They notice that the constructions we focus on as those of good quality Ancient mortars are, in some ways, anomalies, exceptions to the ordinary constructions. Only a few survived; how many disappeared (p131) from the surface of the earth! The buildings which survived were, probably, made with mortars that consolidated and of which the hardness increased with time. The other constructions could have been built with 'light' mortars, soft and less resistant. We are led to believe that their short lives were mostly due to the bad quality and poor solidity of the mortars. *[by Vicat]* Pliny even complains in the book XXXVI of the bad quality of mortars, which cause houses to collapse.

This **variation in the hardness** in mortars, built from unchanging principles and methods can still be observed today. We could still wonder what is this good quality and hardness in the mortar we observe in several antique monuments.

It would be easy to say that the cause of the three ways of lime slaking - indicated by Pliny, Vitruvius, St Augustin etc – is exclusively **related to the nature of the lime itself**. That several limes, slaked by immersion, fusion and maceration can be conserved a long

time in pits; that many of them get better with time and should be used after a few years. However, we should not conclude this method of slaking can be applied to all limes.

Grignon states, page 351 of his *Mémoires de Physique*,

p132 that a 'procuror' of the Bourbonne Benedictines, melted and marcerated a big quantity of lime several months before starting to build. But was quite surprised when he discovered that the melted lime - destined for the mortar - was **in the state of a solid and hard mass, good to use as rubble.**

In this country (he probably means region, not country), as well as in the vicinity of Metz, where the lime has similar properties, **we are accustomed to employ fresh lime just made and to slake it by aspersion or instantaneous imbibition. It falls into dust and we make a mortar by adding water to the powdered slaked lime to reduce it to a paste**. **When slaked by immersion and maceration, the lime should be used in the following eight days of its slaking otherwise it hardens and loses its property to bond, gather, attach and adhere stones together.**

In the areas of Padua and Montélimart, the stone we burn produces a lime, in a very short time, which hardens quickly. This lime therefore could not be slaked by immersion or maceration in mass. We need, if we wish to conserve it, to only slake it by aspersion and imbibition. *[to a dry powder]*

The three methods to slake lime, mentioned by P, V and A etc are necessarily inherent to the nature of the lime and that not all lime stones can be slaked by immersion and maceration to be conserved. Some of them can conserve their properties by only slaking by aspersion, imbibition or by letting them fall into dust naturally. **This method of slaking is still used today, in the Indies, in Europe and in the countries where lime hardens** (p133) **quickly**. It seems we should consider this particular method to slake lime, that Loriot, Delafaye and others, indicate as a way to obtain a better mortar and that we should consider this method for the limes that require it. However, **each method of slaking can be more or less beneficial when applied to each type of lime according to the purpose and the use we wish to make them.**

(…) The Romans were so convinced of the enhancement of the macerated lime, acquired by time in the pits, that Pliny states Ancient laws forbade the people from using the lime unless it was three years of old. And that is the reason why the coatings and daubs (enduits) were not damaged with cracks and crevices. *[for plaster finishes and limewash only]*.

P 134 Fat lime can be easily conserved after being slaked by immersion and maceration and improves by being conserved in a state of paste; it also acquires in many circumstances, great advantages by being slaked spontaneously and conserved in barrels. Thus, made into **mortar mixed with quartz sand, lime can reach a greater hardness by being slaked spontaneously instead of fusion in water whether the mortars were placed in a humid area, in a covered place, or on a roof.** Spontaneous slaking is

(p135) also advantageous when employed for the making of 'béton,' meaning mortars that harden under water.

P137
We saw previously lime can be slaked in three methods, 1. by natural efflorescence (falling into powder), 2. by aspersion (p138) 3. by immersion, fusion and maceration. In the first two cases, some humidity in the air and water penetrate into the stone, combine with the lime, solidify and let escape all the heat liquid water and solid water have. Each particle of water, by coming between the lime particles, to unite intimately with each other, pushes the lime molecules from each other, destroys their cohesion, making them detach and separate themselves from the mass. It is how a piece of solid lime becomes a powdery substance.

In the third case, the first molecules of water, after unified and solidified with lime molecules, attract in return new molecules of water that gather to the first ones. The mass then takes the consistency of a paste and the excess of water dissolved from the lime allows it to turn into a liquid state.

In the slaking by immersion, fusion and maceration, two successive operations must be distinguished. The first how lime reacts to water and by the action of the mass, forces the water to solidify with lime. The second, the action of water on the lime hydrate, increased by the water mass, transforms the hydrate into a liquid. **In the first case, we have a dry hydrate lime and in the second water lime or a dissolution, a mix in a pasty state, of lime hydrate in water.** The pasty state that lime acquires in the maceration can be seen as an 'in-between' state from the two extremes of water combined with dry lime and liquid lime dissolved in water. It is, if you like, lime hydrate combined with lime water.

P144 Talks how Delafaye explains slaking lime.

P150
We can use several methods to slake lime - by dissolving in water (délaiement), immersion and maceration. The most employed method consists into digging in the ground a receiving basin and to form on top of the first one, a second basin destined for the slaking. We link the two basins with a canal that we can open and close at will. The bottom of the slaking basin is solid built with planks or stones, bricks or tiles. The quicklime is placed in it, covered by water, it heats up and dissolves. We stir with wooden tools (rabots = can't find any translation) to facilitate the fusion, break up the big lumps and dissolve it completely.

A few builders add water incrementally to maintain the lime in a liquid paste. Several advise to **be careful in adding too little or too much water. They say that too much water drowns the lime and that too little burns it,** dissolves its particles and reduces it to ashes. It is difficult to know in advance or without previous experience on the exact quantity of water needed, because this quantity depends on the nature of the lime. The purer , the fatter it is, the more water it needs. The more foreign substances it contains,

the less it needs. Usually, the necessary quantity of water varies from one to three parts (of water) for one of lime.

P151 It is essential to deliver all at once the quantity of water necessary to slake lime because cold water reaching non-fused parts, delays and stops the fusion. After being certain that the lime is dissolved, the connection between the two basins is opened. In order to pour into the lower basin, we continue to stir until the slaking basin is completely empty, after which, the passage is closed. The same operation is repeated until the receiving basin is full or we have slaked all the lime we needed. During the discharge from one basin to another, **all lumps and foreign bodies are kept in the slaking basin,** as they will damage the quality of the lime, by placing a grid in the canal.

P152
Some builders advise to use fresh lime right after its slaking, others recommend that the lime rests a few years in a receiving basin. Vitruvius and Palladio share this view, the latter, though, does not mention anything about basins. The lime of Padua, he states, should be used right after its fusion, otherwise if kept, the lime burns, consumes and hardens and would be unusable.

If several limes, as for example the ones with pure calcareous carbonates, can be conserved in basins and improved with time as Vitruvius, Palladio, Philibert Delorme believe, it would be dangerous to recommend this conservation (p153) as a general method because several limes, such as the ones from Padua, Montélimart, Bourbonne etc would harden in a basin and could therefore not be used.

(…) Philibert Delorme proposed, in imitation of the Ancients, to dig a hole and to place the lime out from the kiln in this basin, covering it with a layer of sand thick enough to prevent the escape of steam and to throw on water in great quantities lime to dissolve the lime and not burn it. Seal the cracks at the surface of the sand to prevent the escape of ‘smoke’. . **Because it is essential that the sand should not be mixed with the lime, we place in between them withy panels** *(claies d'osier)* or straw or cane mats. When we wish to use it, we uncover it and (p154) take the quantity needed and cover it back up immediately. The rest under the sand is conserved as long as needed and without being altered. However, this lime needs to have at least fifteen days of fusion before use, the older it is, the better the quality.

(…) Paris builders usually count two parts of slaked lime paste for one part of quicklime. This proportion is variable, there are light and impure limes which make barely one part slaked lime paste for one part quicklime. Some others, such as fat limes, produce three parts and a half of pasty lime for one of quicklime.

(…) dry lime fused by immersion, as practiced in Padua, Montélimart etc gives no inconvenience to this process. However, this slaking method, or dry fusion, is related to the burning of the lime. **As to what we call 'drowning', which is another way of slaking, in a bigger quantity of water needed to conserve it, after** (p 155) **being**

slaked. This (excessive) quantity does not at all prevent complete fusion of the lime
But, **because the temperature is not as high,** the slaking is slower and this excess of water will soon slowly drain into the ground in which the basin was dug, and the lime will reach the degree of humidity and stiffness at which it should to be used.

If slaked with too little water, the temperature becomes too high, lime flows with more difficulty into the second basin and we have to add more water to facilitate the flow, **which delays and stops the fusion**. It is better, then, to add a bit too much water rather than less. However, **the best would be to use the necessary amount of water.**

We find in the Encyclopedia another method to slake lime by immersion and maceration which is based on a prejudice. It needs two basins placed and prepared just as described previously, the lime run into the lower basin. When all the lime is received, we will throw as much water again as we used to slake it and will stir it and let it rest for 24 hours, which will give it time to settle *(Arts et Métiers de l'Encyclométhodique, tome 1 p 462*),
(p156) after which we will find the lime covered in a greenish water which will contain all its salts and we will put this into barrels. After this, we will get rid of the lime at the bottom of the basin, which would have became unusable, and will slake some new lime with this water saved in the barrels. This preparation makes the lime better, perhaps, because it contains twice as much salt. This is where we end the description.

This process is based on the idea that lime has salt, and that it is those salts which convey the good quality and efficacy. It is also on the same idea, that we mix a quantity of water with the lime for it cannot be burnt or drowned because in the first case, salts decompose and disappear and in the second case, salts, dissolved by the abundant amount of water infiltrate with the water through the basin walls *(into the ground)*.

Even if this supposition should not be taken seriously by educated men, we ought, however, to discuss it for a moment as a favor to the numerous entrepreneurs who truly believe in the existence of these salts.
But we have to repeat ourselves in saying we should always employ in one go, all the necessary water needed for the slaking and only this quantity. All the analysis of pure limes, made until now by Vauquelin, Thenard, Klaporth and other distinguished chemists, only found one result which is one only substance: lime without mixtures (p157) or combinations of any types of salt.

The water that dissolved the lime and which we collected in a basin were analyzed and only gave water and lime. At last, the vapour which escapes from the lime when it fuses was also analyzed and only resulted in water and lime content. This vapour is exactly the same as the water on top of the lime.

We do not know in which circumstances the author of the article from the Encyclopedia perceived green water on the surface of the lime. We can assure you that in similar circumstances, we did not obtain green water. At last, to complete our researches, after having removed the water on the surface of the lime, which the author says cannot be used, we compared it with mortar slaked with the floating water from the first basin. We

did not see any difference.

Despite the advantage Vitruvius, Palladio, Delorme, etc, find in employing lime only after it has been kept a few years in a basin, **we think fresh made lime and used straight out of the kiln, whatever the nature of the lime, should produce a good mortar and this, because this freshly lime undergoes fewer alterations** and contains less carbonic acid. **The builders are so convinced of this truth that, in many circumstances, they slake the *(right amount of)* lime as needed (p158) to make mortars by the ordinary method.** The rest of them, as there exist infinite varieties of lime, could some of them acquire improvement by staying longer in basin.

Some shape a basin with sand or cement with which the mortar will be made. They place the quantity of lime needed and slake it by adding all the necessary water. When slaked, they mix in the sand or cement and prepare the mortar to be used immediately. Others place the lime in a small sandy bassin, shape a heap and cover it with sand, then slake it by aspersion under the sand, as the same method of the Ancients and Delorme. **When the lime has slaked, they mix it with the sand and prepare their mortar by adding the necessary amount of water.**

This second method of slaking under the sand that we execute still today in many places, has the intent of stopping the evaporation of salts and obtaining a better mortar. We already know what we think about the evaporation of salts, however this method is favorable because the lime is slaked by aspersion. M. Vicat found this method preferable to the ordinary method and that the sand heap stops the evaporation of saturated lime which would inconvenience the workforce in charge of the slaking. This method with these two real advantages should be advised and even prefered to the ordinary method. This method can also (p159) be applied to any type of lime. But we have to repeat that in many circumstances, slaked lime conserved, improved and should be naturally preferred.

P 160 Chapter II : *On the division of lime*

They gave the name of fat lime to any kind of lime the volume of which increases considerably upon slaking, and can conserve for a long period this unctuousness, this binder allows a considerable amount of sand to be added for the fabrication of mortars.
They gave by opposition, the name of lean lime to any kind of lime the volume of which increases only slightly on slaking, that is rough at the touch, presents little untuousness or binding, in which only a small quantity of sand can be mixed when preparing mortars.

Soon we noticed that several lean limes hardened quickly and the mortar made from them **even hardened underwater**. From this, we concluded that this type of lime could be used in all hydraulic constructions in all places, in foundations exposed to humidity and we gave the name of lean lime (chaux maigre) to the ones we can use underwater.

As not all lean lime hardens underwater, we think it is appropriate to divide lean limes in two categories, lean limes - that do not have any particular properties and which are only distinguished from fat limes (p161) by its increasing only slightly when slaked and does

not take as much sand when making mortar - and lime that hardens underwater, which can be used on hydraulic constructions.

In respect to the various properties of limes, we believe we should divide them into five types : 1° fat lime, 2° lean limes, 3° limes that harden in the air, 4° limes that harden in water, 5° lime that harden in the air and underwater.

(p271) Preparations we make to the slaked lime destined for buildings.
There exist two types of construction, 1° the ones which are exposed continually to the action of air and the ones exposed to the action of water. For each type of construction, we need a different lime or a particular preparation for the same lime.

P368 **In the ordinary constructions, we prefer to employ fat limes and sand to gather stones and to build walls because this mortar is abundant and cheaper. In humid places, in particular underwater, wherever we wish to stop the action and infiltration of water we use a mortar that hardens underwater or we use some 'béton'.**

Depending on the nature and the size of the stones we want to bind together, the mortar requires different preparation. To bind ashlars together, that we place beforehand, the mortar should be very fine and very liquid in order to flow easily and to enter and fill in the narrow space. *[grout?]*

P400 **As to the stucco, meaning the coating we put on the last coat,** we take the best limestone we can obtain. It needs to be white and well slaked, it is slaked with great care by first dipping it in water before putting it (p401) in a basin and giving it water only when it starts to smoke. We need to pour the water progressively when lime starts to dissolve and to stir it constantly to facilitate its fusion. After the lime is slaked, some plasterers dilute it with water to pass it through a sieve to remove any bits. Others grind it on a marble slab. Rondelet believes the latter is the preferable method because it does not weaken it. What would be best is to slake lime by immersion and to let it through a fine sieve. We could also slake it into a mush and pass this mush into a sieve before letting it rest in order for the lime to reject the excess of water. **This sieved lime should rest four or five months and sometimes more because the longer, the better for the stucco for the ease of work and the economy of it.**

Freshly slaked lime is not the best option, unless it has been crushed several times to facilitate its dissolution. We can, thanks to this method, accelerate the process. The lime used for the stuccos should be fat limes because the other limes would harden while resting in the basin.