Champly, René (1910-1914) Nouvelle encyclopédie pratique du bâtiment et de l'habitation. Volume 2, avec le concours d'architectes et d'ingénieurs spécialistes. Paris. H. Desforges.

Champly, René (1910-1914) New pratical encyclopedia of building and of habitation. Paris, H. Desforges.

P40 Chapter II : (Gypsum) plaster,lime, cements and mortars

Plâtre – Stone plaster or gypsum is a sulfate of crystallized lime. We find it in most regions in a more or less pure state. Burnt between 140 and 150°C, it loses its water of crystallization and becomes powdery. We reduce it to a fine powder and if we dilute it in the same weight of water, it forms a binding mortar, with a very quick set. We can delay the set by increasing the quantity of water a little, but if we put too much water, the plaster can no longer set, being drowned.
(Then a paragraph on the kilns).

When the plaster is overcooked, it does not take much water and we say it is *fritté* (sintered); when it is undercooked, it is *aride* (dry) and does not form a binding and solid mortar.
A well cooked plaster should be creamy to the touch and stick to the hands. It should be stored away from air and humidity in bags or, better still, in hermetically sealed barrels, otherwise it takes the air and loses its qualities. A freshly made plaster sets faster than the one which has rested for several days.
Plaster can only be used in dry places. In the humidity, the plaster disintegrates; gypsum plaster mortars, the opposite of lime mortars, lose their consistency with age.
The Paris region produce excellent plaster which become very hard and very resistant to bad weather, thus we even use it for external coatings. But not all plasters have these exceptional qualities and many of them can only be used inside for masonry, coatings and cellings.

We distinguish : 1° *le plâtre au panier (in buckets)* which is delivered as it comes from factories; this is a raw plaster we use for masonry walls, partitions, infills and thick coatings. For thin coatings, we sift the plaster in a wicker basket or hopper.
2° *Le plâtre au sas* which has been sieved through a very fine sieve of metal mesh or horsehair. It is used for fine coatings, mouldings and ceilings.

3°*le plâtre au tamis*, sieved through silk cloth for fine coatings and mouldings.
4° *the plâtre à la pelle* (shovel) or *fleur de plâtre*, made from mixing plaster with a well dried shovel where the fleur de plâtre sticks to it (I assume, very fine particles of plaster) and we let it fall on a cleaned cloth. It is used to fill the mouldings *and something else* (*The verb 'octer' doesn't exist so I don't know what it means about the mouldings)*.
To prepare the plaster, we put the water in a container and add the plaster with a trowel by spreading it in the entire mass of water and stirring it well. We let it rest for a few moments until the set starts to happen. Then the paste needs to be used quickly. We can only prepare what needs to be used immediately, in 2 or 3 minutes, because after this, the plaster becomes too hard to be handle. We use a yellow copper trowel because it rusts the iron. At last, to cover holes, we make *le plâtre en coulis* by almost drowning it, it becomes fluid and delays its set.
To harden it to form stuccoes, we mix it with quicklime milk (*or other ingredients)*.
Plaster stucco is a mix of 3 parts of slaked lime, 1 part of sand to 4 part of plaster *gâché serré* – which means the plaster has fully absorbed a certain quantity of water. We use it for coatings, cornices and ceilings.

Lime – by burning calcareous stones, we obtain lime, which, then, mixed with water, forms a binding mortar which hardens in the air by combining with carbonic acid from this air. A lime carbonate is slowly formed which solidly unites the stones.
When the burnt stones are pure limestone, we obtain a fat, or caustic, lime; when the stone contains clay or marl in greater or lesser proportion, we obtain hydraulic lime or slow or prompt cement. This clay can be added to the stone during the burning, such as an unburnt clayish soil or pulverised bricks or tiles. When the stone (to make lime) has quartz sands, various oxides, or other impurities, it makes a lime of inferior quality called lean lime.
The hydraulicity of the lime depends on the proportion of clay it contains. When the hydraulic limes set, they forms an aluminium silicate […]. this set happens even *under water* (in italics in the text) and the hardening continues for months after the initial set.

P45 Fat lime slakes with energy, expands, increases greatly in volume during slaking, dissolving almost totally in a sufficient quantity of water, forming what we call lime water. But in an insufficient quantity of water, [the lime]

can be conserved indefinitely in the state of paste, ready to be part of the mortar composition.
Hydraulic lime slakes with more difficulty, does not really increase in volume, but when it is reduced into paste, it sets under water and in the air more or less rapidly.
Roman cement does not slake, it needs to be mechanically reduced to a powder, before mixing it with water to obtain a paste. The paste hardens very quickly in water and in the air.

Pozzolans do not slake and only form a paste without any consistency when wetted after being crushed; they do not solidify when used on their own. But they possess, like roman cements, the property of turning non-hydraulic limes into hydraulic limes and to increase the hydraulicity of those limes which are not hydraulic enough.

Lime kilns – Kilns in which we burn limestone have many forms - we will only mention the simplest ones;
1° the intermittent kiln is the oldest, used in the countryside for the making fat lime locally. It is an ovoid (egg-shaped) in which we build a vault with lime stones, on top of which we add other stones, putting the biggest at the bottom and the smallest above to obtain a certain equilibrium in the burning. The fire is maintained under the vault for about 30 hours, and requires 200 kilos of coal or 800 kilos of wood for one cube meter of limestone. The burning is unequal and there are usually unburnt bits.
2° continuous kilns are of two sorts: the one in which the fuel is placed in alternate layers, the reloading always being done from the top (of the kiln) whereas the unloading is done from the bottom. The kilns where a continuous fire is present on the side of the kiln, have the advantage of giving a lime that has not been mixed with specks and ashes like the other ones.
Fat limes are delivered to be used as soon as they come out of the kiln, hydraulic limes and cements are slaked, reburnt, pulverised and delivered in bags from specially equipped factories.
[…]
Fat lime is conserved in heaps away from humidity. Hydraulic limes and cements have to be put in bags or, better, in hermetic barrels and preserved from contact with the air and particularly from humidity. Otherwise, they become stale quickly and lose all their qualities in a matter of months and even within a few days if humidity is great.

Lime slaking - fat lime is placed in a basin formed of planks, masonry or

even a simple hole dug in clay soil. We water the lime with a spray, the burnt stones crack, expand and melt into a beautiful white, cohesive and creamy paste ready to make a mortar.
This slaked lime can be conserved from one year to the next by covering it with a good layer of sand and a roof that will keep the rain water away from it, the sand that covers the lime needing to be kept moist.

Powdered hydraulic lime and cement should have the addition of water just before use by sprinkling and stirring it quickly in order to mix the water well with the mass. We gradually add water to obtain a paste of suitable consistency.
Hydraulic lump limes are slaked by aspersion with water in thin layers, before letting the lime rest, regularly wetting it for 24 hours before using it.

We know a fat lime is good when it expands violently and regularly and when it does not contain any underburnt or overburnt bits. The resulting paste is caustic; it burns the skin of the hands. By setting by the absorption of carbonic acid in the air, the lime is subjected to shrinking which makes it crack, which is avoided by the addition of sand to form the mortar.

Cements are divided into *prompt* cements or *roman cements*, the set of which happens a few minutes after being mixed and *slow cements* or Portlands, in which the set takes several hours and the hardness is only complete after a few months.
The prompt cements are used for under water or underground works, they do not harden well in the air. Slow cements for masonry foundations, basins and reservoirs walls, coatings for humid walls, paving […].

Prompt cement mixed with fat lime in the proportion of 1 to 2 cement to 10 of lime (by volume) gives a *mortier bâtard* (mixed mortar to be polite) that has great hydraulic properties.
Half to one percent of sugar added to the cement promotes its hardness but delays its set a little.

Mortars – Mortars are a mix of lime or of cement with sand and water forming a paste intended for binding masonry materials and for infills, coatings, sealing, etc.
We differentiate mortars thus: fat lime, used for raising walls, hydraulic lime for foundations, substructures, basement and works meant to be immersed. Slow or prompt cement for underwater works or in very humid places. Cement mortars with a slow set are greatly used for coatings, pavings

and facing.
The choice of sand has great importance in the good quality of a mortar. It should preferably have biggish and unequal size grains, except for finish coatings, where sieved sand is used instead. But what is very important is the purity of the sand, it should not contain any soil, particularly for making energetically hydraulic lime or cement.
The presence of sand in the mortar stops the lime from cracking when it shrinks back during setting. The sand also facilitates this set by allowing air access and then, later, of carbonic acid in the thickness of the mortar.
For various uses, the proportions vary from 1 of lime to 2 of sand and 1 of lime to 5 of sand. The first is a very fat mortar, with great cohesion for very solid works or under water. The last mix is a very lean mortar for exterior work of light masonry and infillings.

[…] The dosage of the quantities of lime, cement and sand are measured by the bag, shovel, bucket or wheelbarrow. The method of gauging by volume does not offer great exactitude and it is always preferable to gauge by weight when it involves neat works such as underwater masonries or at sea.
[…]
For certain uses such as pipe joints, stone or brick repointing, sealing, we use a prompt or slow cement mortar made only of pure cement and water without any addition of sand. This pure cement is subject to cracking in the air, so is only used underwater or in the very humid and stuffy places as, for example, iron sealing in the walls (← what ?).
(then a list of various types of mixes and their proportions).

We see from these compositions, so variable in lime, sand, cement and pozzolans, in how many ways it is possible to obtain more or less hydraulic products according to ones needs. But it is safe in any case to try by oneself the various mortars we can form by the judicious combinations of all these elements and to always count on your personal experience of what you can derive from these various elements. Because these elements often vary in composition from the same place, forcing changes to the proportions of the mix.

How to make mortars – mortars and mixes of lime and sand; lime, sand and cement or pozzolans; cement and sand; and sometimes pure cement. The proportions of these elements in the mixes should at all times be determined with care and experience, and particularly for important works, in order to make sure the mortars will have the essential qualities sought.
[…]

In order to have an impervious mortar, it needs to contain, a minimum quantity of lime equal in volume, to the volume of voids between the sands particles.
It is important to mention that fat lime mortars are better for being beaten/mixed several times, that is to say, being made in advance, then to be softened as and when needed, whether with a simple beating or with a beating and slight addition of water which helps them absorb carbonic acid from the air and thus to harden. Hydraulic lime mortars, on the contrary, should not be softened nor mixed with any addition of water once they have started to set. However, we notice that when the set is not too advanced, an energetic beating and a slight addition of lime milk, also hydraulic, will not harm their subsequent hardening.
Above ground masonry of sufficient thickness, so that they should not dry too quickly, can be made from fat lime and sand mortars without building too quickly and avoiding drying out.
When we build, underwater masonry which will be submerged in a distant future, the mortar does not have to be very hydraulic. If, on the other hand, they will be subject to immediate inundation, they need to be very energetic.
In the first case, we make it with feebly hydraulic lime and sand or with fat lime mixed with energetic lime and sand (one method of his) or fat lime, lean pozzolans and sand. In the second case, we use energetic lime with sand, or fat lime, or feebly hydraulic lime or energetic pozzolans and lastly we use sometimes a mortar of pure cement.
[…]
When mortar is mixed by hand, the labourer forms with the sand a crown on planks. In the centre of the crown, he places the lime in paste […] then he mixes with a larry and a shovel.
The larry (*rabat)* is a sort of hoe with curved edge used to smash and pound the material. The mortar is said to be suitable when one cannot see any pasty mass, nor any white traces of lime unmixed with the sand.
This method is tiring and expensive and usually only provides inferior quality to the mortars compared to those made by machine, due to the fact the worker, despite his most active attention, does not sufficiently pound the materials together.

In the section on bricks: Bricks are used with all sorts of mortar: *(gypsum)* plaster, quicklime, hydraulic lime, cements, clay-bearing soil, *brick earth*, *terre à four (in italics in the text)* in this case for the construction of kilns etc...

p121 Timber frame constructions : The walls in a timber frame building are made from a wooden lattice in which we put rubble, bricks or *masoned plâtras* with plaster or lime. When it is for thin walls, the infill is plaster tiles or bricks laid vertically. Sometimes we just nail lathes on each side of the wall and we cover it with a render. We obtain then a sort of a very light double wall, but susceptible to fire and a good space for rats and mice.

[…] Timber framed walls should rest on a base made of rubble and hydraulic lime in order to preserve the wood from rotting and to avoid humidity rising into the timbers.

p122 Construction in rammed earth: Earth is used for fence walls, and houses or farm buildings in a great number of places where stones are scarce.
The departments of l'Ain, Saône-et-Loire, Rhône, l'Isère, l'Auvergne, Dauphiné and Normandy have a great number of cob buildings made of straw and soil and rammed earth, with beaten soil.
When rammed-earth walls are well made and suitably protected from direct rain, they can last several centuries. There is, then, in the use of earth for rural construction. a most interesting resource; the raw material is inexpensive and the labour cost very little thanks to the ease and speed of execution.
In his famous treaty on the art of building, the architect Rondelet wrote more than a century ago (passage on the best soil to use, no roots and if not a good soil, mix it with lime milk).

So, if you have on your property or in the neighborhood, heavy soil or sandy clay soil, you could use it for building. If this soil is too fat and is closer to potter’s clay, we can improve it with an addition of lean soil and sand, mixing it a little at a time with a horse.

Clay which is too fat is difficult to ram, it takes a long time to dry and cracks when drying, which makes it defective (imperfect) for rammed-earth. Lean soil obviously doesn't have the necessary consistency to form solid walls. Thus, follow exactly the precepts of the famous architect mentioned above when choosing the soil.
Do not be scared to leave in this soil any gravel smaller than a nut but do not leave any roots or manure as this would promote organic growth in the wall, or tiny animals which would compromise the solidity and integrity of the walls.
We would not ram the top layers of a soil, which have been cultivated and

which contain all sorts of germs and fragments, animal and vegetable matter. First remove first this layer of humus and only use the virgin (pure) earth found at a depth of 40 or 50 centimeters for wall construction.
Often you will find a suitable soil when digging the foundations for a house-build. It is what almost always happens in the regions I mentioned above.

Foundations and substructure of walls: It is essential to protect a rammed-earth wall from direct contact with the ground from which the humidity would rise in the rammed earth and soon destroy it.
Thus, build the foundations and the substructures with dry stones if it is a simple fence wall or with **stones and hydraulic lime** if it is a house.

Build the stone wall sufficiently high that the humidity will not rise beyond it. If the terrain is naturally healthy and dried, a substructure of 20 to 30 cm height will be sufficient. If the building is being built on a humid soil or exposed to flooding, build the walls high enough that the water will not reach the rammed earth above. The substructure can, in this case, reach a meter of height and even a lot more, depending on local circumstance.
If you wish to build a solid attic above the ground floor, you will need to build the walls up to the floor boards of this attic and only start to build the earth wall above this level. Or you could build stone pilasters under the main timbers of the attic and use earth for the infill.
After the foundations, substructures or supporting pilasters are thought of and the choice of soil is made, there are two methods to use this earth.

1° Bauge ou torchis (cob) : make a very consistent mud by wetting correctly the clayish earth and mix to this paste straw or hay at the rate of one hectoliter (100 litres) to one cubic meter of earth. For the construction of the walls, use straw or hay in great length. To finish the building and the coatings, make a new cob with chopped straw or hay.
Apply these mixes with a pitch fork in successive layers to form a wall of which the extremities and thickness will be determined by wooden pegs and stretched cords.
Beat, level and smooth the faces of the wall with the shovel and the trowel.
Chopped straw cob and wetted earth are also used to fill the panels in a timber-framed building.
You would only, with this simple and primitive method, make light fencing walls or low-ranked constructions. It has the advantage of not requiring any special tools but [this method] **does not offer the solidity of rammed-earth.**

2° Rammed-earth : It is made from very little moistened clay soil and greatly

pounded with the use of kind of a rammer in hard wood called *pison* or *pisoir*, in between a formwork made in boards called *banches*.
(Too technical, some information --> for the formwork, use fir, 2 planks of 34 mm of thickness for 2 meters long. The width = 70-75 cm).

The thickness of the wall is usually 40 to 50 cm depending if it is a fencing wall, a house wall or for a rural building.

[…] bring the soil in buckets or baskets and spread it everywhere in the formwork by ramming it gradually in layers from 10 to 12 cm of thickness. When the formwork is full, you will have made a banchée, a sort of big raw compressed brick the extremities of which will be irregular.
Then dismantle the boards, pull out the transoms by leaving open the holes they made which would help for a quicker drying out of the wall and then reassemble the formwork along or above the portion of the wall already shaped, making sure to reverse the separation lines of the successive *banchées* (crossing the joints)
To join the banchées together, **it is customary in a few countries to spread a layer of mortar of lime and sand on the banchée already rammed.** This is not essential at all if the wall is not very high, with only three to four banchées on top of each other.
If, however, you want to build a house several stories high, apply in between the successive layers of rammed earth, a thick layer of mortar from 2 to 3 cm on all the surface of the wall already made. In this mortar, you will insert wooden lathes which will be imbeded in the mortar and the compressed earth forming a link between the *banchées*.
Also, you will link together the load-bearing walls with the exterior wall by putting wooden poles drowned in these layers of lime mortars.
The holes from the transoms across the banchées will only be blocked with lime mortar after the summer months have passed and drying the earth walls sufficiently
Concerning the quoins, make sure to join together the banchées from the two walls by building them one on top of the other at an angle and by putting poles or lathes in the mortar. Do not be afraid to build the inferior part of the coins with stones and mortars as this part of the building is subject to shocks which may damage the rammed earth.

In the areas where the timbers of the floor or of the roof rest on the wall, create a space with a few large stones and a bit of mortar in such a way the timbers do not rest directly on the rammed earth. This little amount of masonry has the advantage of spreading the load across a larger surface of

the wall and it conserves the timber from the contact of the soil, which would tend to rot the wood.
You will build the window, door frames and lintels with bricks, stones or oak timber framing as in the case of a house built commonly in masonry.

Advantages of rammed earth: the price of the tools required to build a big building in rammed earth does not go above 50 francs; the soil doesn't cost anything and the workforce is a half lower than for a construction in stone or brick.
Once well dried, the walls are healthy, warm in winter and fresh in summer.
In some countries where we cannot find stones, we build very big houses of several stories this way.
The life of rammed earth walls is indefinite under the condition that we protect them in a suitable way from the weather, mainly from beating (heavy) rains by applying coatings made of animal hair and lime, a slate coating, or simply by extending the roof line wide enough.
Norman architecture offers in this respect precious teaching.
The best time to build rammed earth walls is in the spring, which would let them dry completely during the summer and receive the protective coating (render) before the winter.

Special coating (render) for rammed earth wall: Make a clear but binding paste with **one part of slaked lime, four parts of clay and some water.** Add and mix into this paste, as much hair as it needs for the mix to be full of it. Use hair from tanners or from the sheet shavers (the people shaving the sheets made from teaseling as short as possible for a smoother finish).
The hair has to be well divided and beaten, so that it does not form clumps in the paste.
Apply the coating in the autumn on a well dried rammed earth wall with a big paint brush or by throwing it and then spreading it with a trowel.
Do not apply it during heavy rains nor during frost, which would prevent the drying out.