Gillmore Q A (1886, but written 1861) Practical Treatise on Limes, Hydraulic Cements and Mortars.

Chapter VI

Calcareous mortar, being composed of one or more of the varieties of lime or cement, natural or artificial, mixed with sand, will vary in its proportions with the quality of the lime or cement used, the nature and quantity of sand, and the method of manipulation. No fixed rules for its preparation, that shall be equally well adapted to all the varying circumstances of locality, temperature, and the seasons, can be prescribed.

The objects to be attained by the use of mortar are chiefly of two kinds, as follows:

First to bind together the solid materials used in masonry constructions; or, in other words, to produce in each particular case, artificial monoliths, of the required form and dimensions.
Second to form coverings to solid materials…Under this head may be included all exterior covering, and interior plaster work and ornamentation.

Sand exercises no sensible chemical action in the composition and induration of mortars of hydraulic lime; if the sand be silicious, there is believed to ensue a slow formation of silicate of lime, which considerably augments their power of resistance *[compressive strength],* and in positions excluded from contact with the air, such as the interior of thick walls, become an important auxillary in the hardening process *[right, but for the 'wrong' reason – he does not consider the reactive silica burned in the hydraulic limestone, but ascribes their effect to silica within the added sand].*

In practice…mortars are weakened by the addition of sand (or other aggregates, including brick). These…have the important effect, however, of preventing or diminishing shrinkage, of hastening the induration of rich limes, and of rendering all kinds of mortars less liable to crack in drying, which is often of very great advantage. They are, moreover, by far the least costly ingredient of mortar, and a due regard for economy compels their use in the largest possible proportions.

(**However**, whilst)…it might be inferred that the **minimum amount** of the cementing material that can be used in any case is exactly equal to the volume of the voids in the sand, when the latter is well compacted *[typically 1:3].* This theory supposes that there is no shrinkage in the matrix while hardening, and that the manipulation *[slaking]* is complete. But as these conditions can never be fully attained in

practice, it is **unsafe to descend to this inferior limit.** Moreover, mortars composed on this principle would **be deficient in both *adhesive* and *cohesive* power,** from the fact that the particles of sand would present a large area, practically void of matrix, **to the surfaces of the solid materials that are to be bound together,** and would, for the same reason, be in **more or less intimate** contact with each other throughout the mass. In order to avoid these defects, **it is customary** to determine the amount of cementing matter to be used in any particular case, by adding 45 to 50 per cent to the volume of void space in the sand.

[Gillmore perhaps the only historic author on limes to consider that the lime rich nature of traditional lime mortars is for a good reason, rather than simply craft practice and habit].

….

METHODS OF SLAKING LIME

Lime is usually sent to market in barrels, either in lumps, as it leaves the kiln, or, in the case of those varieties that are more or less meagre, and consequently difficult to reduce to a fine pulp by any of the known methods of slaking, in the condition of coarse powder to which it has been brought by grinding. In either case, it must be slaked before it can be employed as a matrix for mortar.

Three methods of slaking lime are usually described in works on mortars; on the continent of Europe, the third method, and in the United States, the second and third are seldom resorted to in practice.

The first or *ordinary* method termed *drowning* from the excessive quantity of water **sometimes** injudiciously employed, consists of **pouring upon the lumps of lime,** collected together in a layer of uniform depth not exceeding six to eight inches, either in a water-tight wooden box or a **basin formed of the sand to be subsequently added in making mortar,** and coated over on the inside with lime paste, to render it impervious to water, **a sufficient measure of fresh water** – previously ascertained approximately by trial – **to reduce the whole to the consistency of thick pulp.** It is important that all the water required for this purpose…should be added at the outset, or, at least, before the temperature becomes sensibly elevated. In this condition the lime will remain entirely submerged, and comparatively quiescent, until after an interval of five to ten minutes, the water becomes gradually heated to the boiling point, when a sudden evolution of vapour, a rapid increase in volume, and a reduction of the lime to pulp, ensues.

This process is liable to great abuse at the hands of workmen, who are apt to use either too much water, thus conferring upon the slaked lime

a condition of **semi-fluidity**, and thereby injuring its binding properties; or, not having used enough in the first instance, they seek to remedy the error by adding more after the extinction has well progressed, and a portion of the lime is already reduced to powder, thus suddenly depressing the temperature *[??]* and chilling the lime, which renders its granular and lumpy.

As soon as all the water required has been poured upon the lime, it is recommended to cover up the vessel containing it with canvas or boards, **in order to concentrate the heat and the escaping vapour,** and direct their action upon the uppermost portions deprived of immediate contact with the water, by the swelling of the portions at the bottom. **When it is not practicable to apply this covering, a tolerable substitute is found in the sand to be subsequently added to the mortar.** This can be spread over the lime in a layer of uniform thickness, **after the slaking has well progressed.**

Another precaution of equal, and perhaps greater importance is **not to stir the lime whilst slaking;** but to allow it gradually to absorb the water by capillary attraction and its natural avidity for it, taking care that all portions are supplied with it to that degree requisite **to produce a paste of the slaked lime, and not a powder.** When the lime is to be used for whitewashing or grouting, the water should be added at the outset in larger quantities than specified above, and the whole mass should be **run off while hot into tight casks, and covered up to prevent the escape of water.**

In slaking, the essential point is to secure, if possible, the reduction of all the lumps. It will be found difficult to do this with the hydraulic varieties, and the difficulty increases in direct ratio with the hydraulic energy…Even with those hydraulic limes that do slake, it is often necessary to employ a mortar mill to reduce the lumps – a condition which should always be secured, as these lumps constitute not only a dangerous substitute for sand, if left intact, but furnish when pulverised, the most energetic portion of the gang.

[For a more familiar (and probably more common) version of this method, see below. It is easy to see how this method became (and doubtless already was] the 'craft method', which saw the sand and the slaking quicklime being mixed together quite soon after the addition of water, for better or worse. Indeed, Gillmore himself ventures this option as an 'improvement' to the method above later in the text, amongst other proposed 'improvements'].

*Slaking by Immersion***.** The second method of slaking (*by immersion)* consists in **suspending the quicklime**, **previously broken into pieces of about the size of a walnut, and placed in a basket or other suitable contrivance, in water, for one or two minutes, taking**

care to withdraw it before the reduction commences. The lime should then be quickly heaped together, or emptied into casks or bins, and covered up, in order to concentrate the heat and prevent the escape of vapour. In this condition it soon begins to swell and crack, and finally becomes reduced to a fine powder, which may be preserved several months without serious deterioration, if packed in casks, and kept from direct contact with the atmosphere. The expense which would ordinarily attend the practical application of this process, and the difficulty, and even impossibility of securing with certainty, at the hands of workmen, the period of immersion, have led to a **modification** of it, which consists in sprinkling the broken fragments formed into heaps of a suitable size, with one-fourth to one-third of their volumes of water. This should be applied from the rose of a finely gauged watering-pot, **after which the lime should be immediately covered with the sand to be used in the mortar.** In this condition it should not be disturbed **for at least a day or two,** and the opinion prevails in the southern portions of Europe that the quality of the lime is improved by allowing the heaps to remain several months, without any other protection from the inclemency of the weather than an ordinary shed, open on the sides. In the vicinity of Lyons this custom very generally obtains, the autumn being usually selected for slaking all the lime required for the following season's operation. In Europe this method of slaking is applied **to the fat and slightly hydraulic limes only,** and not to those that are eminently hydraulic, upon which it seems to act disadvantageously, by depriving them, in a measure, of their hydraulic energy.

Spontaneous Slaking.

Quicklime has a great avidity for water, and when not secured from direct contact with the atmosphere, **gradually absorbs moisture from it and falls into powder,** exhibiting **but very slightly** and sometimes not at all, the other phenomena usually developed in slaking. The lime is then said to be slaked *spontaneously,* or *air-slaked.*

It has been claimed by some engineers that this method, if the precaution be taken to stir the lime frequently, so as to expose every portion of it to direct contact with the air, **confers a slight degree of hydraulicity upon fat lime**….

[common to all methods of slaking is the conviction that the best mortar is produced by using quicklime slaked with a ***minimum of water,*** *begging the question as to whether this is the key 'secret' to the enhanced performance of hot-mixed mortars – and that the intimate engagement of sand may be* ***incidental,*** *borne of the economy and efficiency of doing this.* ***Testing of mortars made to the three methods above – with lime proportion constant between all samples - might answer this question}.***

A great and insurmountable objection to the process, however, is the expense of storage room or sheds which it necessarily involves, to say nothing of the time required for its completion. Spread out in layers of from ten to twelve inches in depth some varieties of fat lime might become thoroughly reduced in twenty or twenty-five days; others would require as many weeks; while with a few, the process would continue for a whole year. Hydraulic limes are greatly injured by spontaneous slaking.

…(takes various issues with Vicat's findings regarding the volumetric expansion of lime on slaking and Vicat) says that the absorption and penetration of (carbonic gas) proceeds more rapidly in the hydraulic limes than in the fat limes – and statement which not only needs confirmation, **but is believed to be the converse of what is true.** My researches lead me to the same results as those enunciated by geo: Robertson Esq…"the depth to which carbonic acid is absorbed into mortar in a given time, and to a certain extent, the induration from that cause **varies inversely with the hydraulic properties of the lime, which depend upon the silica contained in it".**

The incrustation is due in the case of hydraulic limes to the **combined influence of reactions, considerably more complicated and obscure than those which obtain with the hydrate of fat lime.** The hydrosilcate and aluminate of lime…are formed in addition to the hydrocarbonate. The formation of these compounds is **not confined to the crust on the surface** *[as it may be initially in the 'case-hardening' of an air lime mortar],* **but takes place throughout the mass,** and is really the **principal efficient cause** of the induration of this class of limes, when placed under water or in humid localities excluded from atmospheric influences….

The hardness assumed by the hydrate *in the air* is **intimately connected with the process of slaking** and appears to sustain a direct ratio with increase in volume *[are these things true?].* The three modes of slaking arranged in order of their superiority in this respect stand as follows:
1st For fat limes: ordinary slaking; spontaneous slaking; slaking by immersion
2nd For hydraulic limes: ordinary slaking; slaking by immersion; spontaneous slaking….

…(the second and third methods of slaking (by immersion or air have been tested little by practical experience in the USA, and) **the first mode of slaking inasmuch as it is attended with less original outlay, gives more certain results, and requires fewer precautions at the hands of the workman** ***[who probably blends the slaking lime and sand sooner than in Gillmore's description, in practice]*** **may be regarded as the most advantageous in nearly every case,**

provided the precaution is taken to pour on at the outset all the water required to produce a stiff paste, but no more.

General Totten announced the following as the results of experiments made at Fort Adams, upon the different modes of extinction:
1st Slaking by drowning, or **using a large quantity of water in the process of slaking, affords weaker mortars than slaking by sprinkling.**
2nd Experiments with air-slaked lime were too few to be decisive, but the results were **unfavourable** to that mode of slaking.

Preservation of Lime. The paste of fat lime, whatever may have been the mode of extinction, may be preserved intact for an indefinite length of time, if kept from contact with the air. It is usual to put it in tight casks, or in reservoirs or trenches covered up with sand; or, when shed-room is available, to form it into rounded heaps, similarly protected and under cover.

The **powder** derived from the second and third modes of extinction may be preserved for several months, without sensible deterioration, in covered casks or bins, or if heaped up in dry sheds and covered over with straw, cloth or dry sand *[however, most accounts of heaping in practice make clear that the sand and lime are previously engaged and mounded to 'sour out']*

Until quire recently, opinions **among engineers** were divided as to the effect of time upon the quality of paste of fat lime, preserved with suitable precautions for future consumption. General Treussart entertained the opinion that they **should be made into mortar and used soon after their extinction.** This idea finds few advocates at the present day, **although the practice in this country conforms to it with singular unanimity. *[which is to say that, in practice, and craft practice in the US, hot mixing was generally by the first method and taken directly to a mortar and used soon after being made].***

Fabrication of Mortars. The relative quantities in which sand and the cementing substance, whether the latter be derived from common or hydraulic lime, or cement, should exist in in mortar, depend in a great measure on the character of the work in which it is to be used; its locality and position with regard to a state of moisture or dryness; and, if subjected to alterations in this respect, the character of the moisture, depending on its proximity to or remoteness from the sea, the nature and magnitude of the forces which it will be required to resist, the peculiarities of the climate, and the season of the year in which the work is to be performed.

When mortar is to be made in quantities sufficiently large to warrant the expense, a **mortar mill** of some approved pattern should be

provided, for incorporating the ingredients, as the mortar thus obtained is **invariably superior** to that produced by the use of the hoe and shovel only....

(detailed description of a mortar mill constructed for the building of Fort Warren, Boston harbour), (where) mortars composed of lime and sand only, the lime was slaked in the ordinary way with a sufficiency of water, simply to produce a thick pulp....the limes most extensively in use for public works on our Atlantic coast, the largest augmentation of volume in slaking is secured by adhering to the following directions, viz: **put the lime into a box, break up the larger lumps with a hammer; pour in at once the quantity of water (ascertained previously by trial) necessary to reduce them to a stiff paste, and then cover up the box so as to prevent, as much as possible, the escape of heat and vapour, allowing it to remain in that condition, without stirring, until the reduction is complete.** In order to connect this process with the operations of a mortar mill, it might be necessary to provide several boxes, so that the lime might, in all cases, **have at least forty-eight hours to digest before it is made into mortar.**

...Extensive operations requiring large quantities of mortar are frequently carried on by experienced engineers, without the aid of a mortar mill of any kind.

When ordinary lime mortars are thus made by hand, it is customary and convenient to slake the lime by the first method described, and **in no greater quantity than may be required for immediate use.** The operation should be conducted under a shed. **The measure of sand required for the 'batch' is first placed upon the floor, and formed into a basin for the reception of the unslaked lime.** After this, the latter is put in, and the larger lumps broken up with a mallet or hammer; **the quantity of water necessary to form a stiff paste** is let on, from the nozzle of a hose, or with watering pots, or even ordinary buckets. **The lime is then stirred with a hoe, as long as there is any evolution of vapour, after which the ingredients are well mixed together** with the shovel and hoe, a little water being added occasionally if the mass be too stiff. At this stage of the operation, it is **customary to heap the mortar compactly together, and allow it to remain until required for use.** When circumstances admit, it should not be disturbed for several days, and during the period of its consumption **should be broken down and 'tempered' in no larger quantities than may be required for use from day to day.**

It is believed that certain slight modifications of this common method of procedure can be made, with decided advantage in the final results. As follows:

1st All the lime necessary for any required quantity of mortar **should be slaked at least one day** before it is incorporated with the sand.
2nd The sand-basin, to receive the unslaked lime should be coated over on the inside with lime paste, to prevent the escape of water.
3rd All the water required to slake the lime to a stiff paste, should be poured on at once. This will completely submerge the quicklime. **The heap should then be covered with tarpaulin or old canvas, and left until next day.**
4th **The ingredients should be thoroughly mixed, and the mortar heaped up for future use.**

(The mortar used for the construction of Forts Richmond and Tompkins in New York Harbour was made by hand)…

When required for stonemasonry, or concrete, it was composed of **hydraulic cement and sand, without lime.**

Four men constituted a gang for measuring out and mixing the ingredients, who proceeded to the several steps of the process in the following order:

1st The sand is spread in a rectangular layer of two inches in thickness;

2nd The dry cement is spread equally all over the sand;

3rd The men place themselves, shovel in hand, two on each side of the rectangle, at the angles, facing inwards. Furrows of the width of a shovel, are then turned outwards along the ends of the rectangle until the whole bed is turned. The two men on one side thus find themselves together, and opposite the two on the other side…they then move back to their original positions in turning furrows as before…the turning is executed by successively thrusting the shovel under the material, and turning it over about one angle as a pivot….

4th A basin is formed, by drawing all the material to the outer edge of the bed.

5th The water is poured into the basin thus formed.

6th The material is thrown back upon the water, absorbing it, when the bed occupies the same space it did at the beginning.

7th The bed is turned twice, by the process described above.

If required for mason's use, the mortar is then heaped up, to be carried when and where required. If for concrete:

8th The broken stones are spread equally over the bed.

9th A bucket of water, more or less (depending upon the quantity of the stones, their absorbing power, and the temperature of the air), is sprinkled over the bed.

10th The bed is turned once as before, and then heaped up for use. The act of heaping up, which is done with care, has the effect of a second turning.

(takes 20 minutes to make batch; 10 minutes more when for concrete).

When the mortar is required in very small quantities, to avoid deterioration, instead of proceeding to the fourth step of the manipulation, the mixture of cement and sand is heaped up and the water added and paste formed with the hoe, in such quantities as are required.
(Mix for these forts was 1 hydraulic cement powder: 2.44 casks of sand well compacted).

(Mix at Fort Warren was of lime, hydraulic cement and sand:

1 dry cement: ½ Rockland lime: 14 ½ cubic feet of well compacted sand)

Some engineers object to the use (of so much sand as at Forts Richmond and Warren)…others again very seldom add lime to their cement mortars. Touching this last…recent experiments show, with a uniformity quite satisfactory, that **most American cements will sustain, without any great loss of strength, a dose of lime paste equal to that of the cement paste;** while a dose equal to ½ or ¾ the volume of cement paste may safely be added to any energetic Rosendale cement, without producing deterioration in the quality of the mortar…Neither is the hydraulic activity of the mortars so far impaired by this limited addition of lime paste, as to render them unsuitable for concrete, under water or other submarine masonry; while, for constructions not subject to immediate submersion, or the action of the returning tide, **it is to be preferred on many counts.** By the use of lime, we secure the double **advantages of a rather slow mortar** – one that is in no danger of setting before it reaches the mason's hand – and a cheap mortar. We also avoid the principal serious objection to the use of a quick-setting mortar, due to careless and tardy attendance on the masons, and consequently the **constant breaking up of the incipient set on the mortar-board, whereby cements are degraded in energy to a level with ordinary hydraulic limes.**

POINTING MORTAR

In laying up masonry of any character, whether with common or hydraulic mortar, the exposed edges of the joints will naturally be deficient in density and hardness, and, therefore, unable to withstand the destructive action of the elements; particularly variations in temperature, producing extremes of heat and cold. It is therefore **customary** to fill the joints as compactly as possible, to the depth of about half an inch, with mortar prepared specially for the purpose…. The cleaning out of the joints to the requsite depth should take place while the mortar in new and soft; and (in stonemasonry) when the stones come into contact, or nearly so, the joints must be enlarged, to the width of about three-sixteenths of an inch by a stone-cutter *[a new one on me].*

[Gillmore, like almost all historic authors on the subject, has no concern about, or even appreciation of compatibility of materials, although for the most part the buildings he is familiar with will have been built and pointed with the same mortars].
Pointing mortar is compounded of a paste of finely ground cement, and clean sharp silicious sand, in such proportions, in such proportions that the volume of cement paste shall be very slightly in excess of the volume of the voids in the sand. *[pointing with a mix more binder-rich than the bedding mortar has long precedence, certainly in North Yorkshire, with lime-rich pointing over earth or earth and quicklime bedding mixes. Doubtless, this was common with lime mortars. Gillmore is transferring the principle to natural cement work.]*

…Before pointing, the wall should be thoroughly saturated with water, and kept in such a condition, that it will neither absorb water from the mortar, nor impart any to it, two conditions of special importance, the first being paramount.

Walls should not be allowed to dry too rapidly after pointing, but should be kept moist for several days, or better still, for two or three weeks….

INTERIOR PLASTERING

…The mortars used for inside plastering exclusively, are ‘coarse stuff’, ‘fine stuff’, ‘guage stuff’ or hard finish and ‘stucco’.

Coarse stuff **is nothing more than common lime mortar,** suitable for brick masonry, to which has been added a quantity of well-switched bullock’s hair, to act as a kind of bond. The following proportion is a good one:

1 cask lime – 8 cubic feet of paste:
Sand – 16 to 18 cubic feet

Hair – 1 ½ cubic feet.

When ample time for hardening cannot conveniently be allowed, it will be advantageous to **replace 12 to 15 per cent of the lime paste in the coarse stuff, by an equal volume of hydraulic cement or plaster of Paris.** Coarse stuff forms the principal part of all inside plastering. For the second coat, in three-coat work, the quantity of hair given above may be slightly diminished.

Fine stuff is made of **pure lump lime slaked to a paste** with a moderate quantity of water, and **afterwards** diluted to the consistency of cream, and then placed where it can stiffen by evaporation to the proper condition for working *[all this whilst still hot, therefore].*

Fine stuff is used for the finishing coat, but **never** without the addition of plaster of Paris, except for what is termed 'slipped coat'. Even for slipped work, a little fine sand is sometimes added, to make the paste work more freely.

Guage stuff or *hard finish* is composed of fine stuff (lime putty) and plaster of Paris, in proportions regulated by the degree of rapidity required in hardening. It is used for the finishing coat of walls, and for cornices, mouldings and other kinds of ornamentation. **For finishing, the proportions are three to four volumes of lime putty to one volume of plaster of Paris, and for cornices etc about equal volumes of each.**

Stucco is composed of **lime putty and white sand,** with a preponderance of the latter. The usual proportions are **three to four volumes of sand for one volume of lime putty.** Stucco is only used for the finishing coat.

…In 'rendering' (on hard) the joints of the masonry should be raked out to the depth of half an inch, the surface freed of dust, and the walls moistened. Old masonry, if smokey or greasy, should also be scraped out and roughened [*common enough practice, but the opposite of current guidance].* …

Except for very common work, the laying coat should be hand-floated , to give it density and solidity. This is done by using the float in the right hand, and a hair brush holding water, in the left; both…passed quickly over the wall at the same time, the brush preceding the float, and wetting the surface to the required degree. The firmness and tenacity of plastering is very considerably increased by hand-floating, and at a moderate expense.

Hand floating must take place while the mortar is green, when it is intended as a preparation for the setting coat.

…After the first coat, whether it be a laying coat or a screed coat, has become partially dry, so as to resist the pressure of the trowel, it is ready for the setting, or finishing coat….the surface must receive it **must be roughed up with a birch or hickory broom.**

A *slipped coat* is merely a smoothing off of a brown coat (coarse stuff), with the **smallest quantity of lime putty** that will answer to secure a comparatively even surface. It is seldom sufficient to cover the browning up entirely.

Finishing or setting in stucco is suitable for a screed coat, but is never applied to laying (on lath) or to inferior work, on account of the extra work it requires. The stucco is applied with the trowel, to the thickness of about one-eigth of an inch, keeping in view the fact that the straight surface gained by screeding (plumbed screeds being set out and filled between to achieve straight surface) can only be preserved by applying the set in a coat of uniform thickness. The stucco is well hand-floated, the water brush being used freely while so doing. After the wooden float has been used, the surface is again floated with a cork float, which, being soft, leaves the surface in good condition for polishing. The polishing is performed with a trowel and brush; this operation is omitted when the stucco is intended to present a rough appearance for painting, or for any style of ornamentation in distemper.

Bastard stucco, like stucco, is also used as a setting coat on screed work. It is done in stucco mortar, containing a smaller quantity of sand than is suitable for genuine stucco, and **sometimes a little hair.** There is no hand floating in this kind of work, and the trowelling is done with less labour than that conferred on trowelled stucco, as above described. Bastard stucco is superior to slipped work as a preparation for papering.

…*hard finish*…the advantage of hard finish over stucco in its requiring less labour to apply it. It is extensively practiced in the United States.

Three-coat work. The first and second coat are termed respectively the *scratch* coat and the *brown* coat, and the third is either *hard-finish* or *stucco.*

The scratch coat, or first coat, is applied in the same manner as *laying*…to form a good foundation for the *screeding* which follows, its thickness need not exceed one quarter to three-eighths of an inch. When completed and partially dry, though still quite soft, the mortar is *scratched* over nearly to its entire depth, with a pointed stick, in two systems of parallel scorings at right angles to each other, running diagonally between the extreme limits of the surface covered. These scorings are about two inches apart, and assist the adhesion of the coat which follows.

The second coat is applied in screeds and ‘filling out’…

The finishing or setting is also applied as before described.

EXTERIOR PLASTERING OR ‘STUCCO’

Mortars composed of the paste of common lime and sand, either with or without the addition of plaster of Paris, are **unsuitable** for covering surfaces exposed to the direct action of the elements.

Lime, however, forms the basis of many excellent outside stuccos, and, by proper treatment, may be rendered very durable.

If the water for mixing the mortar contains **coarse sugar or molasses in solution**, the effect on the solidification of the outer surface of the stucco is very beneficial. This method is practised (in)…India, as reported by Captain Smith in his translation of Vicat. The proportions for the sweetened water are about one pound of sugar to eight gallons of water, except for the outer or hand-floated coat, in which one pound of sugar should be mixed with two gallons of water *[a lot of water to add to a mortar if the lime is already slaked to a putty or paste].*

Powdered slaked lime and smith’s forge scales mixed up with bullock’s blood in suitable proportions, makes a durable and moderately hydraulic mortar, which adheres well to masonry previously coated over with boiled oil *[ouch!].*

The custom in the United States is to use hydraulic cement and clean sand, mixed up with a sufficiency of water to produce the ordinary consistency of mortar for plastering, and in such quantities that it may be used up before the batch begins to set. The proportions are one volume of stiff cement paste to 1.66 volumes of damp, compact sand; or, if measured dry, one volume of cement powder to two volumes of loose, dry sand….The mortar is laid on in two coats in one operation…

Many of the best cements of the US are of too dark a colour to furnish an agreeable shade for the exterior of dwelling houses. A very simple remedy for this is to use light coloured or white sand, in whole or in part. (Or)…**lime paste may be added, without material injury, until its volume equals that of the cement paste.** Lively tints may be obtained by a judicious use of the several ochres, singly or combined….

As a general fact, within certain limits, solid bodies resist the action of frost in proportion to their density, or inversely as their capacity for imbibing water; but this rule is **not capable of strict application, and it is quite possible for one mortar to be better proof against frost than another less porous in its character.** Moreover, of two mortars

of equal density, one may be materially impaired in tenacity and hardness by the action of frost, while the other exhibits few, if any, evidences of its effects.

CONCRETE OR BETON

(Terms have become synonymous, and) apply to any mixture of mortar (generally hydraulic), with coarse materials, such as gravel, pebbles, shells, or fragments of tile, brick, or stone. Two or more of these materials, or even all of them, may be used together. More strictly speaking, as originally accepted, the matrix or gang of beton possesses hydraulic energy, while that of concrete does not *{or, at least, uses pozzalanic addition to assist its set].*

…*the volume of the cementing material should always be somewhat in excess of the volume of voids in the coarse materials to be united.* The excess is added as a precaution against imperfect manipulation.

In England, some years ago, when concrete first came into extensive application, **common or feebly hydraulic lime, such as the Blue Lias limestone yields,** was generally used for the cementing substance. The quicklime, having been first reduced to a powder by mechanical means, **was incorporated with the sand and coarse materials in the dry state.** Water, in sufficient quantity to slake the lime, being then added, the concrete was rapidly mixed up with a pug-mill or with shovels, conveyed away in barrels or carts, and **used while hot.** It was employed extensively for foundations, or as a sub-stratum in light and yielding soils. In order order to secure the requisite degree of compression and density, it was customary to throw it into its position from a height, and sometimes to ram it afterwards. In mixing the materials for **fat lime concrete,** as usually composed, there is a contraction of about 1/8 in volume; this is succeeded by expansion, when the setting takes place, of about 3/8 of an inch for every foot in height, which does not entirely cease for a month or two afterwards.

Concrete of fat or feebly hydraulic lime has been extensively employed in Europe for making artificial blocks of any required form and dimensions, which, after attaining in the air a degree of hardness and strength sufficient to render the handling of them safe and practicable, are laid up in walls with mortar joints, like ashlar-work.

Of late years, the practice of laying **fat lime concrete hot** has grown into disrepute among English architects and engineers. They now prefer that the lime should be thoroughly slaked, reduced to a pulp, and made into a mortar with the sand before the coarse materials are added. This process is always followed in making beton. The advantages of it are, immunity from the danger of partial slaking before use, superior homogeneity in the mass, and economy in the amount of lime required.

Neither the **English method** of making concrete to be used while hot, (nor artificial block making)…have ever received any extensive application in the United States.

Natural hydraulic cement to which…paste of fat lime is sometimes added, in quantities seldom greatly exceeding that of the cement, is almost invariably used as the basis of the concrete mortar: and the concrete, when made, is at once deposited in its allotted place, and well rammed in horizontal layers of about 6 inches in thickness, until all the coarser fragments are driven below the general surface. The ramming should take place before the cement begins to set, and care should be taken to avoid the use of too much water in the manipulation (so as to avoid any 'quicksand motion')…(but too much water better than too little, because) a too rapid desiccation of the concrete might involve a loss of cohesive and adhesive strength, if insufficient water be used….

On account of its continuity and impermeability to water, (concrete) is well suited to the purposes of a substratum in soils infected with springs, for sewers and conduits, for basement and sustaining walls, for columns, piers and abutments, for the hearting and backing of walls faced with bricks, rubble, and ashlar-work, for pavements in areas, basements, and cellars; for the walls and floors of cisterns, vaults etc. Groined and vaulted arches, and even entire bridges, dwelling houses and factories, in single monolithic masses, with moulded ornamentation of no mean character, have been constructed of this material alone.

(Long discussion about the hydration and setting of hydraulic limes. Most pertinently says that the clay compounds will combine with their equivalent of lime, the rest of the lime remaining 'free).

…The setting of mortars of fat lime and pozzuolana, natural or artificial, is likewise due to the formation of hydrated compounds of lime with silica and alumina. The lime attacks the silica and alumina, freeing them from previous combinations, when such exist, and **slowly** forms with them calcium silicate and calcium aluminate.

It has been recommended to allow these mortars to **remain mixed for some time before tempering them just previous to use,** a precaution which rests upon a plausible, and doubtless, a sound theory; for while the combinations of lime with silica and alumina **previously exist in the hydraulic limes and cements (**having been formed during the calcination, and are, therefore, in condition to **become hydrates at once,** in presence of water), the conditions are quite different with mortars of fat lime and pozzuolana, in which the silica and alumina have first to free themselves from combinations peculiar to, and existing in the pozzuolana **before** they can form in

the wet way those compounds those compounds, which **afterwards** become hydrates, and confer hydraulicity.

From this we can comprehend why fat lime should be used in preference to hydraulic lime for pozzuolana mortars, since the compounds formed during the burning of the hydraulic lime will have become hydrates, and will have **initiated the hydraulic set, before those formed in the wet way between the free caustic lime and the pozzuolana will have completed the preliminary decomposition;** and because, for the same reason, if we employ hydraulic lime, it is only the excess of caustic lime in it that combines advantageously with the pozzuolana. The operation in the mortar of two dissimilar powers, one *composing,* and the other *decomposing* in character, might operate disadvantageously. The conditions should be such, that the different combinations of the lime with the silica and alumina, no matter how, when or where formed, should become hydrated **simultaneously.**

[There is much more in Gillmore of value and interest].