Vitruvius (30-20 BC) *Ten Books on Architecture.* Translated by Rowland I D; eds Rowland I D & Howe T N (1999) Cambridge University Press.

Xiii Translators Preface.

No translator can approach Vitruvius without making hard choices about individual words in a text that has come down from antiquity with significant alterations. All of the surviving medieval manuscripts have many confusing or nonsensical passages and impossible – or missing – numbers for the dimensions of buildings, aquaducts and machines. From 1511 onward, however, readers of Vitruvius could avail themselves of a printed text in which many of these errors had been corrected by a brilliant process of guesswork. The editor of this printed Vitruvius was an Italian monk, Fra Giovanni Giocondo da Verona, who had worked both as a classical scholar and a practicing architect in Italy and France; he was one of the few people in the Renaissance, and one of the few people ever afterward, who had the range of experience to understand every aspect of Vitruvius's text and therefore to anticipate what might have been misread as generations of scribes copied down the Ten Books with all too human fallibility….the notes to the present translation show how often the Veronese monk seemed to be the first reader in fifteen centuries to understand what Vitruvius must really have said.

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BOOK 1.

THE PRINCIPLES AND THE LAYOUT OF CITIES

Chapter 1: The Education of the Architect.

1. The architect's expertise is enhanced by many disciplines and various sorts of specialised knowledge; all the works executed using these other skills are evaluated by his seasoned judgment. This expertise is

born both of **practice** and of **reasoning**. Practice is the constant, repeated exercise of the hands by which the work is brought to completion in whatever medium is required for the proposed design. **Reasoning,** however, is what can demonstrate and explain the proportions of completed works skilfully and systematically.

2. The architects who **strove to obtain practical manual skills but lacked an education have never been able to achieve an influence equal to the quality of their exertions;** on the other hand, those who placed their trust entirely in theory and in writings seem to have **chased after a shadow, not something real.** But those who have fully **mastered both skills, armed, if you will, in full panoply, those architects have reached their goal more quickly and influentially.**

P22 3) (the architect) ought to have a native talent, and be amenable to learning the disciplines (of the profession). For neither native talent without learning nor learning without native talent create the master craftsman.

BOOK 2

BUILDING MATERIALS

(Section on mud brick masonry, of which Vitruvius approves and declares to be common).

P36. Chapter 4. Sand for Concrete Masonry

1. In concrete structures one must first enquire into the sand, so that it will be suitable for mixing the mortar and not have any earth mixed in with it…the type that crackles when a few grains are rubbed together in the hand will be the best, for earthy sand will not be rough enough.

(pit sand is the best; river sand next; beach sand the least good, mortars made with it being slow to set up and if used

for walls and then plastered, the wall will 'give off salt and dissolve the surface)…

2. Excavated sands, on the other hand, dry quickly in construction, and the plastering stays in place…(but should be freshly quarried) (p37)…But even though newly excavated sands have so many virtues in construction, they are not useful for plaster precisely because in mixing with lime, because of its own density, and with **straw,** it cannot dry without cracks, it is too intense. Although its fine grain makes it useless in construction…, river sand, when flattened down by the action of a plaster float, acquires firmness for plasterwork.

Chapter 5: Lime for Concrete Masonry

1. Now that everything has been clarified about supplies of sand, then we must be careful about our lime, and whether it has been cooked down from limestone or silex (hard limestone). And that which is made from denser and harder stone will be useful in construction, and that made from porous stone, for plaster *[this notion, that the durability of lime was in direct relationship with that of the limestone from which it was made was accepted by all writers on lime hereafter, until Smeaton disproved it. As an idea, it persisted even then].* **When it has been slaked, then the materials should be mixed so that if we are using excavated sand, three parts of sand and one of lime should be poured together.** *[Is this proportioned before slaking – when mixed by the 'ordinary' methods, this would be so, as Pasley insists it always should be, in 1826].* If, on the other hand, it is river or sea sand, **two parts of sand** should be thrown in with one of lime. In this way the rate of mixture will be properly calibrated. Furthermore, if one is using river or sea sand, then **potsherds**, **pounded and sifted,** and added to the mixture as a **third part,** will make the composition of the mortar better to use.

(Morgan translates this as:

….. After slaking it, mix your mortar, if using pit sand, in the proportions of three parts sand to one of lime; if using river or sea-sand, mix two parts of sand with one of lime. These will be the right proportions for the composition of the mixture. Further, in using river or sea-sand, the addition of a third part composed of burnt brick, pounded up and sifted, will make your mortar a better composition to use.)

2. When lime absorbs water and sand it reinforces the masonry. Evidently this is the reason: because stones, too, are composed of the four elements. Those which have more air are soft, those with more water are dense with moisture, those with more earth are hard, those with more fire are more friable. Because of this, if we take this stone before it has been cooked, pound it fine and mix it with sand in masonry, it will neither solidify nor bond. If, on the other hand, we throw it into the kiln, then, caught up in the flame's intensity, it will shed its original property of hardness, and with its strength burned away and sucked dry, it will be left with wide-open pores and voids. Therefore, with its air and water burned away and carried off, it is left with a residue of latent heat. When the stone is then plunged in water, before the water absorbs the power of its heat, whatever liquid enters into the pores of the stone boils up, and thus by the time it has cooled it rejects the heat given off by lime.
3. Therefore, whatever the weight of stones when they are cast into the furnace, they cannot have retained it by the time they are removed, when they are weighed, although their size remains the same, they will be found to have lost a third part of their weight because of the moisture that has been cooked out of them. And thus, **because their pores and spaces lie so wide open, they absorb the mixture of sand into themselves and hold together; as they dry, they join together with the rubble and produce the solidity of the masonry.** *(This seems to describe hot mixing, despite what was said above].*

Chapter 6: Pozzalana for Concrete Masonry.

1. There is also a type of powder that brings about marvellous things naturally. It occurs in the region of

Baiae and in the countryside that belongs to the towns around Mount Vesuvius. Mixed with lime and rubble, it lends strength to all the other sorts of construction, but in addition, when moles (employing this powder) are built into the sea, they solidify underwater. (Supposes this effect due to their having been affected by 'huge fires' beneath)…Hence, when these three ingredients (lime, fired rubble and pozzalana), forged in similar fashion by fire's intensity, **meet in a single mixture, when this mixture is put into contact with water, the ingredients cling together as one and , stiffened by water, quickly solidify.** Neither waves nor the force of water can dissolve them. *{Once again, this reads as a description of hot mixing of lime concrete, with brick aggregate and pozzalanic sands].*

(Morgan:
There is a kind of powder which from natural causes produces astonishing results. It is found in the neighbourhood of Baiae and in the country belonging to the towns round about Mt. Vesuvius. The substance when mixed with lime and rubble, not only lends strength to buildings of other kinds, but even when piers of it are constructed in the sea, they set hard under water.

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4. [In building with pozzalana underwater] unlike and unequal entities that have been forcibly separated **are brought together all at once.** Then the moisture-starved heat latent in these types of ingredients, **when satiated by water, boils together, and makes them combine.**

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Chapter 8. Styles of Concrete Masonry.

1. These are the types of masonry: *reticulatum* ('network'), which is used by everyone now, and the old style which is called *incertum* ('random work'). Of these, the more attractive is reticulatum, but it is inclined to split apart because it has discrete seams and junctures in every direction. Rubble, in opus incertum, with stone sitting upon stone and sloping every which way, affords a masonry that is not pretty, but is more durable than reticulate construction.

2. Either type of masonry should be built up of the most fine-grained ingredients, so that the wall surfaces, **thickly saturated by a mortar of lime and sand,** will hold together longer. For soft and porous in nature, as they are, **they dry out by sucking the sap from the mortar.** When the supply of lime and sand superabounds, the wall surface, having more moisture, will not become feeble quickly, for it is held in bond by these two substances. As soon as the **moist power** has been sucked out from the mortar because of the porous structure of the rubble, the lime pulls away from the sand and dissolves; the stones, in turn, cohere with neither lime nor sand, and in the long run it makes for ruined walls. *[Vitruvius seems to saying that the slow carbonation of air lime mortars represents a structural advantage and that this is weakened once carbonation has occurred to full depth and throughout a solid wall…a radical notion].*

3. This can be observed, indeed, in some monuments that have been erected around the City of marble or squared stone. Inside they have been filled with rubble work, and with the mortar weakened by age and sucked dry by the porous nature of the tufa, they go to ruin…

4.For which reason, if one wants to avoid falling into this error, reserve a hollow zone in the middle of the wall along the orthostates *[the backs of the independent skins of masonry should be as upright as the faces of the same, leaving a clean cavity]*. On the inside, two-foot walls should be constructed of squared Anio tufa or terracotta or split stone, and along with these the front surfaces should be linked by iron clamps and lead. For in this way the work is not heaped but coursed, forever flawless, because the beddings and joins, settling with one another and bound together at the seams, will not bulge the masonry outward, nor do they allow the orthostates (which are clamped together) to slip out of place.

[It is not the mortar which is at fault here, but the form of construction, with an almost independent rubble core, little attached to the facing masonry, as the below indicates:]

5. Therefore the masonry of the Greeks is not to be condemned. They do not use a surfaced masonry of

soft rubble, but whenever they depart from building with ashlar blocks, they lay courses of split stone or hard flagstone, and bind the joints together in alternate layers just as if they were building in brick, and thus they achieve powers of durability for the walls such as they will last an eternity. (p40) They construct these walls in two types….one is isodomic, the other…pseudoisodomic.

6. Masonry is called isodomic when all the layers are constructed of an equal thickness; pseudoisodomic when the rows are alternating, and unequal layers are preferred. Both of them are durable for these reasons: first, because the flagstones themselves are of a dense and solid nature and will not, therefore, suck the moisture out of mortar, instead, **they preserve its moisture intact** even to the greatest age. And similarly, because the bedding for this masonry has been planed and levelled, it does not allow the mortar to settle, for it is bonded all along to the thickness of the walls, held in place to the greatest age.

P73 Chapter 12.

Ports.

…This is how harbour enclosures should be designed. The masonry that will be underwater should be made by bringing in that powder (pozzalana)…this should be mixed **two-to-one** as if with a mortar and pestle. 3. Then, in the place that has been marked out for the purpose, caissons of oak planks, bound in chains, should be sunk into the water and set firmly in place. Then, within their (p74) perimeter, from small crossbeams, the lower part should be levelled underwater and dredged out, and the place should be heaped up with pounded rubble, and the mortar mixed as has been described, until the space between the caissons has been entirely filled…

BOOK 7 – FINISHING.

P87 Chapter 1 Flooring.

P88…When the decking is finished in an upper story, it should be strewn with fern, or otherwise with straw, so that the woodwork will be protected from damage by lime. 3. Above this the underlayer is set down of stones no smaller than can fill the hand. Once the underlayers have been installed, if the rubble for the sub-pavement is new, then mix it **three to one with lime;** if it is re-used, then the mixture should be **five to two.** Then the sub-pavement is laid in with wooden rods by ten-man work gangs, and compacted by steady pounding. By the time the pounding is done, it should be no less than a *dodrans* (three-quarters of a foot) thick. Above this, a core of **crushed terracotta** should be installed, **mixed three-to-one with lime,** and it should be no less than six digits thick. Above the core the pavements should be laid to the square and to the level, whether they are in stone inlay or mosaic….

…Pavements in Tiburtine herringbone tile work should be carefully executed so that they have neither protruberances nor ridges, but are uniform and polished on the level. Above this, once the floor has been ground with rough and fine polish, powdered marble is sprinkled over it, and coats of lime and sand are laid down over this.

Chapter 2 Plasterwork

1….This will be done properly if clods of first-rate lime are softened **long before there is need for them**. *[This is the first time Vitruvius discusses laying down slaked lime before use – in the context of plastering, not general building].* If a clod is baked lightly in the kiln, then, as it is softened over many days, the remaining liquid, forced to boil away, will bake the clod to an even degree *{the lime is being slaked to a stiff paste].* If it has not been softened all the way through, but is used when only recently fired *[he does not say when recently slaked, which may suggest hot mixing]* then, when applied, it will develop blisters, because it has **raw grains hidden inside.** If these grains are put into the work without having been softened to an even degree, they dissolve and break apart the finish of the plasterwork.

(Morgan's translation reads quite differently:
Book VII -Chapter II The slaking of Lime for Stucco
….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,….
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.)

3. If the softening has been done reasonably, and the work is to be prepared with care, take an axe, and chop through the softened lime to its core as it lies in the pit, jst as if it were wood being chopped. If the axe meets with granules, (p89) then the lime is not yet ready. When the tool comes through dry and pure, it indicates that the lime is weakened and parched. When it is rich and properly softened, then, clinging all around that tool like glue, it shows that it has been tempered in every respect. Then get the machines (the editors suggest this means scaffolding) ready and set the ceilings of the rooms…*[No mention is made of mixing this lime with sand – as it is for the walls.}*

*(*Description of preparing the background of ceilings, with battens to receive 'Greek reed'. The tops of the ceilings to be sealed with 'a mortar of lime and sand')….Once the ceilings have been laid out and interwoven, their lower surfaces should be plastered, then sanded, and then polished with chalk and marble.

[It seems very likely that the lime prepared as above is to be used for ceilings without any addition of sand. When discussing the plastering of walls – below – sand and lime *mortars are specified, with a base coat of 'rough plaster. There is no specific indication that all lime for all aspects of plastering should be laid down to mature (or rather, to fully slake) other than the finish (and only) coat on ceilings and, it may be presumed, those for the three marble finish coats detailed below. This passage was translated thus by Morgan Hickey:* 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*].*

When the ceilings have been polished, then crown moldings should be placed underneath them, which ought to be as slender and fine as possible, for if they are large, they will be pulled down by their weight and unable to stay in place. For these, **gypsum is the last thing one wants to mix in;** instead, they should be composed of marble sifted to a uniform consistency, **so that one part will not anticipate the other in drying, but the whole will dry at a uniform rate**…5. Once the crown mouldings have been put in, **the walls should be plastered as roughly as possible,** and afterward, when the plaster is nearly dry, the layers of sand mortar should be applied so that the planes of the walls are flat and on the level, their rise on the perpendicular and their corners at right angles…As the plaster dries, a second and third layer should be applied. Thus the more solid the levelling produced by sanding, the sounder the solidity of the frescoes, and the more durable. 6. If no fewer than three layers of sand mortar have been applied, in addition to the rough plastering *{which may even be of earth, perhaps]*, then coats of large-grained powdered marble should be applied and levelled, so long as the material is of this consistency: when it is being worked, it never clings to the trowel, but instead allows the tool to come free when it is removed from the mortar. Once the layer of large-grained marble powder has been applied and is drying, then another layer of medium-grained powder should be laid on. When this has been worked and sanded down well, then a layer of fine-grained marble dust should be applied….

P90. 10. The Greek plaster makers not only create long-lasting work according to these principles, but they also do this: **when the mortar trough has been set in place, with the lime and sand poured together into it,** they bring in ten-man work gangs who pound the mortar with wooden pestles, and they use it after it has been vigorously worked by these teams.

Chapter 4 Plasterwork in Damp Locations.

…For rooms on ground level, instead of sand mortar, terracotta sherds should be rough plastered and applied up to a height of three feet above pavement level, so that these parts of the plaster will not be damaged by moisture.

(If constantly damp, then a cavity wall should be built with a drainage channel at its base and weep holes to the outside and ventilation holes higher up.)…

Then the walls should be whitewashed with lime dissolved in water, so that they will not reject the terracotta rough plastering, for because of the dryness induced in the tiles by baking them in the furnace, they cannot absorb the rough plastering nor hold it in place unless the addition of (p91) lime glues each component together and forces them to join. Once the rough plastering has been laid on, with broken terracotta in place of sand, then everything else should be completed as has already been described in the instructions for plastering.

Correctness in Painting, Winter Dining Rooms.

…This form of decoration for the pavements, used by the Greeks for their winter dining rooms, will give not unattractive, not to mention inexpensive and useful, results: underneath the level of the dining room one should excavate to a depth of about two feet, and when the soil has been packed down, either lay in a rubble underpavement or a terracotta pavement, sloped so that it has openings onto a channel. Then, onto coals that have been trampled to compactness, a **mortar mixed of gravel and lime and ash** should be laid to a thickness of half a foot. The topmost layer, planed to the rule and the level by polishing with a whetstone presents the appearance of black pavement.

NC 05.01.16 (Morgan transcribed PM).