Mortars and plasters: the information provided by ancient literary sources

The challenges of ancient written sources

- The *goals* and *intended audience* of a written source (literary or inscriptional) → rhetorical purposes?

- The *modes of transmission* from antiquity to present → human errors?

- The problem of *interpretation* when translating Latin or Greek into modern languages

The literary sources

- **Language**: Latin texts > Greek texts

- **Chronology**: few texts dated to the Classical and Hellenistic Age; increase from the 2nd century BC onwards (connected to the spreading use of lime mortar in Italy)

- **Types of texts**: mainly architectural and agricultural treatises, but also poems, letters, medical texts, encyclopediae, historic and geographic treatises

The literary sources: Greek world

Author	Title	Chronology	Type of text
Theophrastus	*On Stones*	4th cent. BC	treatise
-		Classical - hellenistic age	Inscriptions of building contracts

The sources: Roman world

Author	Title	Chronology	Type of text
Cato the Elder		160 BC	agricultural treatise
Varro	*Rerum rusticarum*	end of the 1st cent. BC	agricultural treatise
-	*Lex parieti faciendo Puteolana*	105 BC	building inscription
Vitruvius	*De Architectura*	25 BC	architectural treatise
Strabo	*Geographica*	1st cent. AD	geographic treatise
Pliny the Elder	*Natural history*	1st cent. AD	encyclopedia
Columella	*De re rustica*	1st cent. AD	agricultural treatise
Dioscorides	*De materia medica*	1st cent. AD	medical text
Dio Cassius	*Roman history*	3rd cent. AD	historic treatise
Faventinus	*Artis architectonicae priuatis usibus adbreuiatus liber*	3rd cent. AD	architectural treatise
Symphosius	*Aenigmata*	500 AD	collection of riddles
Palladius	*Opus agriculturae*	5th cent. AD	agricultural treatise
Isidore of Seville	*Etymologiae*	7th cent. AD	etymological treatise

Mortars and plasters: recipe

Mortars and plasters

=

binder
(clay, lime or gypsum)

+

Aggregates and additives
(straw, chaff, sand, volcanic ash, crushed terracotta)

+

water

1.Earthen-based binders

Earthen-based binders

Source	Information
Inscription for the repair of the Long Walls of Athens	Binding material of clay (πηλοσ) mixed with chaff or finely chopped straw (ἀχυροωσισ)
Cato, *Agr. 38*	Lime kiln made of rubble held together with clay daub
Vitruvius, *De arch. 5.10.2*	Binding of clay and hair between the fired bricks of the *pilae* in the *suspensurae* in bath buildings
Vitruvius, *De arch. 5.10.3*	Binding of clay and hair as a joint filler between the tiles of a hanging tile ceiling in a bath
Palladius, 1.34.4	Garden walls made of stones held together by clay daub

1.Earthen-based binders

Earthen-based building techniques: pisé and mud-bricks

Source	Information
Vitruvius, *De arch. 2.3*	Unbaked bricks made of white clay earth or red earth mixed with chaff/straw
Varro, *Rust.* 1.14.4	Earthen wall construction diffused in Spain and in the area of Taranto which consist of earth and gravel inside formwork
Pliny, *HN* 35.169	Walls made of earth packed between two wooden forms (*formaceos*) in Spain and Africa
Palladius, 1.34.4	Wall made up of «*luto inter formos*»

1.Earthen-based binders

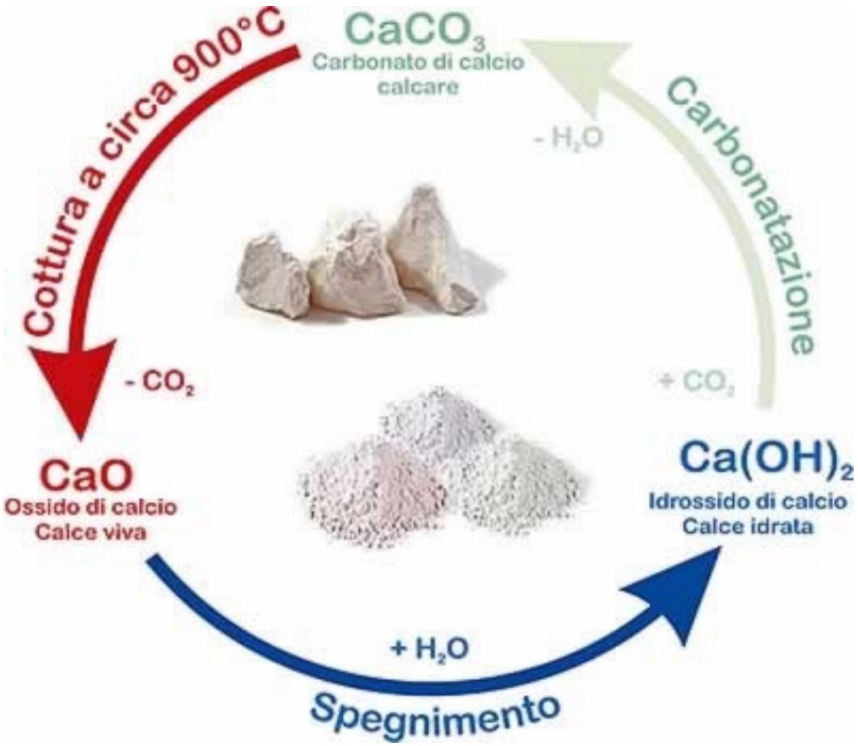
Earthen-based wall coatings

Source	Information
Cato, *Agr.* 92	Walls of granaries covered by a daub containing chaff/straw and oil lees
Varro, *Rust.* 1.57.1-2	Walls of granaries covered by a daub made of clay, grain chaff and oil lees
Palladius, 1.19.2	Walls of granaries covered by a daub made of clay, oil lees and dried olive leaves
Vitruvius, *De Arch.* 10.15.1	Coating of clay and hair over the skins of the protective shelter of a battering ram to defend it from fire
Vitruvius, *De Arch.* 7.3.11	Coating method for walls of *opus craticium*: two layers of daub and an external one of lime plaster + reeds between the layers

2.Lime-based binders

Lime production process

Calcium-based rocks



Quicklime

Slaked lime

The quality of the lime depends on the **type of stone** burned and on the **duration and temperature** of firing

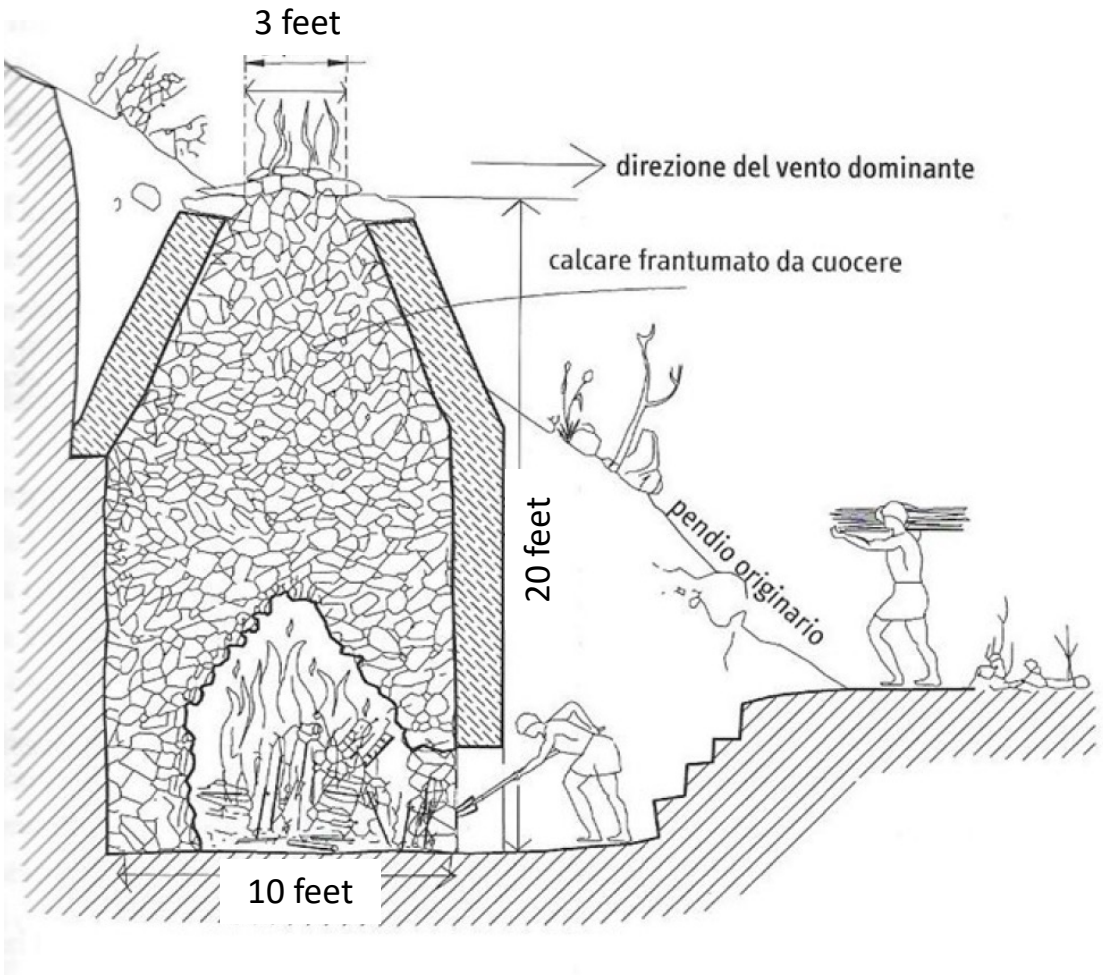
2.Lime-based binders

The selection of the stones

Source	Information
Cato, *Agr.* 38.2	Good stone, as white and uniform as possible
Vitruvius, *De Arch.* 2.5.1	White stone or *silex* (= hard stones); lime from dense hard stone is best for structural uses whereas lime from porous stone is better for plasterworks
Pliny, *HN*, 36.174	White stones; lime from dense hard stone is best for structural uses whereas lime from porous stone is better for plasterworks; condemn the use of silex; quarried stones are better than collected ones; high-quality lime made from stones used for millstones (volcanic stones or hard limestones? → hard stones)
Faventinus	White stones, **travertine** (*spolia*!), gray river stone, red stone or sponge stone (calcareous tufa)
Palladius, 1.10.3	White stones, travertine, gray river stone, red stone, sponge stone (calcareous tufa), **marble**

2.Lime-based binders

Firing the stones: lime kiln (Cato, *Agr.* 38)



Product = quicklime (*calx viva*) in powder form or in lumps

2.Lime-based binders

Slaking the lime

Source	Information
Vitr., *De Arch.* 2.5.2	Comments on the heat generated by the slaking process and tells us that it depends on the latent heat left in the calcinated stones from the firing
Pliny, *HN*, 36.174	Finds the exotermic reaction of slaking lime in water to be miraculous
Vitruvius, *De Arch.* 7.2.1	Recommends slaking the lumps of quicklime for making plaster long before using them: unslaked pieces can cause damage to plaster walls
Vitruvius, *De Arch.* 7.2.2	To test the proper slaking for plaster an *ascia* should be used to chop the lime in its pit, and if no lumps are encountered, it is ready to be used
Pliny, *HN*, 36.176	Older slaked lime is best for plaster citing an ancient law that contractors should not use lime slaked less than 3 years earlier

3.Gypsum-based binders

Advantages:

- much cheaper due to lower calcining temperature
- shorter burn time
- does not require slaking
- very quick set time

Disadvantages:

- If during the firing the temperature becomes too high, the resulting material cannot be used because it will not recombined with water
- more soluble in water
- can deteriorate in moist conditions
- does not have the same chemical potential as slake lime to combine

with high silica additives to produce hydraulic mortar

3.Gypsum-based binders

Source	Information
Teophrastus, *On stones* 64-66	Practice of burning gypsum common in *Phoenicia* and *Syria*, and in *Thurii* in southern Italy; fired stones must be pulverized before combining them with water
Cato, *Agr.* 39	fired stones must be pulverized before combining them with water
Pliny, *HN*, 36.182	Gypsum is produced by calcining stone in *Syria* and in *Thurii*; stone used should be similar to alabastrites or marble-like; the best stone to be used is *lapis specularis*
Vitruvius, *De Arch.* 7.3.3	Advises not to use gypsum in the plaster for crown moldings because it dries too unevenly
Pliny, *HN*, 36.183	Reccomends to use of gypsum for making pleasing moldings

Mortars and plasters: recipe

Mortars and plasters

=

binder
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+

aggregates and additives
(straw, chaff, sand, volcanic ash, crushed terracotta)

+

water

4.Fine aggregates

Aggregates

Inert materials (river/sea sand): the result mortar hardens on contact with air

Reactive materials containing soluble silica (volcanic ash, crushed terracotta, organic ash): the result mortar is hydraulic and hardens by means of a chemical reaction which requires water

4.Fine aggregates

Fine aggregates in ancient sources:

- river or sea sand (*harena fluviatica / marina)*
- quarry sand (*harena fossicia)*
- volcanic ash from the Bay of Naples (*pulvis puteolanus)*
- crushed terracotta (*testae tunsae*)

Ancient authors did not understand the chemistry behind different types of mortar, but they **were aware of the difference in quality and performance** that came **from using different types of fine aggregates**

4.Fine aggregates

Inert sand (river sand and sea sand)

Source	Information
Cato, Agr. 18	Simply refers to the use of sand (*harena*) in mortars to obtain a *calx harenata*
Vitruvius, *De Arch.* 2.4.2	Distinguishes between river sand (*fluvialis*), sea sand (*marina*), quarry sand (*fossicia*) and the powder (*pulvis*) from the Bay of Naples. He advises to use river and sea sand only if quarry sand is not available, because they create weaker mortars which do not support vaulting and that dry very slowly; in addition, sea sand causes salty efflorescence in plaster
Vitruvius, *De Arch.* 1.2.8	Sea sand should be washed
Pliny, *HN* 36.175	Three types of sand: *fossicia*, *fluvialis*, *marina*
Faventinus, 8	Attributes the faults listed by Vitruvius to sea sand only
Palladius, 1.10.3	Instructions for how to wash sea sand by dropping it into a freshwater pool before using it for plaster

4.Fine aggregates

Volcanic ash: *harena fossicia*

Source	Information
Vitruvius, *De Arch.* 2.4.1	Distinguishes quarry sand from river and sea sand; lists 4 types of quarry sand: black (*nigra*), white (*cana*), red (*rubra*) and *carbunculus*
Pliny, *HN* 36.175	Simply lists *harena fossicia* along with river and sea sand
Faventinus, 8	Lists 3 types of quarry sand: black, red and *carbunculus*
Palladius, 1.10	Lists 3 types of quarry sand: black, red and white and says that red is best, white is next and black is last
Vitruvius, *De Arch.* 2.4.3	Quarry sand used for structural mortars should be freshly excavated, while freshly excavated sand is too fat to be used in plaster
Vitruvius, *De Arch.* 2.6.5	*Harenae fossiciae* can be found in different parts of Etruria and Italy but do not occur beyond the Appennines or east in Greece or Asia Minor

4.Fine aggregates

Volcanic ash: *pulvis puteolanus* (pozzolana)

Source	Information
Vitruvius, *De Arch.* 2.6.1	Identifies a *pulvis* found around Baiae and in the area around Vesuvius
Vitruvius, *De Arch.* 5.12.2	When building port structures under water, a *pulvis* from the region strechting from *Cumae* to the promontory of Minerva should be used
Strabo, 5.4.6	Describes the great harbor at *Puteoli*, with moles extending into the sea as made of local sand mixed with lime
Seneca, *Q. Nat.* 3.20.3	Speaks about the *puteolanus pulvis*, which becomes rock when it touches water
Pliny, *HN* 35.166	Associates the *pulvis* with the hills around *Puteoli* and claims that it becomes like stone on contact with water
Dio Cassio, 48.51.3	Locates it as coming from the hill behind Baiae

4.Fine aggregates

Crushed terracotta

Source	Information
Vitruvius, *De Arch.* 2.5.1	Recommends the use of crushed and sifted terracotta to mortar with river or sea sand to make it stronger
Pliny, *HN* 36.175	Advises adding pounded terracotta to mortars
Faventinus, 9	Advises adding *testae cretae* to mortars

Mix of slaked lime and crushed terracotta = cocciopesto (Italian term)

Common uses: pavements, plasters

4.Fine aggregates

Crushed terracotta and *opus signinum*

Citation	Context	*Opus Signinum*	Crushed Terracotta	Verb for "Compress"	Term for "Wooden Piles"
Cato, *Agr.* 18.7	paving		yes		
Vitr. *De arch.* 5.10.3	plaster on hanging ceiling		yes		
Vitr. *De arch.* 5.11.4	walkway paving	yes			
Vitr. *De arch.* 7.1.3	paving		yes	*solido*	*vectes lignei*
Vitr. *De arch.* 7.1.5–6	paving		yes	*pisto*	
Vitr. *De arch.* 7.4.1, 7.4.3	plaster on damp walls		yes		
Vitr. *De arch.* 8.14.6	cistern	yes	*testa* or *tecta*?	*calco*	*vectes lignei ferrati* (w/iron tip)
Columella, *Rust.* 8.15.3	paving of duckpond	yes		*inculco*	
Columella, *Rust.* 8.17.1	coastal fish farm	yes			
Plin. *HN* 35.165	paving	yes	yes		
Plin. *HN* 36.176	plaster on damp wall		yes		
Frontin. *Aq.* 10.5	aqueduct intake	yes			
Faventinus 4	well	yes		*denso*	*vectes lignei*
Faventinus 9	structural mortar		yes		
Faventinus 18	paving		yes	*calco, solido*	*vectes lignei*
Faventinus 19	paving		yes		
Palladius 1.17.1	cistern wall	yes			
Palladius 1.17.1	cistern paving, wall plaster		yes		
Palladius 1.19.1	granary sub pavement		yes	*imprimo*	
Palladius 1.40.4	vaults in a bath	yes			
Palladius 1.40.5	plaster on hanging ceiling				

4.Fine aggregates

Crushed terracotta and *opus signinum*

Opus signinum (term used by 6 ancient authors)

Dense compacted mortared rubble used to build cisterns (Giuliani 1992, 2006; Grandi Carletti 2001; Braconi 2009)

Paving of crushed terracotta mortar, synonimous of cocciopesto (Gros 2003, 2015)

4.Fine aggregates

Ash VS Charcoal:

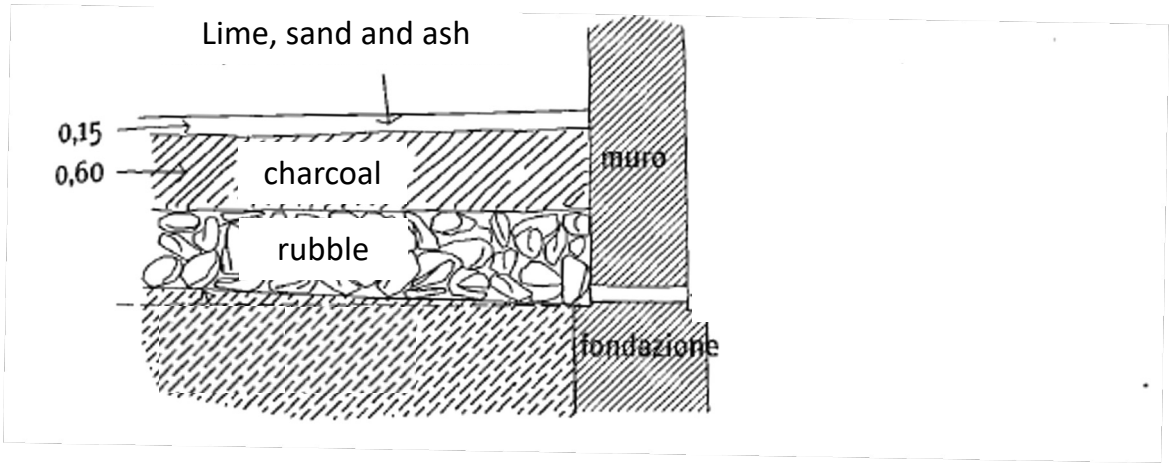
Different properties

Certain types of organic ash (grass, grains, olive pits, herbivore manure) have high levels of silica which when burnt can create ashes with soluble silica that reacts and produce hydraulic mortars

Charcoal consist mainly of carbon, which does not react with lime

4.Fine aggregates

The practice of adding burnt material to mortar is mentioned by Vitruvius (*De Arch.* 7.4.5) in relation to the method for laying the pavement of winter *triclinia* (dining rooms)



The layer of **charcoal**, thanks to its natural permability, aids in draining water away

The layer of **ash** creates a permeable but resistance surface

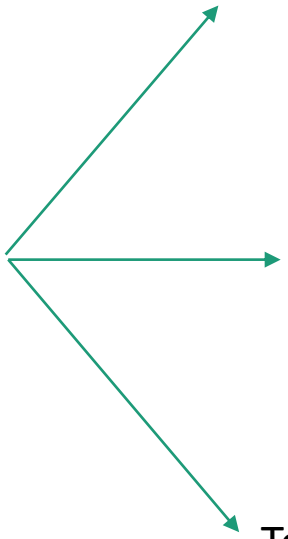
4.Fine aggregates

Marble dust

Source	Information
Varro, *Rust.* 1.57.2	Advises to line the ceiling, walls, and floor of fruit storage room with marble plaster to keep out vermin
Varro, *Rust.* 3.7.3	Recommends the same for lining a dovecote
Vitruvius, *De Arch.* 7.3.6-8	Recommends the addition of marble dust to plaster to obtain a smooth and lustrous surface; marble dust provides the plaster a pure whiteness, strenght and a sheen once polished

5.Methods and recipes for making mortars

The 3 main uses of mortars in building contexts:



To bind structural elements

To coat floors, walls and ceilings

To create caulk for waterproof seals

How to mix the final substance? Ancient literary sources provide us information about: the proportion between binder and aggregates; the use of water; the quality test

5.Methods and recipes for making mortars

Structural mortars: ratios of lime to fine aggregates given for mortars and plasters

Source	Use	Ratio Lime:Sand	Ratio Lime:Sand:TCotta	Ratio Lime:TCotta	Ratio Lime:*HarenFoss*	Ratio Lime:*PulvisPut*
Cato, *Agr.* 15	structural	1:2				
Lex Puteol. 2.16–21	structural					1:2
Vitr. *De arch.* 2.5.1	structural/plaster	1:2	1:2:1		1:3	
Vitr. *De arch.* 5.12.2	marine					1:2
Vitr. *De arch.* 7.1.3	paving			1:3		
Vitr. *De arch.* 8.14.6	cistern				2:5	
Plin. *HN* 36.173	cistern				2:5	
Plin. *HN* 36.175	structural	1:2	1:2:1	1:3		
Faventinus 4	well				2:5 (1:2 better)	
Faventinus 9	structural/plaster	1:2	1:2:1 (struct)			
Palladius 1.10	structural/plaster	1:2	1:2:1 (struct)			

Sand = river/sea sand; TCotta = terracotta; *HarenFoss* = *harena fossicia*; *PulvisPut* = *pulvis puteolanus*

Materials where probably **measured by volume** rather then by weight

5.Methods and recipes for making mortars

Structural mortars: the importance of water for hydraulic mixtures

The only source with indirectly underlines the **importance of continuous moisture for the mortar to develop strenght** is *Frontinus* (1st cent. AD), who notes that work on aqueducts should occur between April and November to avoid freezing the mortar, and that a hiatus should be taken in the hottest part of summer to avoid eccessive heat

5.Methods and recipes for making mortars

Plasters: tests to verify the quality of the mixture according to *Vitruvius* (*De Arch.* 7.2.2)

To determine the **proper consistence** of slaked lime before fine aggregates is added → the slaked lime must stick to the hoe like glue when it is withdrawn from the mixing pit

To determine if the plaster is **properly mixed** after the marble dust has been added → the mixture must not stick when it is removed by the mixing pit

5.Methods and recipes for making mortars

Caulks and sealants

Source	Information
Vitruvius, De Arch. 7.1.7, 8.6.8	Mix of quicklime and olive oil into a paste for sealing between brick pavers and segments of terracotta water pipes
Pliny, *HN* 36.181	Slake freshly calcined quicklime in wine and pound it together with pork fat and fig to create a type of caulk he calls *maltha*
Palladius, 1.17	Advises the use of fats to waterproof a cistern

Key concepts and best practice for using ancient sources

- **Check multiple translation** of the same passage; if you have philological training, compare the translation to the original Greek or Latin

- **Consider the chronology** of the text: later authors usually depend on previous one (Vitruvius –> Faventinus → Palladius)

- **Be mindful of the genre** in which the author is writing and his overall intention

- Remember that **many ancient technical terms are ambiguous** (ex. *materia* = wood or ligneous matter but also general meaning of substance, like mortar): consider the context

- **Written evidences are not sacrosant**!

Modern archaeometric studies allow the investigation into ancient building materials to go beyond what the ancient written sources tell us

Matching literary sources and archaeological records

Ancient sources:

- Do not mention the practice of adding gypsum to lime mortars
- Do not mention quarry sand outcrops outside Italy
- For building marine structures *pulvis puteolanus* should be used

Archaeological record

- Lime mortars with gypsum are attested at the Trajan's Markets in Rome (Ungari et al. 1993)
- Builders outside Italy were using their own local quarry sands, as on Cos and in the Eiffel region along the Rhine in Germany (Livadiotti 2006; Lamprecht 1984; Massazza and Costa 1977)
- Local types of *harenae fossiciae* were also employed in marine structures (Brandon et al. 2014; Marra et al. 2016)

Matching literary sources and archaeological records

Ancient sources:

- Do not mention the practice of use ashes in contexts different from triclinia floors

Archaeological record

- Ash is often used in addition to or as a substitute of crushed terracotta in the waterproof plasters of liquid containment structures (Lancaster 2012; Bonetto, Dilaria 2020)