

# **DAAD Summer School**

***“Dialogue on Cultural Heritage in Times of Crisis”***

***“ROMAN BUILDING MATERIALS AND TECHNIQUES: FROM  
OPUS QUADRATUM TO OPUS INCERTUM, THE DEVELOPMENT  
OF THE TECHNIQUE TO BUILD”***

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## **Abstract**

Roman architecture is an amazing world that illustrates the magnificence of the achievements of ancient Romans. The architectural remains are still witnesses of the great roman past giving precious details for the techniques and materials that were employed by Romans. This article focuses on the different building materials and techniques that developed throughout roman period. The main aim of the paper is to display a chronological evolution of building techniques that developed mainly in Italy, the heart of roman world. An additional goal is to expound the various materials that Romans used and how these materials influenced building techniques. Apart from that, the article demonstrates the reasons that determined the choice of building materials and beyond that tries to trace the society that developed all these techniques. This endeavor shows how Romans manage to incorporate materials that contribute to the evolution of building techniques and led to the monumental complexes of imperial period.

**Keywords:** buidling techniques, materials.

## **About the Author**

Rafail Evzonas is a graduate of the University of Cyprus. He received his B.A. degree in Archaeology in 2016. He took part in many excavations of different kinds with the University and the Department of Antiquities of Cyprus in Cyprus and Greece. Except archaeology, Rafail has special interests in conservation and restoration. For this reason he took part in many seminars and workshops that related with Conservation. Now he intend to follow Conservation as master degree.

## **1.Introduction**

Roman world holds a fascination for many people, capturing our imagination with all these roman miracles which are still visible today. Ruins and literary sources are the remains of this great civilisation which left behind an enormous heritage to humanity. Roman architecture still influence modern world with its achievements. Modern scholars stand with respect in front of the magnificence of romans. Many studies are still focused on the vast archaeological material which is related with romans, from ancient authors to simple remains of buildings. An important field of study for roman world are building materials and techniques that developed throughout roman period. Scholars try to trace the evolution of roman building techniques, and how romans incorporate materials that influence the development of building techniques. All these studies of roman building techniques, contribute to a better understanding of roman society and the relation between this society and its built environment (Ulrich B. R. & Quenemoen K. C., 2013: 2-3).

## **2.Sources of evidence**

There are three sources of evidence for materials and building techniques. These sources provide various details such as the vocabulary that Romans used for different materials or building techniques. The first category, which is the richest, encompasses the remains of roman buildings that survived through centuries in all the parts of roman world (Lancaster & Ulrich, 2013: 157). Pompeii, Herculaneum, Oplontis and other places represent excellent examples for this category giving precious details for buildings and materials. Apart from that, all these remains not only provide information about buildings techniques but also giving information for the society who developed all these techniques (Anderson, 1977: 21). Literary sources comprise the second category. A handful of ancient text like Vitruvius's "Ten Books of Architecture", Pliny's "Historia Naturalis", the correspondence of Cicero and other literary sources such as the imperial biographies of Suetonius provide details of building materials and processes. Beyond that, literary sources uncover the purposes behind the construction of a building and in some cases the person who was responsible for that. These sources also allow partially the recovery of ancient vocabulary for materials or building techniques. The last category includes the various depictions such as wall paintings, relief sculptures and numismatic images which depict buildings and in some cases the processes that were followed. Trajan's Column (Fig.1) is one of the best examples of this category with depictions of buildings and building activities (Lancaster & Ulrich, 2013: 157).

## **3.Materials**

Romans exploited a variety of different building materials that influenced roman architecture and beyond that building techniques. The Italian peninsula has rich natural sources like timber, metals and many rivers that facilitated the transportation of raw materials (Lancaster & Ulrich, 2013: 159). The volcanic environment provided Romans

with different types of stones known as tuffs (Fig.2). Additionally, within volcanic stratification were layers of volcanic ash, pozzolana. This ash was one of the basic components of the well-known opus caementicium. The roman concrete was, according to many scholars, the milestone of roman architecture that changed sharply the development of building techniques (Anderson, 1977: 146). Apart from all these materials Romans used also metals and glass for building and particularly for decorative purposes. Roman builders were fortunate in having all these natural materials from volcanic tufas, limestones and marbles to clays, bricks and mortar that contributed to the development of the different building techniques (White, 1984: 84).

#### **4. Selecting the right material**

The selection of the right materials for a building was very important and crucial because the wrong choice might led to serious situations. There are many reasons that determined that choice. The most important reason for the proper choice was the qualities of each material. Some materials were durable to moisture, other were more stable or impervious to fire like peperino tuff as Tacitus inform us «...stone from Gabii or Alba, that material being impervious to fire..» (Tacitus, Ann., 15.43). Each material had his own qualities and was selected according to the nature of the structure because there were structures like cisterns that needed special materials like waterproof mortar. Funding was also an important reason for choosing a material due to the fact that the owner could import materials from all the corners of the known world. The availability and accessibility of sources were serious reasons too. We should bear in mind that the accessibility of materials for Romans was changeable throughout centuries. While Rome was expanded, new materials and also techniques were added to builders' repertoire. New techniques that contribute to the improvement of technical knowledge which was a crucial factor for the construction of a building (Lancaster & Ulrich, 2013: 175). Usually technical knowledge was acquired by experiments and errors that led in some cases to great failures such in the case of the collapse of the amphitheatre of Fidenae in the early first century A.D. «...on account of a disaster at Fidenae, where upwards of twenty thousand persons had been killed by the fall of the amphitheatre...» (Suetonius, Tib., 40). Time, local building traditions, aesthetic reasons and especially workforce were also factors that determine the choice of a material (Taylor, 2013: 202-203). Generally, there were many reasons behind the choice of materials. In most cases the final selection of the proper materials was determined by a combination of different reasons.

#### **5. The development of Roman building techniques**

In early phases Romans used unshaped or roughly shaped stones, unfired bricks and unsawn wood for their buildings, influenced from the Etruscans and Latins of central Italy. Traces of dwellings and other simple structures are attested on the Palatine Hill from the end of ninthth century B.C. (Fulminante, 2014: 84). The development of technology, especially the evolution and use of iron tools allowed employing raw materials, building

larger structures which could support heavier loads such as roofing tiles (Lancaster & Ulrich, 2013: 161).

From the end of eighth century B.C., the local population manage to quarry the local soft tuff which was used first in rubble form, into blocks. Opus quadratum or ashlar masonry consisted of rectangular blocks set in horizontal courses and held together by clamps and dowels. In some cases was used mortar as bond between rows (Fig.3) (Anderson, 1977: 139). This technique was widespread from the sixth century B.C., particularly in central and southern Italy and Sicily where there were greek colonies due to the fact that this technique was common in main Greece. Initially opus quadratum was used for structures such as city walls, cisterns and temple podia and there was a tendency to leave the outer face roughly finished. From the late fourth century B.C. it was introduced into monumental architecture, mainly as facing (Marta, 1986: 11).

Another form of ashlar construction which was rare was “chequer-work” (Fig.5). The origin and ancient name of this technique is still unknown. “Chequer-work” consisted of squared blocks placed on one another in a lattice acted as supporting elements. The interstices were infilled by rubbles with mortar. Examples of this rare technique are attested in Campania and Etruria from the fourth century to second century B.C. Its disappearance is connected with the appearance of lime mortar in early second century B.C. (Adams, 1994: 119-120).

In regions in central Italy where the tuffs were not soft, they were quarried into irregular blocks. This technique, known as opus siliceum, indicates polygonal masonry consisted of irregular blocks work to fit together and were held with clumps and dowels (Fig.4). These blocks were not set in rows and their interstices were filled in some cases by mortar (Anderson, 1977: 139) . Opus siliceum was very popular technique and have been used for city walls, roads, cisterns, tombs etc. until the early first century B.C. (Marta, 1986: 9).

Another technique that have been used in southern Italy and Sicily and especially in north Africa where was born during the republican period, is opus africanum or as archaeologist called it “opera a telaio” (Fig.6). This technique was introduced in Sicily and southern Italy during the Punic Wars. It's made of large stone blocks placed vertically and horizontally forming the supporting element of the wall. The interstices are filled by roughly square blocks (Lancaster & Ulrich, 2013: 189). Although this technique survived until the sixth century A.D., there are only few examples such as in the House of Surgeon at Pompeii and in the House of Trifolium in Tunisia (Adams, 1994: 121).

Opus africanum is very similar to another technique known as opus craticium (Fig.7). This technique is common in many parts of the world until today. It had a wooden framework with the spaces fill by stones and mortar (Marta, 1986: 24). Opus craticium have been used especially for walls and partitions, usually on the walls of the upper floors due to the vulnerability of wood. Only few remains were left behind because of the perishable nature of wood. There are few examples at Pompeii and elsewhere particularly at Herculaneum (Adams, 1994: 122-123).

From the end of the third century, there was a tendency to use harder stones like travertine and imported marbles as in the case of the so called Temple of Hercules Victor in Rome. The use of such hard stones enriched Roman builder's repertoire and contributed to the evolution and improvement of roman architecture (Lancaster & Ulrich, 2013: 163).

At the same period, builders manage to develop a new material that change radically and revolutionized roman architecture giving an impetus to the development of building techniques. This material was opus caementicium or the roman concrete, which consisted of small stones or tile fragments held together with mortar made of lime, water and volcanic ash known as "pozzolana" (Lancaster & Ulrich, 2013: 172). The qualities of this new material, especially the plasticity and strength, allow the romans builders to experiment with new ideas and applied them and on other architectural elements such as arches and vaults and the construction of structures like bridge and harbors (Lancaster, 2008: 260).

Opus caementicium was used mainly as core of walls with different facings in stone and brick creating a smoother surface for walls. Facings were functioned as framework when builders poured the mixture to create the core. There are many facings which in some cases were combined even in the same wall (Anderson, 1977: 146).

Opus incertum is a type of facing for rubble and concrete core of wall (Anderson, 1977: 148), consisting of irregular small tufa stones laid in random pattern (Fig.8). The stones are bound with mortar (Marta, 1986: 18). It is contemporary with the appearance of opus caementicium between the 3rd and 2nd century B.C. and is one of the earliest facing for concrete walls (Lancaster & Ulrich, 2013: 165). Opus incertum appears in many buildings such as the Temple in Palestrina and the Basilica in Pompeii at the end of second century B.C.. During the second and first century B.C this technique saw its greatest evolution with more carefully finished appearance (Adams, 1994: 127). It remained in use through the first quarter of the 1st century B.C. and occasionally appears later than that, particularly in opus mixtum (Anderson, 1977: 148). It was declined in the 1st century B.C and replaced by opus reticulatum. The decline of the technique was due to the socio-economic evolution which was took place in those years bringing a systematization of the work and leading to massive production of prefabricated elements which made the job of the builders simply (Adams, 1994: 128).

The transition from opus incertum to more reticulate facings was gradual and took place in the last quarter of the second century B.C. (Fig.8). It was in this time that Romans used uniform-sized blocks of tufa laid at 45 degrees arrangement with mortar as bounding and bricks as quoins producing a multi-coloured appearance (Anderson, 1977: 148). At the beginning, the new technique had rough form and fail to have regularity in the rows of the tufa stone. For this reason archaeologists called the earliest attempts as opus quasi-reticulatum which is very difficult to distinguish it from opus incertum. There are many examples of the earlier reticulatum such as the House of Griffins on the Palatine, in the Sullan walls and in the second phase of the Villa of Mysteries (Adams, 1994: 129). From the first half of 1st century B.C., the new technique achieved the regularity in the lines of the blocks. That new arrangement of the stones is in line with the economic and social evolution of Romans. From the third century the use of an abundant supply of servile labour

allowed the massive production of prefabricated elements. Something that led Romans to the creation of new building techniques. Opus reticulatum was adopted in central and southern Italy at the end of the Republican period until the early second century A.D. when the kiln-dried bricks began to be used (Anderson, 1977: 150).

Opus vittatum was another facing of opus caementicium which consisted of small blocks laid in horizontal courses with the same height bond with mortar. It is an isodomic or pseudo-isodomic construction on a small scale (Anderson, 1977: 155). This technique attested from the third century B.C. at Pompeii mainly for restorations. In Augustan period opus vittatum was used more systematically but not in every region of the empire. In central Italy it has been used for some periods until the reign of Maxentius unlike Gaul where it became the standard form of architecture (Adams, 1994:136).

In the second half of first century B.C. builders began experimenting by replacing opus reticulatum with another technique which used bricks as facing (Lancaster & Ulrich, 2013: 167). Initially, opus testaceum or opus latericium used roof tiles until the mid-first century A.D. with the creation of flat triangular bricks with different sizes for facings, arches etc (Fig.11). Brick industry managed to dominate in building due to the fact that bricks could be produced more quickly, were easier to use and offered an impressive coloured effect. Opus testaceum have been used for the construction of the most remarkable structures of imperial period such as Pantheon and the Trajan's Forum and for other buildings at Ostia, Pompeii and elsewhere (Adams, 1994: 145-149).

Opus reticulatum was not entirely abandoned and continued to be used as part of opus mixtum (Fig.9) which was made up by alternating opus reticulatum or incertum with opus testaceum and survived until the third century A.D. (Marta, 1986: 26). Examples of this technique are still visible at the Odeon of Pompeii and elsewhere. In some cases bricks were alternated with small rectangular blocks. This alternation is known as opus vittatum mixtum (Fig.10) and has been used mainly in Late Antiquity (Lancaster & Ulrich, 2013: 168).

There is another technique that employed baked bricks. Opus spicatum (Fig.12) was the technique of setting bricks or even stones into concrete in a herringbone pattern. This technique was used especially for floors, roads and terraces from the first century A.D. onwards. In the western provinces appears also as wall facing, particularly in Gaul (Anderson, 1977: 155).

## **6.Conclusions**

During roman period, took place a great development of different building techniques. Techniques were developed in all the corners of roman world from the simplest methods such as rubble masonry to more sophisticated techniques like the facings of opus caementicium. There was an evolution of constructive techniques which was determined by many factors such as funding, technical knowledge and building traditions (Lancaster & Ulrich, 2013: 175). Etruscans and Greeks of southern Italy and Sicily, influenced the

romans builders at least at the first steps of roman architecture. Romans managed to adopt knowledge and skills and created their own advanced techniques. While the empire was expanded new materials, technical skills and other elements were added to roman architecture. The development of roman technology led to important inventions such as opus caementicium which change the route of roman building techniques. Apart from that, we should also remember that the transition from one technique to another, was usually gradual and didn't take place in all regions. The development of a new technique didn't mean necessarily that the other techniques were abandoned. Many techniques co-existed while others were never abandoned. All of them, in any case contributed to the evolution of roman architecture, created from poor structures to imperial monumental complexes. Today, the miracles of roman architecture are still visible, witnesses of the great roman world. Scholars study this vast archeological material and try to understand roman society in periods. However, there is still much work to do and new technologies could be very helpful for this purpose.

## **7. Acknowledgment**

I extend first my heartfelt thanks to the director of the programme Erwin Emmerling and the organizing committee Dr. Roberta Fonti, Dr. Sara Saba and Dr. Anna Anguissola who give me the great opportunity to take part to the Summer School "Dialogue on Cultural Heritage in Times of Crisis". I especially thank Dr. Roberta Fonti who guided me throughout this project and offered me precious advices. I am also grateful to all scholars that I had the privilege to meet during the Summer School whose research and scientific experience helped me to synthesize my project.



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## **9. List of Tables**



Fig.1 - Cutting down trees, Trajan's Column

*Roman Building Materials and Techniques: From Opus Quadratum to Opus Incertum, the development of the technique to build*

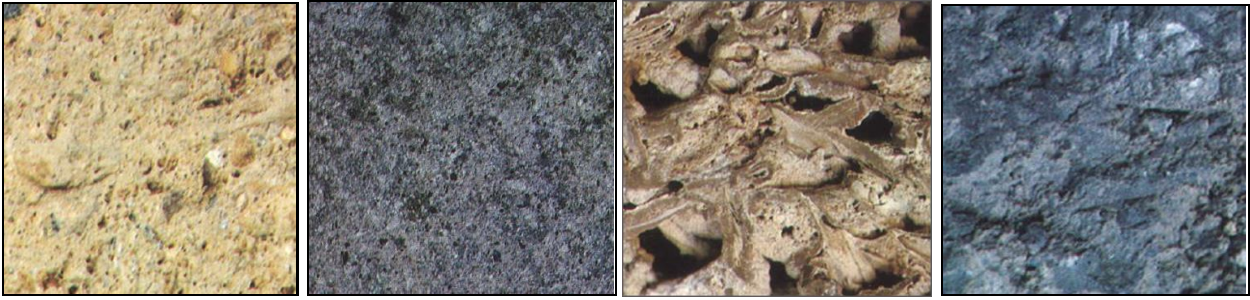


Fig.2- Different kind of tuff: *from the left*: Grotta Oscura, Peperino, Tartaro and Cappellaccio (Marta, 1986: 60-61)



Fig,3 - Opus quadratum (Coarelli, 1974: 342)

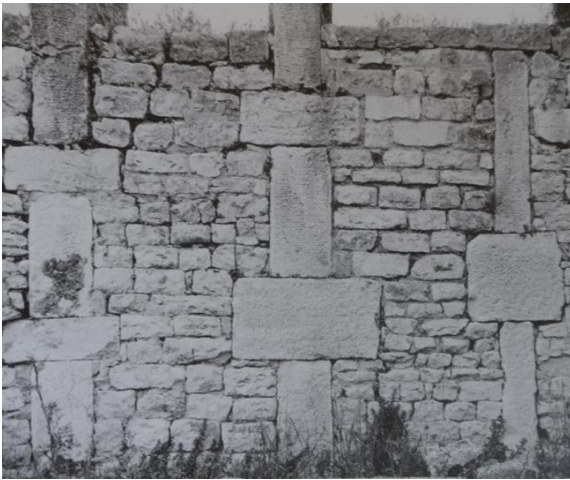


*Left:*Fig.4 - Opus siliceum, Pompeii, VIII.5.30



*Right:* Fig.5 - Bolsena, wall of chequer-work construction, 2nd century B.C. (Adams, 1994: 104, 119)





*Left:* Fig.6 - House of Trifolium, Tunisia (Adams, 1994: 120-121)



*Right:* Fig.7- Herculaneum, opus craticium with rubbles as infilling (Rafail Evzonas)

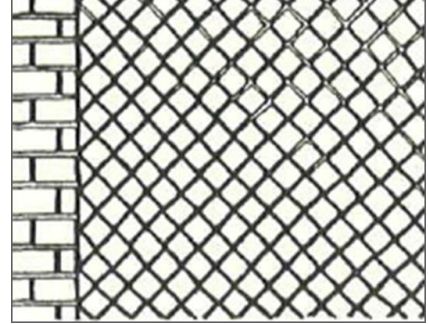
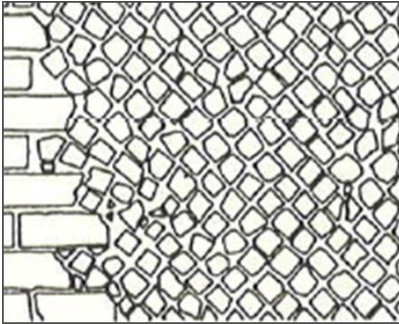
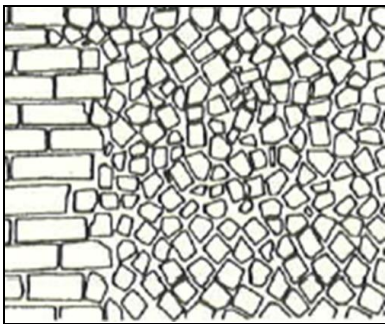
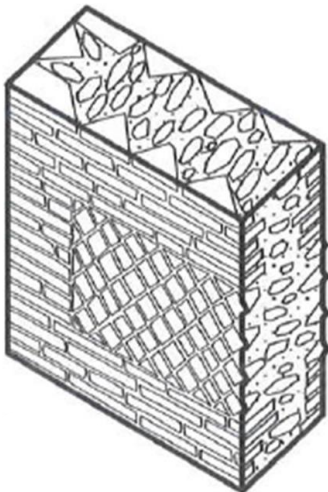


Fig.8- from left: Opus incertum, Opus quasi-reticulatum, Opus reticulatum (Coarelli, 1974: 342)



*Left:* Fig.9 - Opus mixtum (Lancaster, 2008:263)



*Right:* Fig.10 - Opus vittatum mixtum, Pompeii (Rafail Evzonas)

*Roman Building Materials and Techniques: From Opus Quadratum to Opus Incertum, the development of the technique to build*



*Left: Fig.11 - Opus testaceum, Colloseum, Rome (Rafail Evzonas)*



*Right: Fig.12 - Detail from opus spicatum, Colosseum (Rafail Evzonas)*



## Rafail Evzonas

*“Roman building materials and techniques: From Opus Quadratum to Opus Incertum, the development of the technique to built”*



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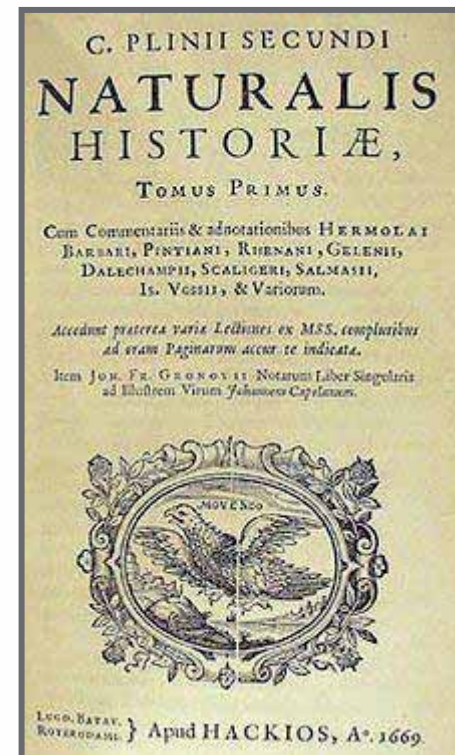
Hotel Principe Napolit'Amo, Naples

## Sources of evidence

- ❖ Remains of Roman buildings
- ❖ Literary sources
- ❖ Depictions (wall paintings, numismatic images etc.)



Construction of Roman military fortifications ,  
Trajan's Column (Thill, 2010: 30)



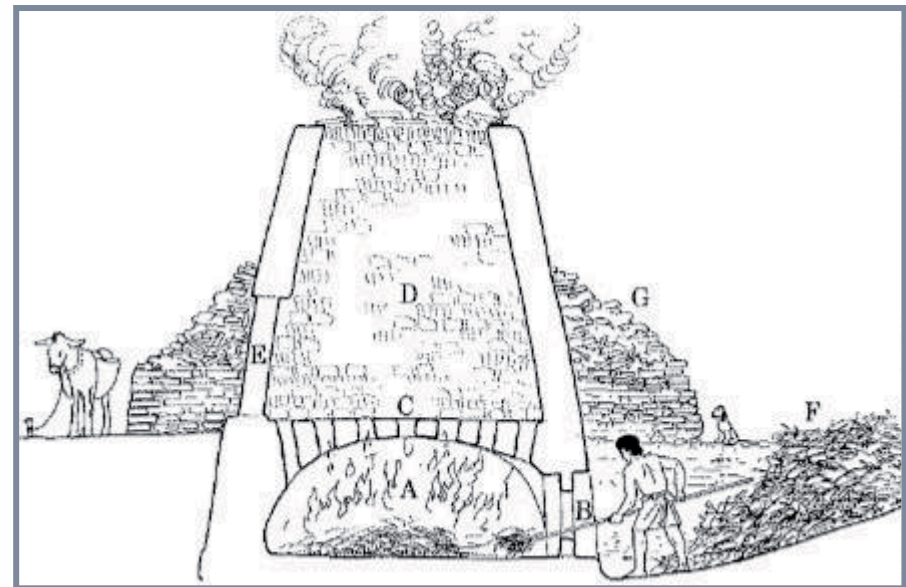


## Materials

- ❖ Stone, Marbles
- ❖ Clay (unfired or fired bricks)
- ❖ Concrete (Opus caementicium)
- ❖ Wood
- ❖ Glass
- ❖ Metal



Cutting down trees, Trajan's Column



Above: Quarrying in galleries

Below: A brick kiln (Adams, 1994: 27, 34)



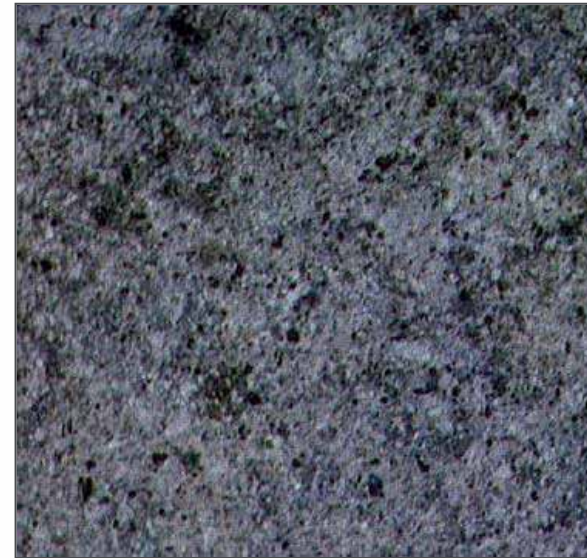
Grotta Oscura



Cappellaccio



Tartaro



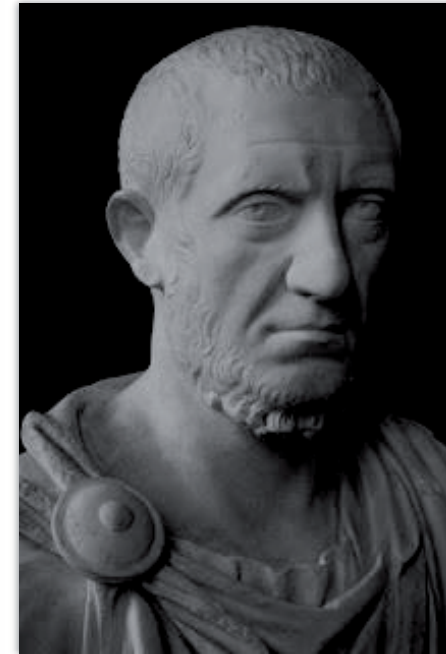
Peperino

Different kinds of tuff (Marta, 1986: 60-61)



## Selecting the right material

- ❖ Qualities of the material
- ❖ Funding
- ❖ Availability and Accessibility of sources
- ❖ Technical knowledge
- ❖ Time
- ❖ Workforce
- ❖ Local building traditions
- ❖ Desired longevity
- ❖ Aesthetic

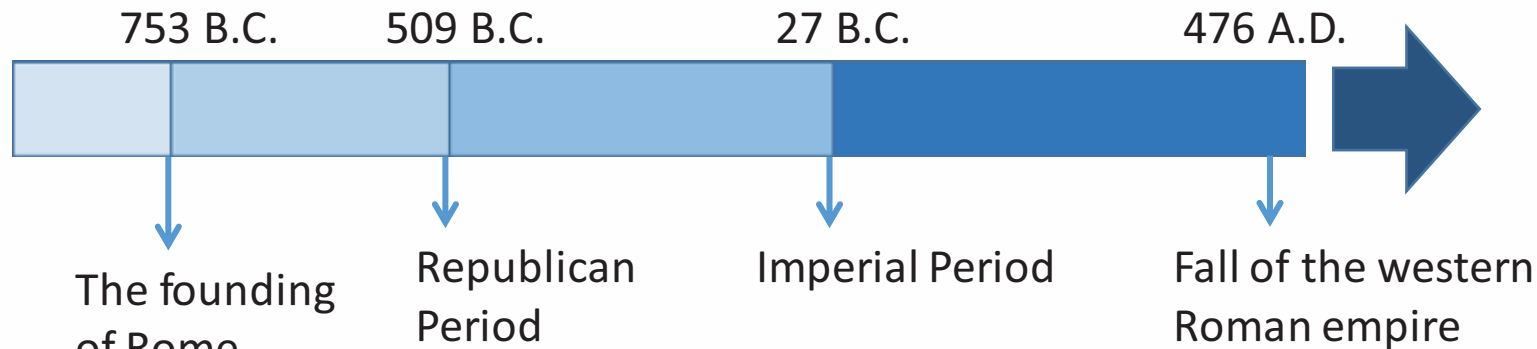


Publius Cornelius Tacitus (1<sup>st</sup>-2<sup>nd</sup> cent. A.D.)

*«...saxo Gabino Albanove solidarentur, quod is lapis ignibus impervius est...»*  
*«...stone from Gabii or Alba, that material being impervious to fire..»*  
 (Tacitus, *Ann.*, 15.43)

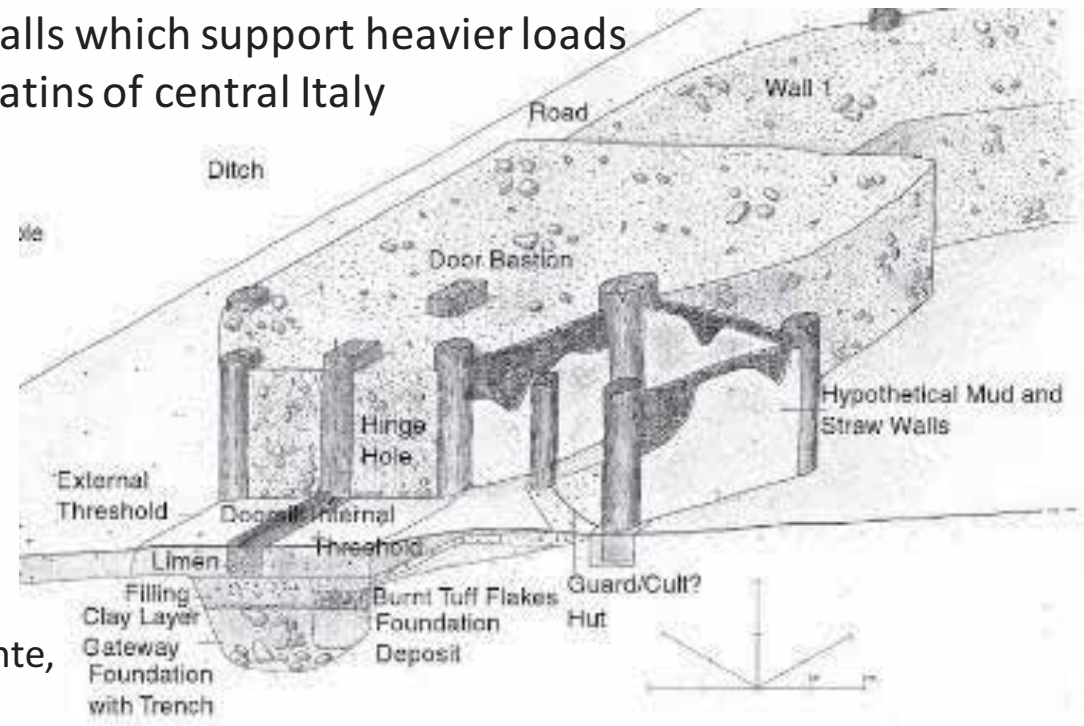
*«...qua apud Fidenas supra uiginti hominum milia gladiatorio munere amphitheatri ruina perierant...»*  
*«...on account of a disaster at Fidenae, where upwards of twenty thousand persons had been killed by the fall of the amphitheatre...»*  
 (Suetonius, *Tib.*, 40)

## The development of roman building techniques



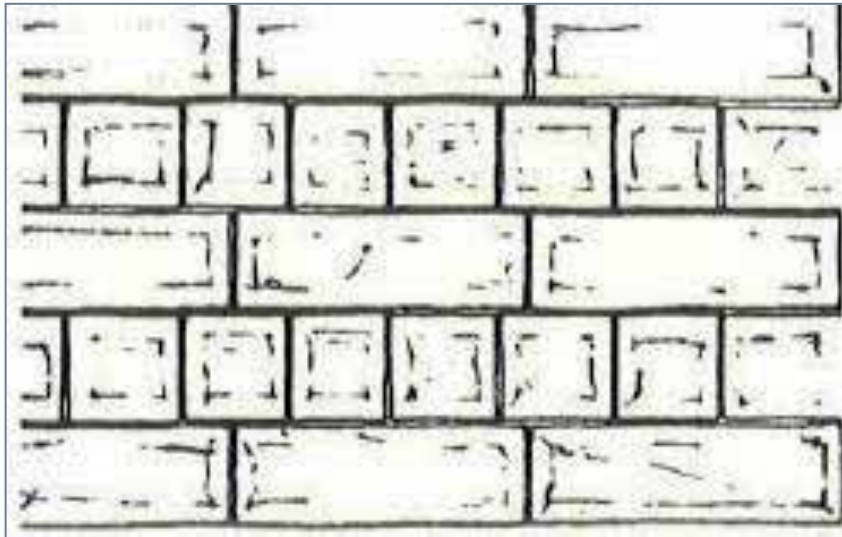
### In early times

- Simple structures from wood and roughly shaped stones
- From the 7<sup>th</sup> century stronger walls which support heavier loads
- Influences from Etruscans and Latins of central Italy

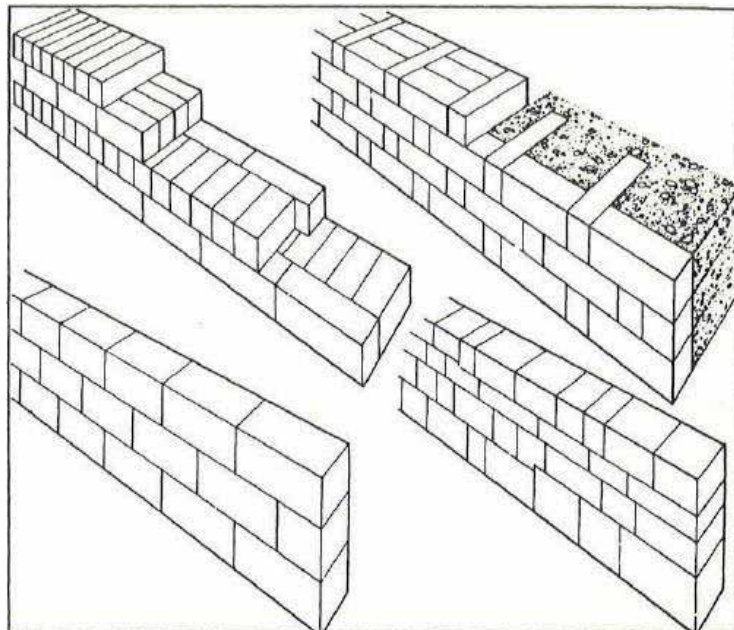


Reconstruction of an earthen wall, 8<sup>th</sup> cent. B.C., Palatine hill, Rome (Fulminante, 2014: 84)

## ❖ Opus quadratum



Opus quadratum (Coarelli, 1974: 342)



Methods of building wall in opus quadratum  
(Adams, 1994: 110)





Forum of Augustus, Rome



House of the large Fountain,  
Pompeii(Adams, 1994: 111, 113)

## “Chequer-work” technique



Chequer-work  
infilling, 3<sup>rd</sup> c

Bolsena, wall  
2<sup>nd</sup> century



stone blocks





## Opus siliceum



Pompeii, VIII.5.3

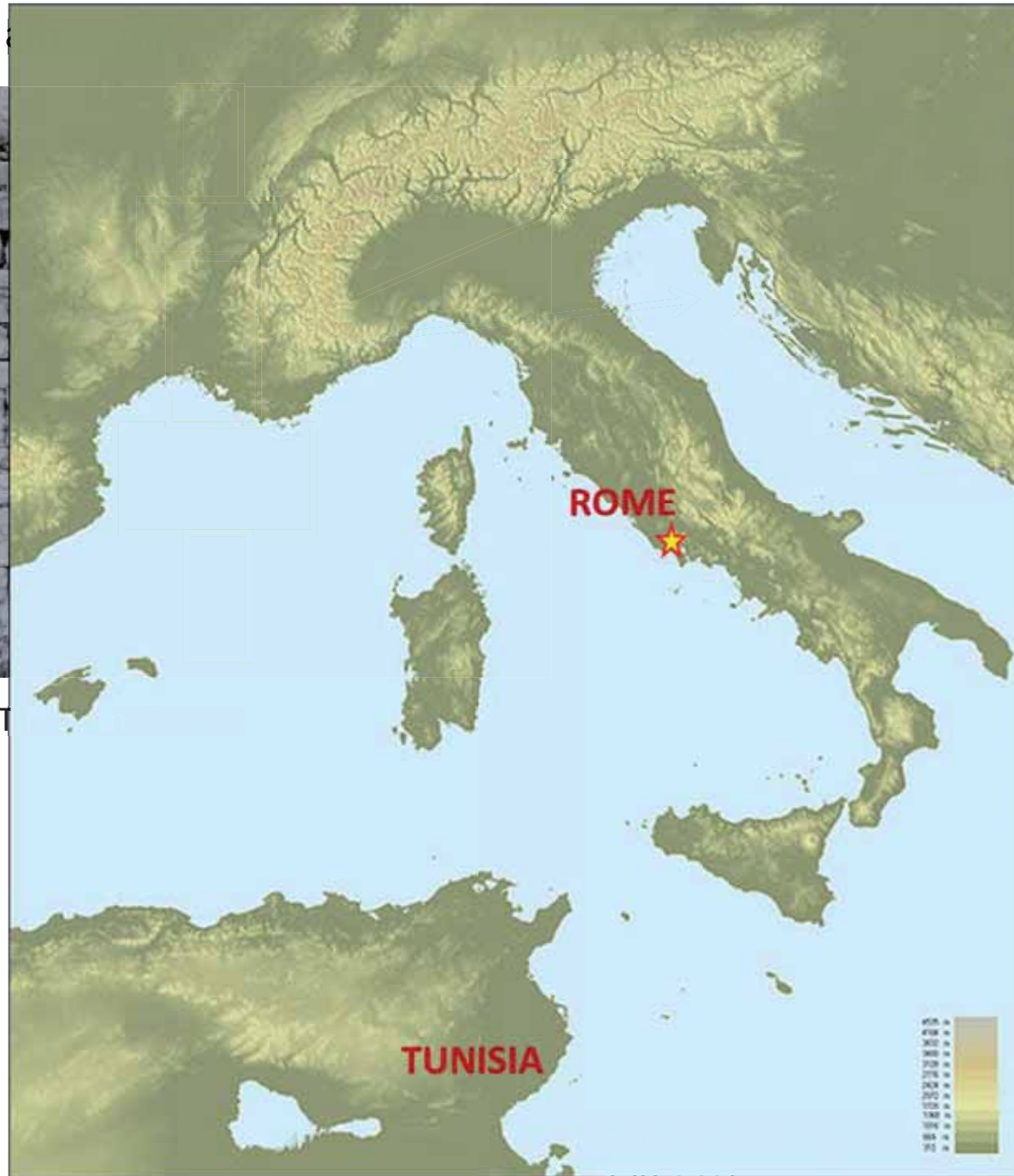


The acropolis  
siliceum, south

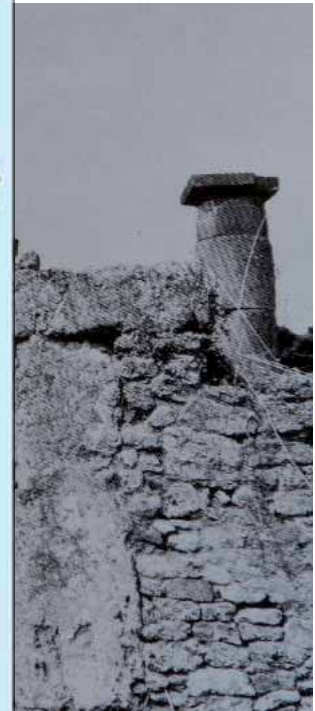
❖ Opus



House of T



blocks,  
work of the



Adams, 1994:

120-121)



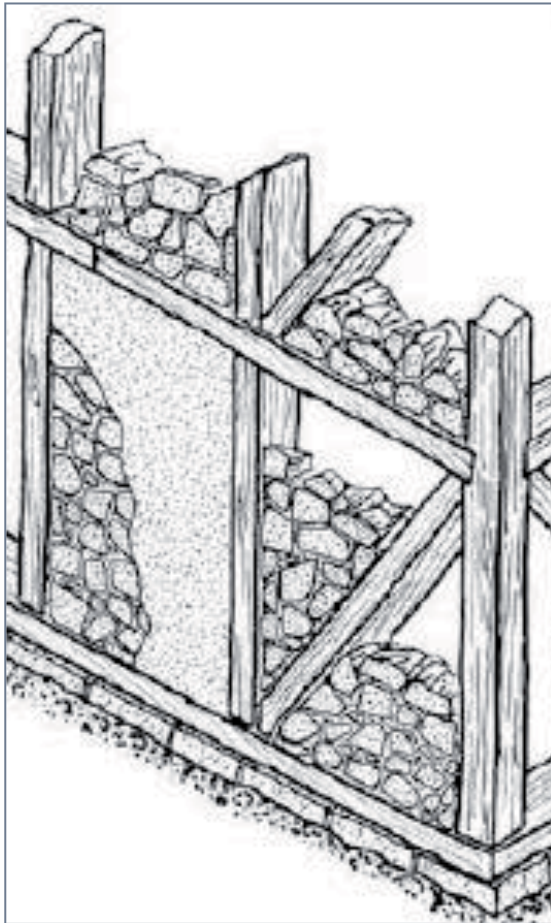


Opus Africanum, Pompeii, VII.





## ❖ Opus craticium



Opus craticium (Lancaster & Ulrich, 2013: 161)



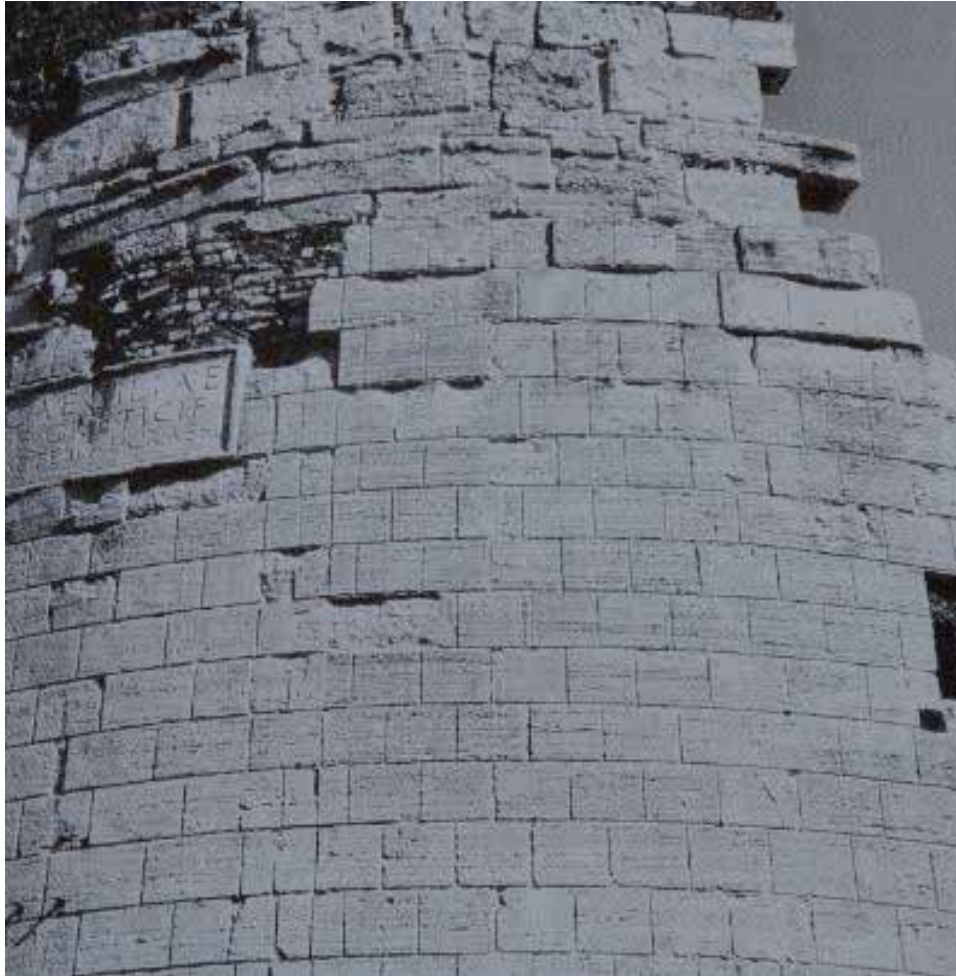
Herculaneum, opus craticium with rubbles as infilling



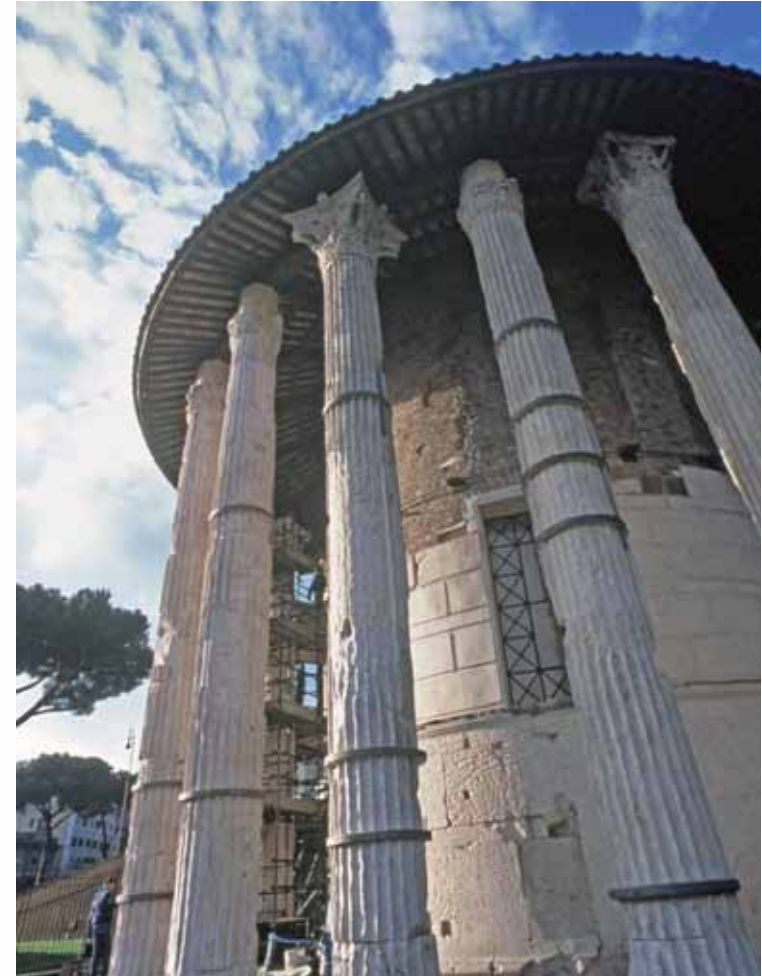
Restored partitions of opus craticium,  
*above:* Pompeii  
*below:* Herculaneum







Facing of travertine , tomb of Caecilia Metella,  
outside Rome (Adams, 1994: 114)



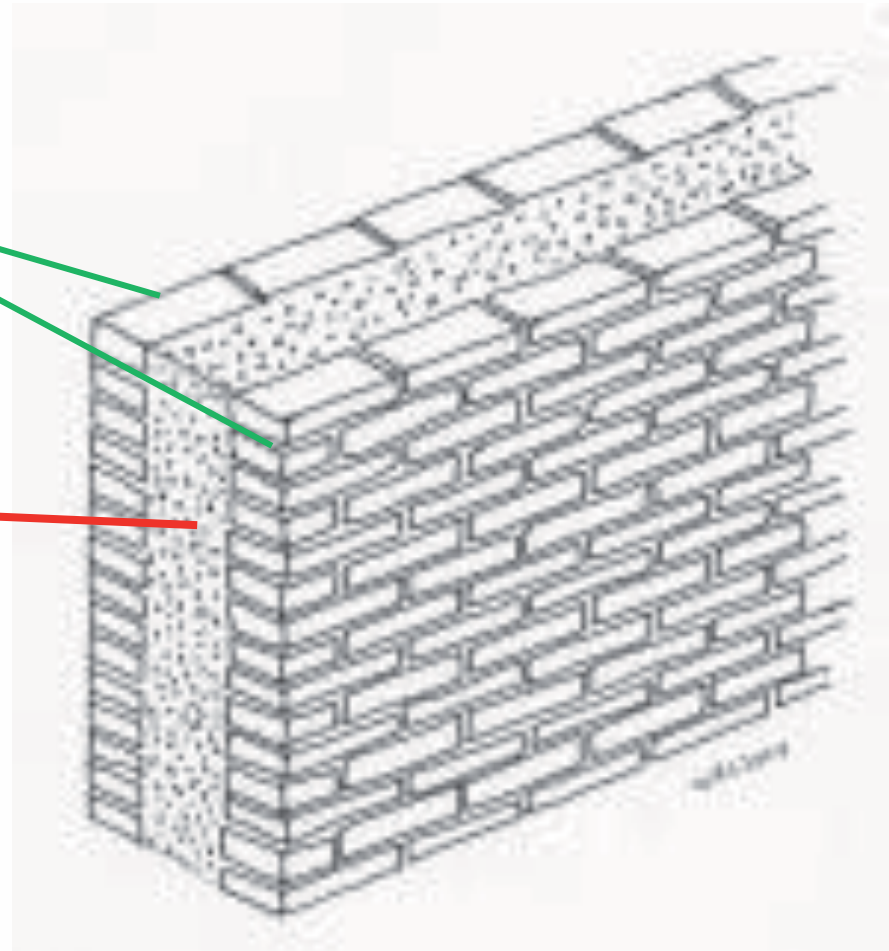
Temple of Hercules Victor, Rome

## Opus caementicium

- a mixture of small stones or tile fragments with mortar made of lime, water and volcanic ash (pozzolana)

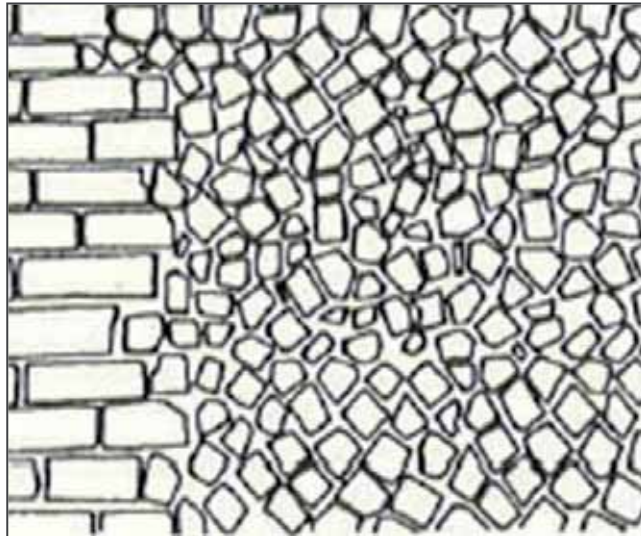
Facings, function as  
framework for concrete

Opus caementicium  
as core of wall

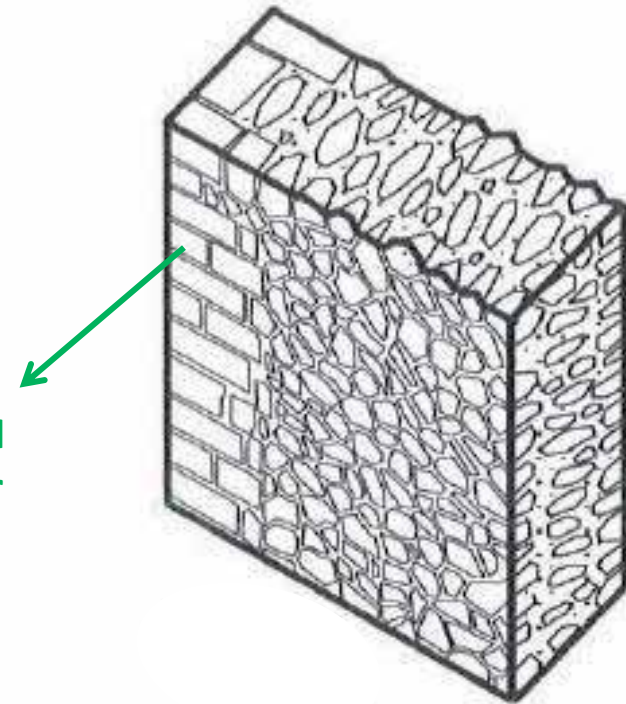


## Types of facing in stone and brick

### ❖ Opus incertum



Opus incertum (Coarelli, 1974: 342)



Quoin, formed  
from stones or  
bricks

(Lancaster, 2008: 263)

«*Structurarum genera sunt haec: reticulatum, quo nunc omnes utuntur, et antiquum, quod incertum dicitur..*»

«*There are two styles of walls: “opus reticulatum,” now used by everybody, and the ancient style called “opus incertum.”*» (Vitruvius, *De Arc.*, 2.8.1)





Opus incertum (Lancaster, 2008: 166)

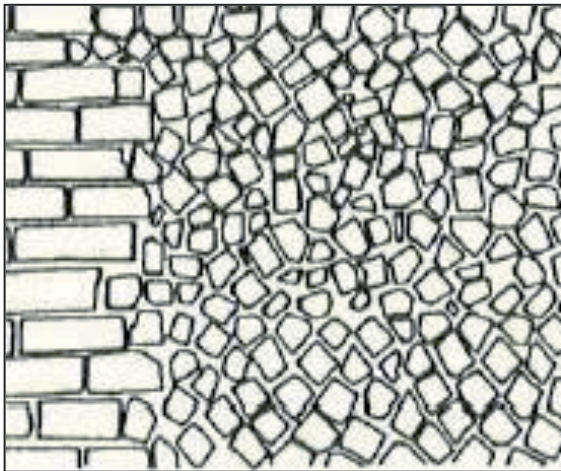


House of Obelius Firmus at Pompeii

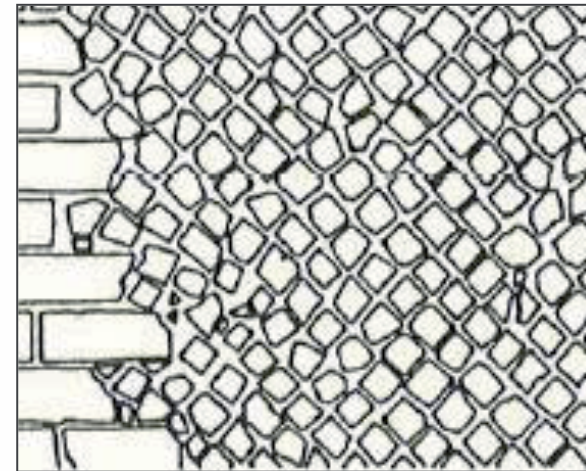


Temple of Fortuna at Palestrina, near  
Rome (Adams, 1994: 127-128)

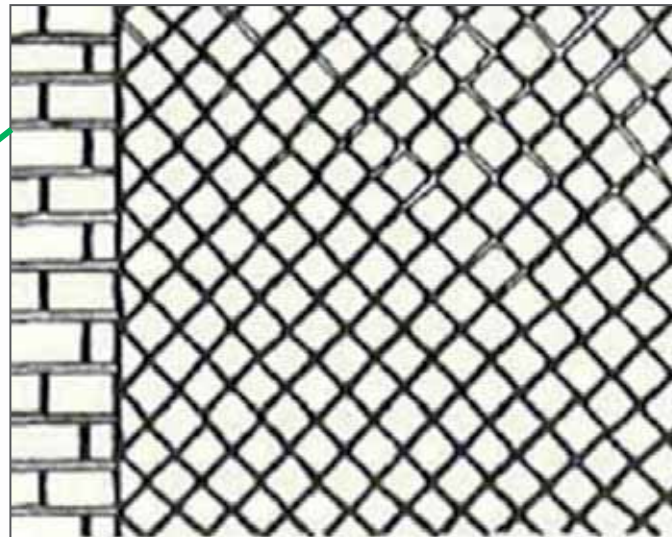
❖ Opus quasi-reticulatum and Opus reticulatum



Opus incertum



Opus quasi-reticulatum



Opus reticulatum

quoin from bricks  
or stones

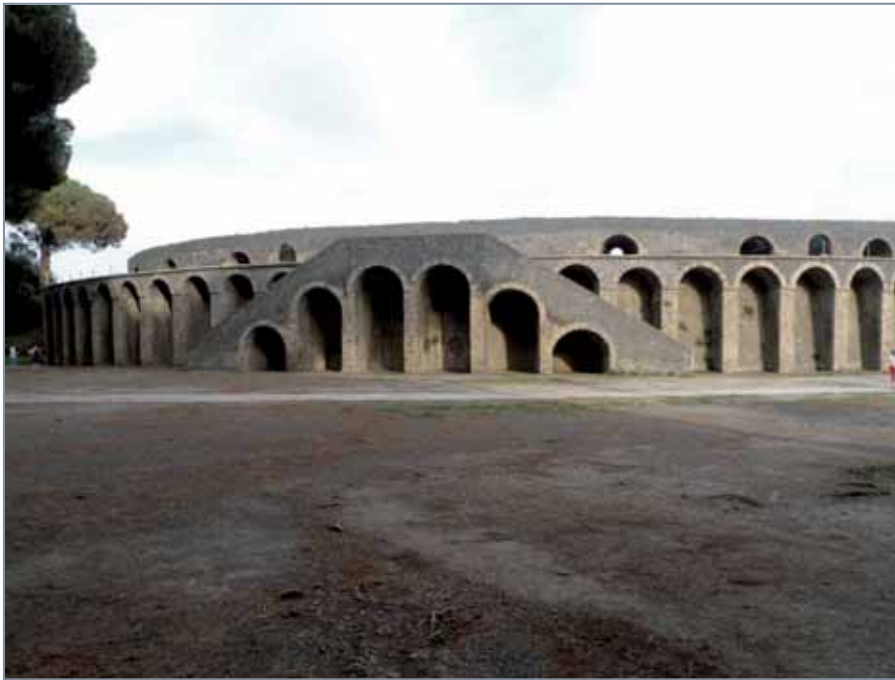






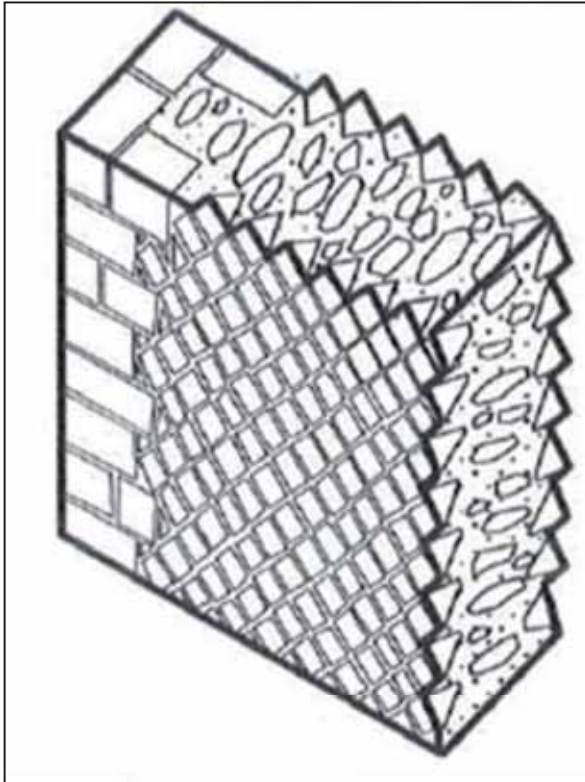
Odeon of Pompeii, opus quasi-reticulatum





Opus quasi-reticulatum, Amphitheatre of Pompeii

## ❖ Opus reticulatum



Opus reticulatum (Lancaster, 2008: 263)

«...ex his venustius est reticulatum...»

«...of these, the reticulatum looks better...» (Vitruvius, *De Arc.*, 2.8.1)

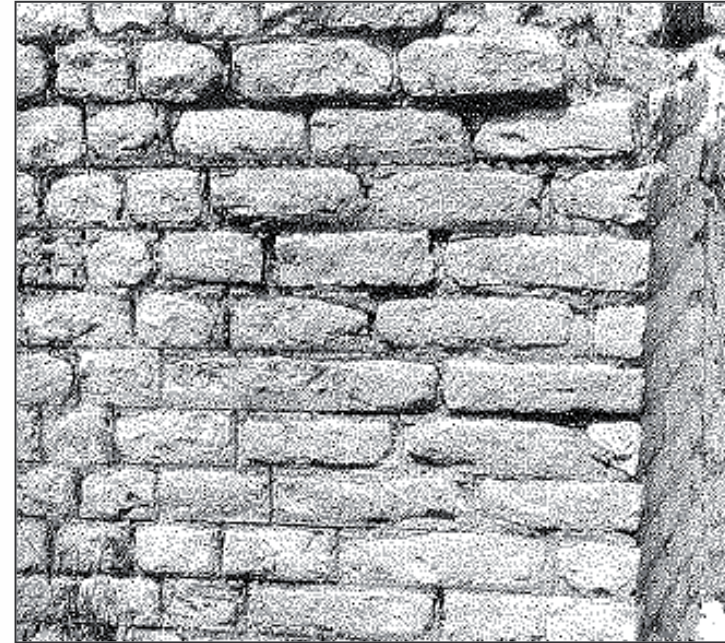
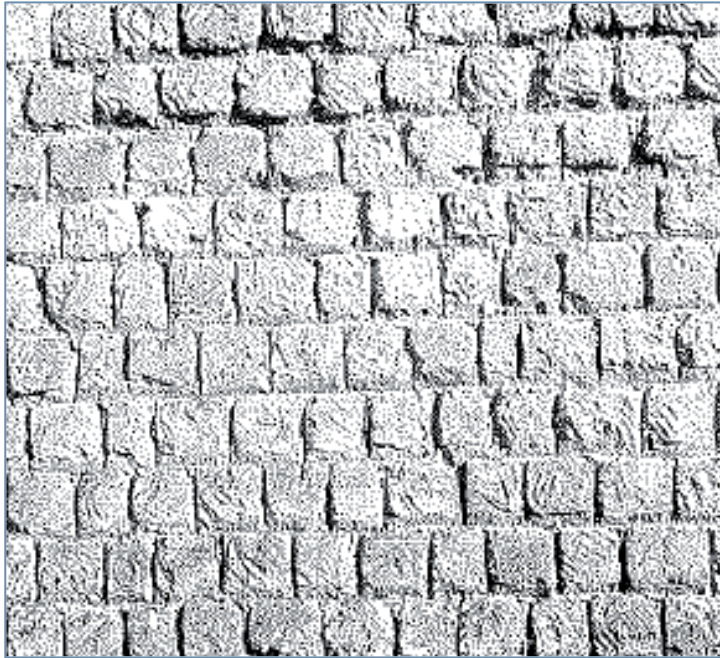




Opus reticulatum, Pompeii, VIII.2.30



## ❖ Opus vittatum



Pompeii, VIII.2.30 (Adams, 1994: 138)



Stabiae



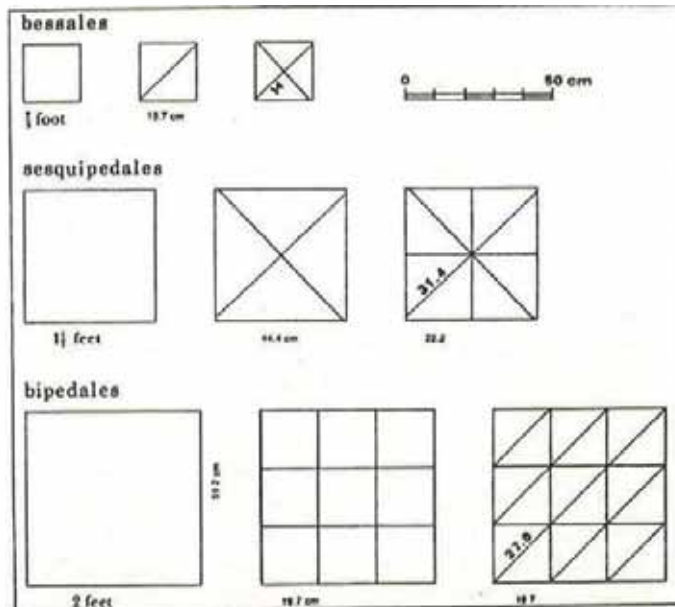
Pompeii



Tower in the walls of Frejus, Gaul (Adams, 1994: 136)



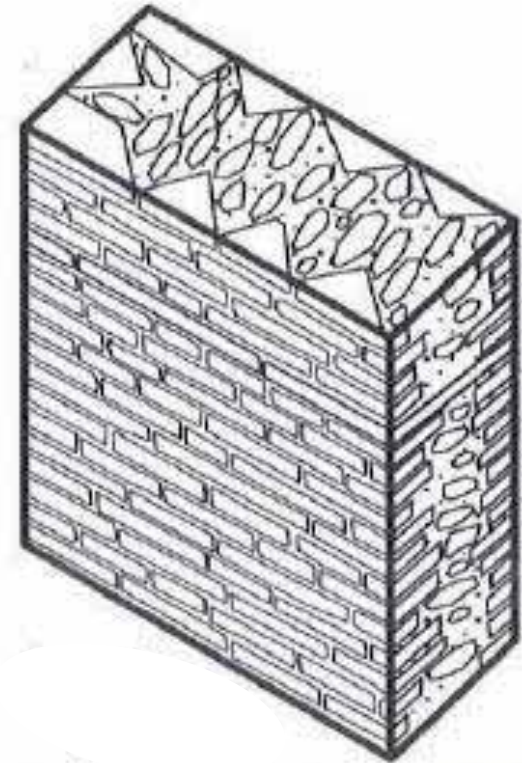
## ❖ Opus testaceum



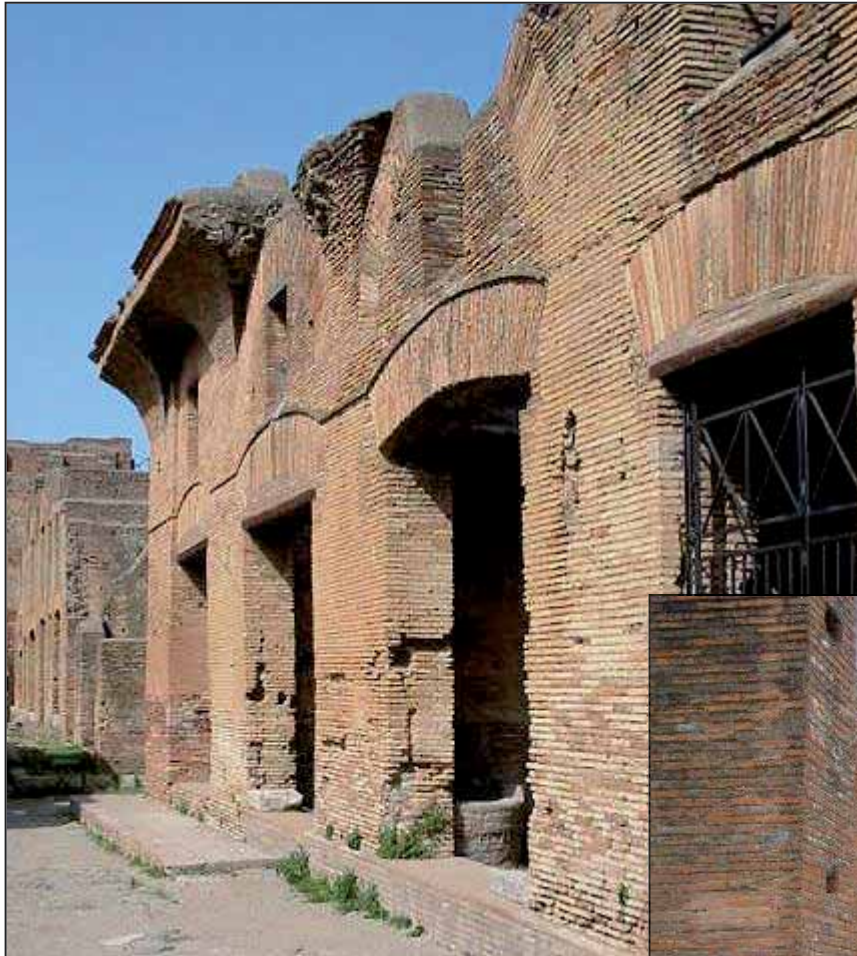
Different sizes of roman bricks (Anderson, 1977: 153)



Bipedales, Forum Romanum, Rome



(Lancaster, 2008:263)



Caseggiato di Diana, Ostia



The office of Aediles, Pompeii



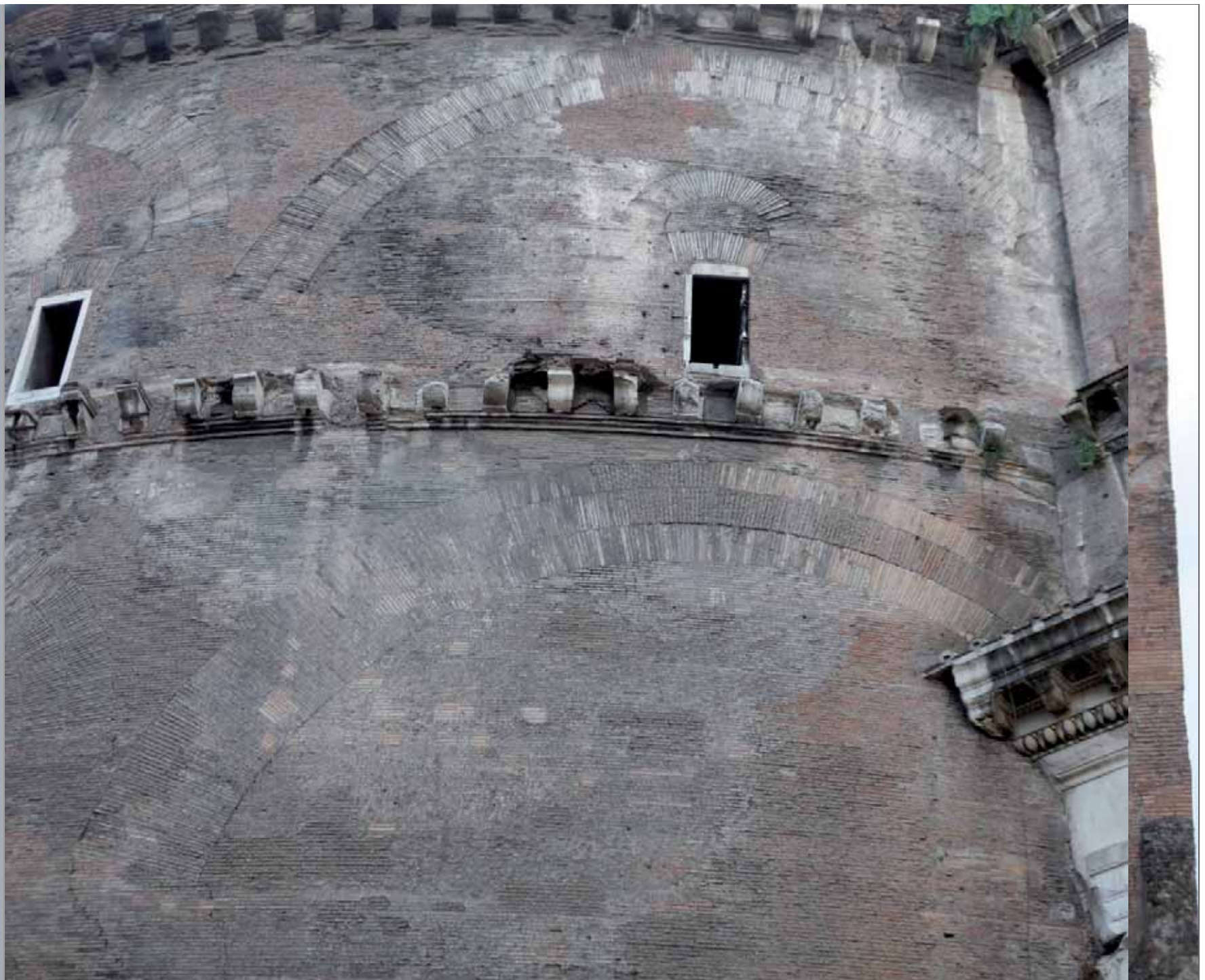


Temple of Antoninus and Faustina, Forum Romanum, Rome

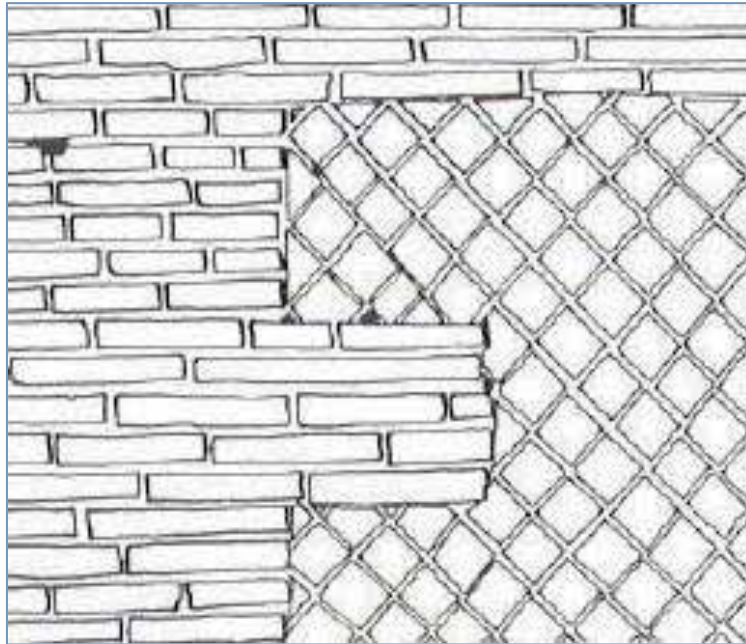


Colloseum, Rome

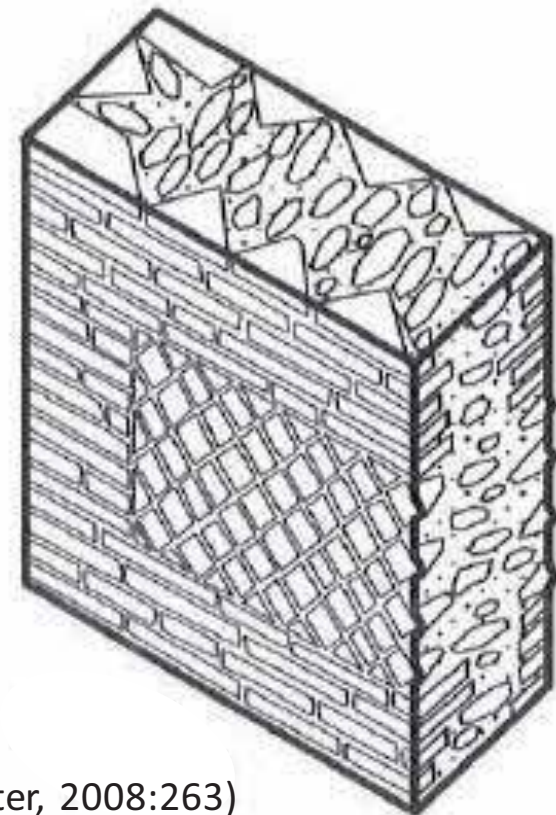




## ❖ Opus mixtum



Opus mixtum (Coarelli, 1977: 342)



(Lancaster, 2008:263)





Ostia

Pompeii, VI.10.15



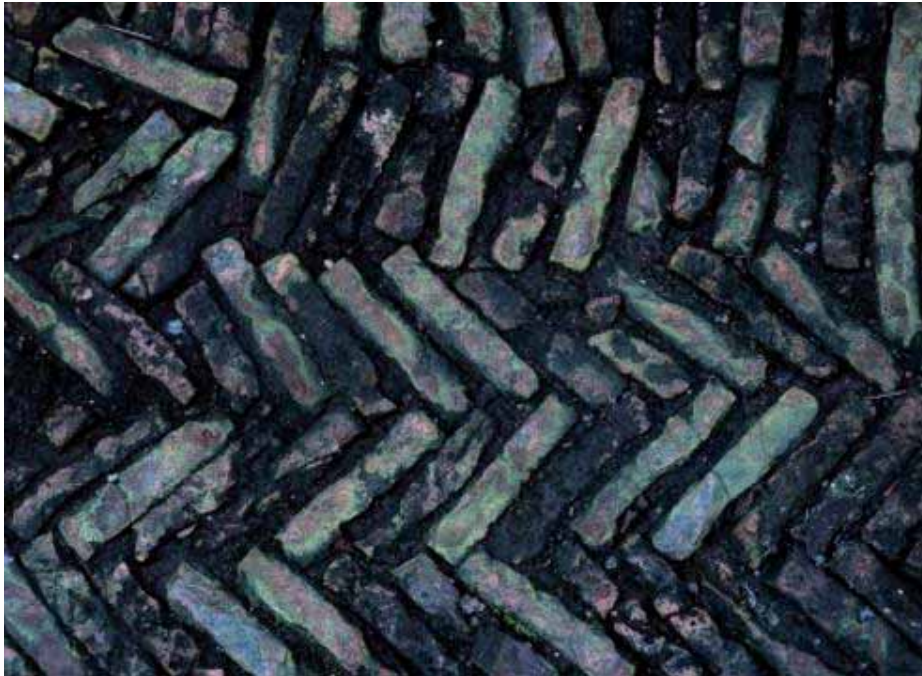


Opus vittatum mixtum, Ostia



Pompeii

❖ Opus spicatum



Detail from opus spicatum, Colosseum



Ostia, tomb(Adams, 1994: 144, 148)



## Conclusions

- ❖ During roman period was developed a variety of building techniques
- ❖ Many factors determined this evolution
- ❖ Influences from Etruscans and Greeks
- ❖ The expansion of the empire contribute in the development of building techniques
- ❖ Inventions such as opus caementicium revolutionizes roman architecture
- ❖ All these techniques contributed to the improvement of roman architecture





Thank you!!

