THE SECRETS OF ROMAN CONCRETE

IMAGINE BUILDING STRUCTURES THAT LAST 2,000 YEARS. HOW DID THEY DO IT?

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OUTLINE

- Introduction
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- The Secret Roman Recipe
- Buildings
- Conclusions

TREVI FOUNTAIN



CONCRETE AQUEDUCT

- 11 Aqueducts 300 miles 150 200 gallons per person per day
- Aqua Virgo 19 B.C. (Jesus Christ was not born!)
 11 miles from Salone springs
- Aqua Claudia
- 50 miles Arcades of arches 60 feet high
- <u>Aqua Alsietina</u> <u>Aqua Appia</u> <u>Aqua Augusta</u>
 <u>(Naples)</u> <u>Aqua Augusta (Rome)</u> <u>Aqua Claudia</u> <u>Aqua Julia</u> <u>Aqua Marcia</u> <u>Aqua Martia</u> <u>Aqua</u> <u>Tepula</u> <u>Aqua Traiana</u>

CONCRETE AQUEDUCT



Aqua Claudia

Segovia



- Lime-coated mud walls were constructed in central India as early as 2,500 B.C.
- Romans, used it as a sort of stucco covering for mud walls and other crude structures
- It is not known exactly when the Romans first began mixing lime with other substances to form concrete
- a wall of rubble in Pompeii was held together with a firm black *pozzolan* and lime mortar dating to the late third century before Christ
- by 199 B.C. the Romans were already using hydraulic concrete to line the harbor works at Puteoli, which indicates a
- striking degree of sophistication.

- Use of Roman concrete reached its zenith during the reigns of the Emperors Trajan and Hadrian, 98 to 138 A.D.
- By that time the craftsmen were well trained with many tools and they were sufficiently educated to attain teamwork.
- An example of concrete construction from this period is Trajan's Forum, the forerunner of today's shopping mall: 150 stores in the middle of old Rome.
- The ruins of this landmark can still be observed today, including its centerpiece, the Great Hall, whose vaulted roof is still intact.

Trajan Forum



• The Romans had two distinct types of concrete mortar:

binder	aggregate	water	"DE ARCHITECTVRA"
1 part lime	3 parts crushed sand	15-20%	(Vitruvius, II, v, 5)
1 part lime	2 parts river sand	15-20%	(Vitruvius, II, v, 6)
1 part lime plus 1 part of til	2 parts river sand e fragment	15-20%	(Vitruvius, II, v, 7)
1 part lime	2 parts pozzolan	15-20%	(Vitruvius, v, XII, 8-9)

- Marcus Vitruvius Pollio
- Vitruvius an engineer and architect for the Emperor Augustus, wrote 10 books on architecture and engineering: DE ARCHITECTVRA

"there is also a kind of powder which from natural causes produces astonishing results. It is found in the neighborhood of Baiae and in the country belonging to the towns round about Mount Vesuvius. This 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."

"Est etiam genus pulveris quod efficit naturaliter res admirandas. nascitur in regionibus Baianis et in agris municipiorum quae sunt circa Vesuvium montem. quod commixtum cum calce et caemento non modo ceteris aedificiis praestat firmitatem, sed etiam moles cum struuntur in mari, sub aqua solidescunt."

- Pozzolan
- A siliceous or aluminous material which in itself possesses no cementitious value, but will, in a finely divided form, and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties
- By using volcanic ash in the place of river sand in their concrete, the Romans were able to mimic the process by which Portland cement chemically bonds lime to clay through the application of heat.
- But finely divided pozzolan must be amorphous (glassy) to chemically react.

How was this possible?

Because the volcano Vesuvio had already heated the pozzolan for them!

the pozzolan was *calcined* by the volcano, enabling it to chemically react with calcium hydroxide in slaked lime, no heating required.

Using pozzolan in such high concentrations, pozzolan can decrease concrete porosity, create greater long-term strength, and help to reduce the deleterious effects of alkali aggregate reaction and sulfate attack.

Volcano Vesuvio



Other "secrets"

- Rigid quality control,
- Low water to cementitious materials ratio, and
- Expert placement and compaction.
- the Romans had no knowledge of present-day chemistry,
- they nonetheless knew how to distinguish a good quality lime and other concrete ingredients through empirical observation
- Vitruvius "We must be careful that it [lime] be burned from stone which, whether soft or hard, is in any case white, and lime made of close-grained stone of the harder sort will be good in structural parts; lime of porous stone, in stucco."

Other "secrets"

- Low water to cementitious materials ratio and compaction
- Roman mortar was comparable to a modern-day zero-slump concrete like
- RCC: so stiff and firm that it would not flow into the spaces between the rocks in the aggregate.
- The Romans even used a special tool called a *beetle to tamp it and pound it* into place. The Romans also used wooden casting forms,

BUILDINGS COLOSSEUM









BUILDINGS

Pantheon









TRIUMPHAL ARCH



BRIDGES



A DARK NIGHT...

- After the emperor Hadrian passed away in 138 A.D., the Romans ceased building new towns, much less cities.
- Further the Romans neglected to maintain their infrastructure, a costly mistake that holds lessons for the modern age.
- The final blow came in 410 A.D. when Alaric the Goth sacked Rome.
- The world would soon enter a Dark Age, and the miracle of concrete would be lost
- until 1824,
- when Joseph Aspdin concocted his first stove-top brew

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