10 Cool Engineering Tricks the Romans Taught Us

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The sprawling aqueduct in Segovia, Spain, is a splendid example of Roman architectural prowess. Miguel Palacios/The Image Bank/Getty Images

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Some stuff the ancient Romans were good at -- other stuff they weren't. In terms of the abstract sciences and literature, they were always in the shadow of their Greek neighbors. Their poetry never reached the same heights, their philosophies of Stoicism and Epicureanism were borrowed, and anyone who's ever used Roman numerals knows how difficult the system was even for even simple arithmetic.

If you wanted someone to explain geometry, you asked a Greek. If you wanted someone to build you a floating bridge, a sewer network or a weapon that could fire flaming balls of gravel and tar 300 hundred yards (274 meters), you called a Roman. As much as the Greeks gave us, Rome's brilliant architectural, organizational and engineering feats that make them stand out among the ancient peoples. Despite the fact that their knowledge of math was rudimentary, they constructed models, experimented, and built as sturdily as possible to compensate for their inability to calculate for stress and weight. The result is a set of edifices and architectural achievements that stretch from the Limyra Bridge in Turkey to Hadrian's Wall in the United Kingdom.

With so many brilliant examples, many of which are still in excellent condition, it's hard not to have picked up a few pointers about how to build structures that last.

They came, they saw, they built some domes. The Pantheon is a pretty fabulous example of how the Romans conquered interior space. ~ Grant V. Faint/Iconica/Getty Images

10: The Dome

We take interior space for granted in the modern world, but we shouldn't. Our enormous vaulted arches, huge atriums (a Latin word, by the way), hollow steel and glass skyscrapers, even a simple high school gymnasium -- all of these structures were inconceivable in the ancient world.

Before the Romans perfected dome-building, even the best architects had to deal with the problem of a heavy stone roof, forcing them to crowd the floors of temples and public buildings with columns and load-bearing walls. Even the greatest architectural achievements before Roman architecture -- the Parthenon and the Pyramids -- were much more impressive on the outside. Inside, they were dark, confined spaces.

Roman domes, by contrast, were spacious, open and created a real sense of interior space for the first time in history. Stemming from the realization that the principles of the arch could be rotated into three dimensions to create a shape that had the same supportive power but an even larger area, dome technology was mostly due to the availability of concrete, another Roman innovation that we'll discuss later in this article. This substance was poured into molds on a wooden scaffolding, leaving the hard, strong shell of the dome behind.

The ancient Romans built the first versions of this siege weapon, the onager. ~ Hulton Archive/Getty Images

9: Siege Warfare

Like a lot of technology, Roman siege weaponry was mostly developed by the Greeks and then perfected by the Romans. Ballistae, essentially giant crossbows that could fire large stones during sieges, were mostly back-engineered designs from captured Greek weapons. Using loops of twisted animal sinews for power, ballistae worked almost like springs in giant mousetraps -- when the sinews were tightly wound and then allowed to snap back, they could launch projectiles up to 500 hundred yards (457 meters). Since it was light and accurate, this weapon could also be fitted with javelins or large arrows and used to pick off members of opposing armies (as an anti-personnel weapon). Ballistae were also used to target small buildings during sieges.

Romans also invented their own siege engines called onagers (named after the wild donkey and its powerful kick) to fling larger rocks. Though they also used springy animal sinews, onagers were much more powerful mini-catapults that fired a sling or a bucket filled with either round stones or combustible clay balls. Though they were much less accurate than ballistae, they were also more powerful, making them perfect for blasting down walls and setting fires during sieges.

We take concrete for granted (especially when it's under our feet), but, as the Romans knew, it's a remarkable building material. ~ Martial Colomb/Photographer's Choice RF/Getty Images

8: Concrete

As far as innovations in building material go, a liquid rock that's both lighter and stronger than regular stone is hard to beat. Today, concrete is so much a part of our daily lives that it's easy to forget just how revolutionary it is.

Roman concrete was a special mixture of rubble, lime, sand and pozzolana, a volcanic ash. Not only could the mixture be poured into any form you could build a wooden mold for, it was much, much stronger than any of its component parts. Though it was originally used by Roman architects to form strong bases for altars, starting in the 2nd century B.C., the Romans began to experiment with concrete to produce more freestanding forms. Their most famous concrete structure, the Pantheon, still stands as the largest unreinforced concrete structure in the world after more than two thousand years.

As we mentioned earlier, this was a major improvement on the old Etruscan and Greek rectangular styles of architecture, which demanded heavy walls and columns everywhere. Even better, concrete as a building material was cheap and fireproof. It could also set underwater and was flexible enough to survive the earthquakes that plague the volcanic Italic Peninsula.

They don't build them like they used to. Ancient Roman roads like the Appian Way were made to last. ~ Marco Cristofori/Iconica/Getty Images

7: Roads

It's impossible to mention Roman engineering without talking about roads, which were so well-constructed that many of them are still in use today. Comparing our own asphalt highways to an ancient Roman road is like comparing a cheap watch to a Swiss version. They were strong, precise and built to last.

The best Roman roads were built in several stages. First, workers dug about 3 feet (0.9 meters) down into the terrain where the planned road would be. Next, wide and heavy stone blocks were set in the bottom of the trench and then covered with a layer of dirt or gravel that would allow drainage. Finally, the top layer was paved with flagstones, with a bulge in the center for water to run off. In general, Roman roads were about 3 feet (0.9 meters) thick and enormously resistant to the ravages of time.

In typical Roman fashion, engineers of the Empire insisted on using straight lines for their roads primarily and tended to push through obstacles rather than building around them. If there was a forest, they cut it. If there was a hill, they tunneled through it. If there was a swamp, they drained it. The drawback, of course, to that type of road building is the enormous amount of manpower required, but manpower (in the form of thousands of slaves) was something that the ancient Romans always had in spades. By A.D. 200, there were more than 53,000 miles (85,295 kilometers) of major highways crisscrossing the Roman Empire [source: Kleiner].

6: Sewers

The great sewers of the Roman Empire are one of the oddities of Roman engineering in that they weren't exactly built to be sewers in the first place -- as immense and complex as they were, they weren't so much invented as they just sort of happened. The Cloaca Maxima (or Biggest Sewer if you want to translate it directly) was originally just a channel built to drain some local marshes. Digging commenced around 600 B.C., and over the next 700 hundred years, more and more waterways were added. Since more channels were dug whenever it was deemed necessary, it's hard to tell when the Cloaca Maxima stopped being a drainage ditch and became a proper sewer. Primitive though it was initially, the Cloaca Maxima spread like a weed, stretching its roots deeper and deeper into the city as it grew.

Unfortunately, because the Cloaca Maxima drained directly into the Tiber, the river became absolutely swollen with human waste. That's certainly not an ideal situation, but with their aqueducts, the Romans didn't need to use the Tiber for drinking or washing. They even had a goddess to watch over their system -- Cloacina, the Venus of the Sewer.

Perhaps the most important and brilliant innovation of the Roman sewer system is the fact that it was (eventually) covered, cutting down on disease, smells and unpleasant sights. Any civilization can dig a ditch to go to the bathroom in, but it takes some impressive engineering to monitor and maintain a sewer system so complex that Pliny the Elder even declared it more stupendous than the Pyramids as a monument to human achievement.

Some Roman hypocausts are still (mostly) intact. These were discovered beneath the city of Chester, England, in 2008.~ Christopher Furlong/Getty Images

5: Heated Floors

Controlling the temperature in any building efficiently is one of the hardest engineering tasks humans have had to deal with, but the Romans had it solved -- or at least, almost solved. Employing an idea that we still use to this day in the form of radiant heat flooring, hypocausts were sets of hollow clay columns spaced every few feet below a raised floor through which hot air and steam were pumped from a furnace in another room.

Unlike other, less advanced heating methods, hypocausts neatly solved two of the problems that have always been associated with heating in the ancient world -- smoke and fire. Fire was the only available source of heat, but it also had the unfortunate side effect of burning down buildings from time to time, and smoke from an indoor flame can be deadly in a closed space. However, because the floor was raised in a hypocaust, hot air from the furnace never actually came into contact with the room itself. Rather than entering the room, the heated air was piped through hollow tiles in the walls. As it passed out of the building, the clay tiles absorbed the heat, leaving the room itself steamy and Roman toes toasty warm.

When it came to building aqueducts, the ancient Romans were pros. ~ ©iStockphoto/Thinkstock

4: The Aqueduct

Along with roads, aqueducts are the other engineering marvel that the Romans are the most famous for. The thing about aqueducts is that they're long. Really long. One of the difficulties of watering a large city is that once the city gets to a certain size, you really can't get clean water from anywhere near it. And though Rome sits on the Tiber, the river itself was polluted by another Roman engineering achievement, their sewer system.

To solve the problem, Roman engineers built aqueducts -- networks of underground pipes, above-ground water lines and elegant bridges, all designed to channel water into the city from the surrounding countryside. Once in Rome, water from the aqueducts was collected in cisterns before being distributed to the fountains and public baths the Romans loved so dearly.

Just like their roads, the Roman aqueduct system was incredibly long and complicated. Though the first aqueduct, built around 300 B.C., was only 11 miles long, by the end of the third century A.D., Rome was supplied by eleven aqueducts, totaling more than 250 miles in length.

With the help of water wheels and other technologies, the ancient Romans harnessed the power of water to their advantage. ~ ©iStockphoto/ Thinkstock

3: Water Power

Vitruvius, the godfather of Roman engineering, describes several pieces of technology that the Romans used for water power. Combining Greek technologies like the toothed gear and the water wheel, Romans were able to develop advanced sawmills, flourmills and turbines.

The undershot wheel, another Roman invention, rotated under the force of flowing (rather than falling) water, making it possible to build floating waterwheels to grind grain supplies. This came in handy during the siege of Rome in 537 A.D., when the defending general, Belisarius, solved the problem of the Gothic siege cutting off food supplies by building several floating mills on the Tiber to keep the populace supplied with bread.

Strangely, archaeological evidence suggests that though Romans had the mechanical expertise necessary to build all sorts of water-powered devices, they did so only rarely, preferring cheap and widely available slave labor instead. Nonetheless, their watermill at Barbegal (in what is now France) was one of the largest industrial complexes in the ancient world before the Industrial Revolution, with 16 waterwheels to grind flour for the surrounding communities.

2: The Segmental Arch

Like almost all of the engineering feats we've listed, the Romans didn't invent the arch -- but they sure did perfect it. Arches had been around for nearly two thousand years before the Romans got a hold of them. What Roman engineers realized (quite brilliantly, as it turned out) was that arches need not be continuous; that is, they don't have to span a gap in one go. Instead of trying to cross gaps in one great leap, they could be broken up into several, smaller sections. Turning an arch into a perfect semicircle wasn't necessary so long as each section had struts underneath. That's where the segmental arch came in.

This new form of arch-building had two distinct advantages. First, because the arches could be repeated rather than having a single stretch across a gap, the potential distance for a bridge span could be increased exponentially. Second, because less material was required, segmental arch bridges were more amenable to the flow of water underneath them. Instead of forcing water through a single small opening, water under segmented bridges could flow through freely, reducing both danger of flooding and the amount of wear on the supports.

Pilgrims cross the Ganges river on a modern-day pontoon bridge in India. ~ Pablo Bartholomew/Getty Images

1: Pontoon Bridges

Roman engineering was mostly synonymous with military engineering. Those roads that they're so famous for weren't built so much for day-to-day use (though they were, of course, useful for that) as for marching legions quickly into the countryside, hitting trouble spots and getting out again. Roman-designed pontoon bridges, constructed mostly during wartime for the shock and awe of quick raids, served the same purpose and were a specialty of Julius Caesar's. In 55 B.C., he built a pontoon bridge that was around 437 yards (400 meters) long to cross the Rhine river, which was traditionally thought by the Germanic tribes to be safely out of reach of Roman power.

Caesar's Rhine bridge was clever for a couple of reasons. Building a bridge without diverting a river is notoriously difficult to do, and even more so in a military setting where construction must be guarded at all times, so engineers had to work fast. Rather than driving beams straight into the river, engineers rammed timbers into the bottom of the river at an angle against the current, lending the foundation extra strength. Protective pilings were also driven in upstream to catch or slow down any potentially destructive logs that might float down the river. Finally, the beams were lashed together, and a wooden bridge was built on top of it. In total, the construction took only ten days, used entirely local lumber and sent a firm message to local tribes about the power of Rome: if Caesar wanted to cross the Rhine, he could do it.

There's also the possibly apocryphal story of Caligula's (yes, that Caligula) pontoon bridge built across the sea between Baiae and Puzzuoli, a roughly

2.5-mile (4-kilometer) span. Supposedly, Caligula commissioned the bridge because a soothsayer had prophesied that he had roughly the same chance of becoming emperor as he did of crossing the bay of Baiae on a horse. Never one to practice restraint, Caligula allegedly took it as a dare, lashed a chain of boats together, covered them with dirt and went for a ride.

Sources

- Kleiner, Diana E. "Technology and Revolution in Roman Architecture." Academic Earth. 2009. (February 11, 2011)http://academicearth.org/lectures/technology-and-revolution-roman-architecture
- Richard, Carl J. "Why We're All Romans." Rowman & Littlefield. 2010.
- Hansen, Roger D. "Water and Wastewater Systems in Imperial Rome." Waterhistory.org. 2011. (February 12, 2011)http://www.waterhistory.org/histories/rome/
- Roman-Empire.net. "Siege Warfare." 2011. (February 11, 2011)http://www.roman-empire.net/army/leg-siege.html
- Miller, Jonathan D. and Daniel Postlewaite. "Hypocaust." Drexel University. November 9, 2005. (February 14, 2011)http://www.pages.drexel.edu/~jpm55/AE390/A5/hypocaust.htm
- Hansen, Roger D. "Water Wheels." Waterhistory.org. 2011. (February 12, 2011)http://www.waterhistory.org/histories/waterwheels/
- Franklin Road Academy. "Gallery of Ancient Greek and Roman Artillery Weapons." November 24, 2004. (February 14, 2011)http://www.frapanthers.com/teachers/white/roman_siege_project.htm
- Deming, David. "Science and Technology in World History. Volume 1: The Ancient World and Classical Civilization." McFarland & Company, Inc. 2010.
- Moore, David. "The Roman Pantheon: The Triumph of Concrete." Romanconcrete.com. January, 2004. (February 15, 2011)http://www.romanconcrete.com/