

Building Roman Roads

Martyn Shuttleworth54K reads

The Roman Surveyors

If you took a poll about Roman engineering and asked people what defined Roman engineering, the famous Roman roads would lie towards the top of the list. These, more than anything, were the backbone of the Roman Empire and allowed the Romans to hold sway over a great area.



Pompeii Street (Creative Commons)

Primarily, the roads were for military use, allowing troops to be quickly moved to where they were most needed. However, they also allowed the movement of people and goods, and the Roman highways connected isolated communities, helping them to absorb new ideas and influences, sell surplus goods, and buy what they could not produce locally. This trade resulted in an increase of wealth for everyone and is one of the reasons why many subjugated people soon saw themselves as Roman, eagerly adopting the lifestyle of their conquerors. The Roman roads were a truly amazing piece of engineering, acting as a poignant and enduring legacy for the engineers who designed these marvels. However, laying down a network of highways also involved another class of skilled professionals, the Roman surveyors, called *Agrimensores*.

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The Roman Surveyors

The Roman surveyors were highly skilled professionals, able to use a number of tools, instruments, and techniques to plan the courses for roads and aqueducts, and lay the groundwork for towns, forts and large buildings. We half-jokingly talk about the Romans and their straight roads, but that throwaway statement is not far away from the truth.



Main Roman Roads of the Roman Empire (Public Domain)

The Romans preferred to build straight roads wherever possible and relied upon their surveyors to chart the route of their great highways. In most cases, the military would be responsible for plotting the route of new roads, but civil surveyors were used to survey courses for aqueducts, settle boundary disputes, and prepare the groundwork for buildings.

To help in their task, they used a number of instruments, most borrowed from earlier culture but refined and improved by the Romans. With these simple tools and a good knowledge of geometry, they managed to plot complex courses for roads and aqueducts, their skill so great that they could design huge aqueducts with a gradient of less than 1 in 400.

The Decempeda - The Tool of the Trade

The *Decempeda*, Latin for 'ten feet' was the main tool of the trade, and was simply a graduated measuring rod of ten Roman feet. Fitted with iron or bronze end-caps, this staff could be used for measuring distances, the agrimensores using two rods laid flat and 'leapfrogging' to measure the distance in ten-foot increments.

The Roman Groma: the Roman Surveyor's Workhorse



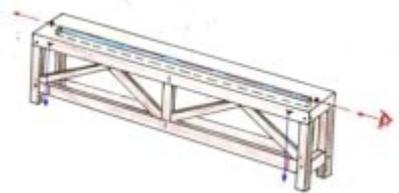
The Groma ([Creative Commons](#) [1])

For road building and laying out settlements in the distinctive grid patterns, the main tool of agrimensores was a device known as the *groma*, believed to have had its origins in Egypt. This instrument consisted of a long wooden staff, pointed at the lower end and topped with a wooden arm, about 25cm/10" long. This cross arm had a pivot to support the *stellata*, which was the main part of the instrument and consisted of a wooden cross with plumb bobs at the end. To use the groma, the surveyor set it up where two roads were to intersect at right angles, and used the plumb bobs as guides for laying out a line of stakes or flags. Using the naked eye, these stakes could be constantly realigned, to maintain a straight line as the course of the road was plotted. The Romans knew enough geometry to create right angles using Pythagoras' triangles, and it is likely that they plotted out the rough course for the road using the stars, astrolabes, and armillary spheres, with the groma ensuring that the course of the road was perfectly straight and true.

Leveling the Ground: Water Levels and the Inclinometer

For much of their work, the Roman surveyors had to prepare flat surfaces or maintain an incline. For leveling ground, especially where it needed to be flat, the Roman surveyors used a rudimentary spirit level, which consisted of an elongated basin with a mark at either end to signify the level. There is little literary or archaeological evidence that they used this, but it was used by the Egyptians and the Greeks making it very likely that the Roman surveyors used it. The other rudimentary level used by the Romans was the inclinometer, which was a braced triangle or A-frame with a plumb line hung from the apex. There was a mark on the cross strut signifying where the weighted plumb line should rest if the ground was level. Other inclines could also be marked on the inclinometer, rather like a protractor, allowing the surveyor to create inclines and gradients. It seems that this instrument was reserved for laying the groundwork for buildings and was too crude for roads and aqueducts.

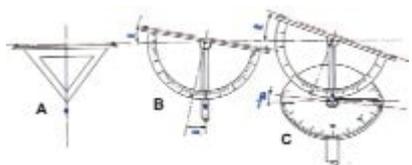
The Chorobates - The Roman Spirit Level



The Chorobates ([Creative Commons](#) [2])

The instrument known as the chorobates was described by [Vitruvius](#) [3] (born c. 80-70 BCE, died c. 15 BCE) as the way that the Roman surveyors checked levels. The *chorobates* took the form of a long bench with vertical legs and a small channel carved into the top. The instrument used four plumb bobs, with sightlines, to help to find the true horizontal. If the conditions were too windy for the bobs to work effectively, the surveyor could pour water into the trough and use this to find a level. The idea was that the surveyor could insert wedges under the legs of the chorobates until it was at level and, by looking through the eyeholes, a graduated staff could calculate the angle of an incline via trigonometry. The chorobates was an excellent instrument for leveling ground before building, certainly helping the Roman engineers to lay out the groundwork before construction proper began.

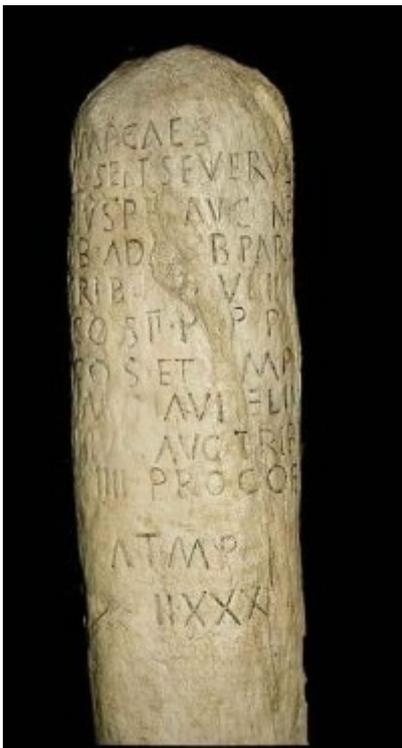
The Dioptra - Accuracy



The Dioptra ([Creative Commons](#) [2])

With little evidence other than Vitruvius' writing, historians are not sure how effective the chorobates was and how often it was used by Roman surveyors and builders. Tests have shown that it may not have been accurate enough for the gentle gradient required for building aqueducts, but it would have found use for leveling the ground prior to road building and

ensuring that road followed a constant gradient. For higher accuracy work, the Romans probably used a device based upon a Greek design, known as the *Dioptra*. This device, described by the inventor Hero of Alexandria [4] (c. 10-70 AD), could be used to find the angle of a gradient, through simple geometry. When complex angles and vertical angles were needed, or the terrain was too steep for the Groma and Chorobates, the Dioptra came into its own. This instrument was the forerunner of modern surveying instruments and the complexity of the Dioptra is where the skill of the Roman surveyors came to the fore. The Dioptra consisted of a circular table affixed to a tripod or monopod, and this was calibrated with angles. Using four screws, the user leveled the table, using two small water levels set at 90 degrees to each other and, once level, he could measure the angle between two distant objects. Using a rotating bar with sights, pivoted around the center of the table, the surveyor could look at a distant object and then, by rotating the circular table, calculate the angle to a second object.



Roman Milestone ([Creative Commons](#) [5])

Cleverly, the agrimensores could measure distance with the Dioptra, especially useful where the terrain was too inaccessible for rods or ropes. The agrimensor could take two readings from different points, a known distance apart, and use triangulation to calculate distance. The surveyor could also use the Dioptra to measure vertical angles, in exactly the same way that modern surveyors do. He would set up the Dioptra and measure the height from a calibrated rod held by an assistant on a reference point. This would then act as a zero point and the surveyor could measure the height of other points around the site, expressing these measurements as plus or minus, allowing him to use geometry to calculate gradients. The Dioptra incorporated a vertical semi-circular disc, calibrated with angles, which allowed the surveyor to pivot the instruments and take measurements at vertical angles.

The Libra

Little is known about the *Libra*, used by the Romans to measure gradients. Most modern historians assume that it was simply a set of scales with a sighting tube incorporated. If these were suspended, they would find a true level, and the agrimensores could look through the sighting tube at a calibrated measure. These instruments would certainly be accurate enough to measure the tiny gradients used in aqueducts.

The Hodometer

The Roman odometer was a very advanced surveying tool for measuring distance, consisting of a small cart that the surveyor or his assistant could push along. A one-toothed gear attached to the wheel of the cart engaged another gear with 399 short teeth and one long tooth. After a distance of one Roman Mile, this long tooth would push a pebble into a bowl, and the surveyor could count the distance traveled at the end of the day. The Romans liked to set up milestones along major highways, letting the military and other travelers see how far they were from cities.

The Legacy of the Roman Surveyors

The work of the Roman surveyors was largely built upon the work of other cultures, but they refined the process. With a collection of simple tools, they managed great feats of engineering that would be unrivaled in Europe for nearly a thousand years, including bridges and fortresses. Their most enduring legacy would be the Roman roads, many of which are still in use today and determined the course of many modern roads. The Roman tools and techniques form the basis of our own methods of surveying and the principles of surveying have not changed much since that time, only the accuracy of measurements.

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