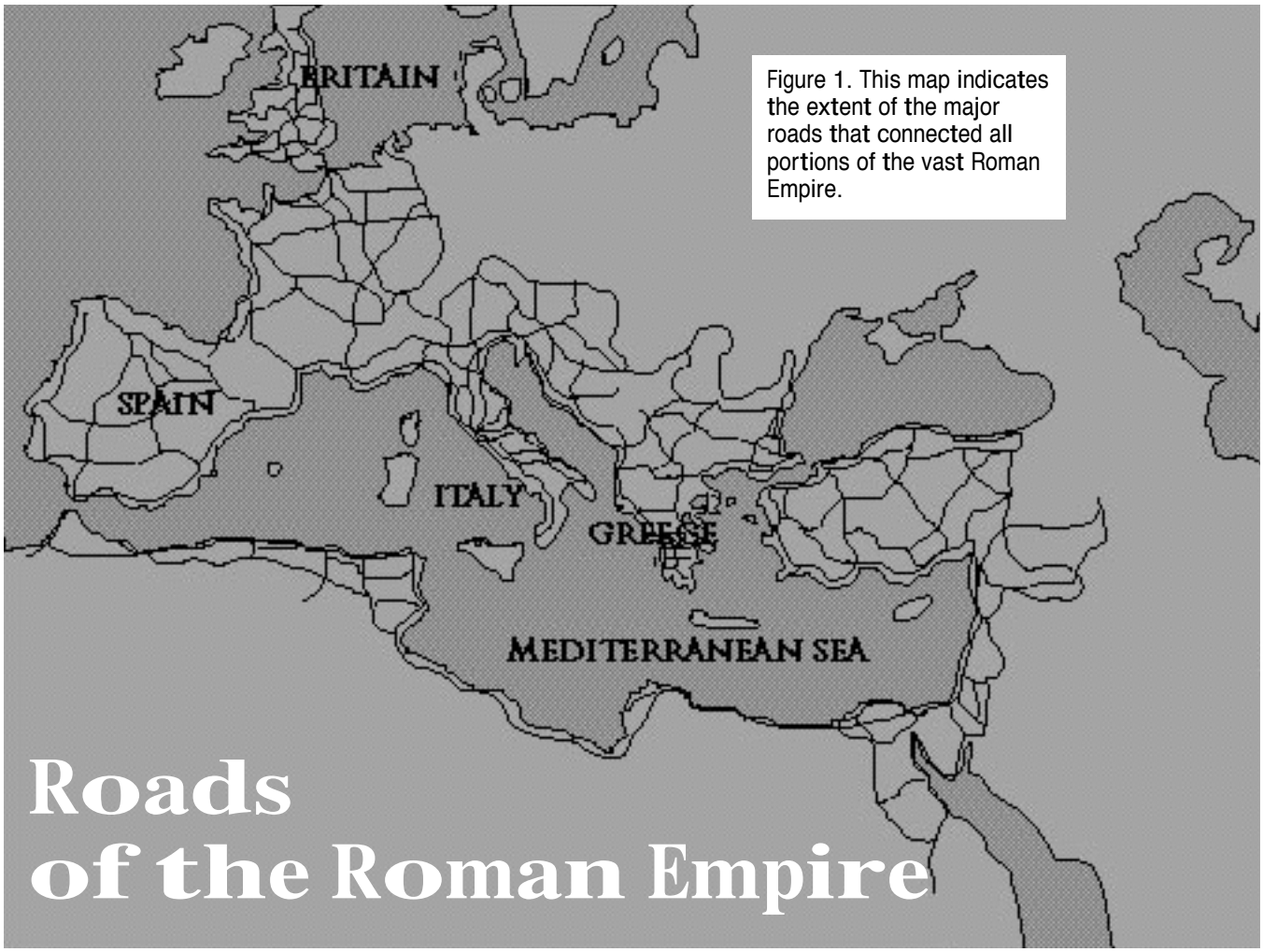

Figure 1. This map indicates the extent of the major roads that connected all portions of the vast Roman Empire.

Roads of the Roman Empire

Roman concrete and road-building technology contributed to the amazing endurance of ancient Roman roads

By Richard W. Steiger

The Romans built nearly 53,000 miles of roads linking the capital to their far-flung empire. To put this amazing feat in context, consider that the United States, to date, has built 42,000 miles of interstate highways.

Major roads began in Rome and spread in every direction, spawning commerce, communication, and travel, while permitting rapid movement of Roman legions. The roads covered the empire like latticework, joining the different territories (Figure 1). This included Italy, Germany, France, and Spain; the roads even extended as far north as Britain. To the east and south the roads linked the Balkans, Greece, Turkey, the Middle East, and North Africa, including Egypt and Tunisia.

Roman roads were remarkable for preserving a straight line from point to point, regardless of obstacles. They traversed marshes, lakes, ravines, and mountains. By their bold conception, these roads have challenged and excited modern engineers.

Roman Road Design Sets the Standard for Two Millennia

Roman road building began in earnest in 312 B.C., when the Roman Senate approved construction of a 132-mile highway from Rome south to Capua—the Appian Way (Figure 2). From Capua, the highway was later extended eastward, ending on the Adriatic coast at Hydruntum, a total of 410 miles. The empire expanded over the next 600 years, and Roman legions required good roads to achieve their conquests and to maintain supply and communication lines.

A major Roman road such as the Appian Way was up to 5 feet thick and cambered in the middle to shed

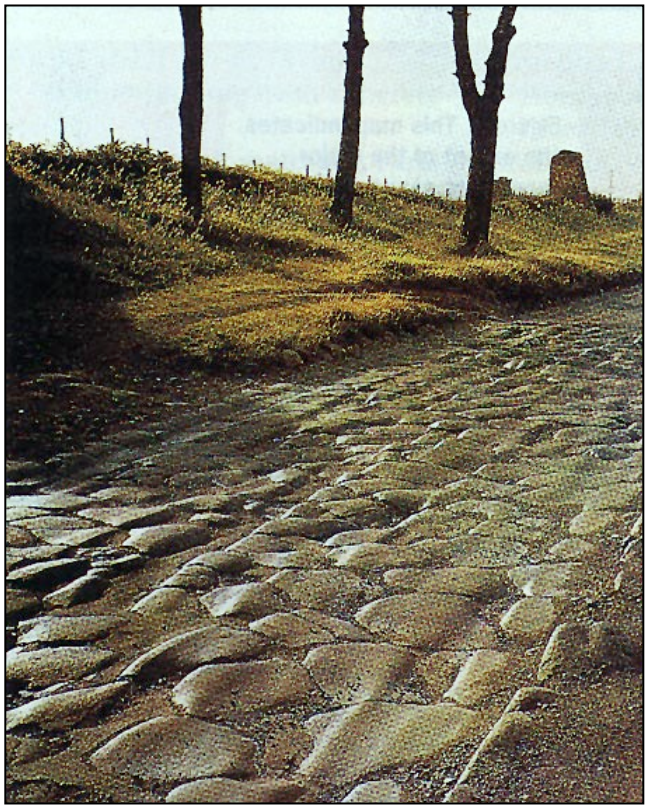

Figure 2. A segment of the Appian Way as it appears today, more than 2,300 years since it was built as a major highway leading south out of Rome.

rainwater. This massive road cross section (Figure 3) set the standard of practice for the next 2,000 years, until 18th-century French engineers developed thinner cross sections (see sidebar).

The width of the Appian Way was 36 Roman feet (35 English feet). The two-way center lane, heavily crowned, was 15½ feet wide flanked by curbs 2 feet wide and 18 inches high on each side and paralleled by one-way side lanes 7¾ feet wide.

In its most advanced stage of development, the Appian Way was constructed by excavating parallel trenches about 40 feet apart to mark the exact road location and to indicate the nature of the subsoil. The foundation was then covered with a light bedding of sand and mortar upon which four main courses were constructed:

1) A *statumen* layer of large, flat stones 10 to 24 inches thick
2) A *radus* course, about 9 inches thick, consisting of smaller stones mixed with lime
3) A *nucleus* layer, about 1 foot thick, consisting of Roman concrete made with small gravel and coarse sand mixed with hot lime and water
4) A *summa crusta*, or wearing surface of flintlike lava stones, fitted tightly, about 6 inches thick

Soldiers, slaves, and convicts provided much of the muscle required to construct a Roman road. First they cleared brush, trees, and rocks. Then they dug

The Romans Had the Right Idea

In 1775 Pierre Tresaguet, an engineer, became inspector general of all roads and bridges for France. He developed an entirely new, relatively light road surface, based on the theory that the subsoil rather than the surface should support the load. His standard section was 10 inches thick and consisted of a course of uniform stones laid edgewise covered by a layer of walnut-sized broken stone. The roadway crown rose 6 inches in its 18-foot width and had a uniform cross section. This differed from the very heavy Roman cross section that had been used for so long throughout Europe.

This type of road served traffic, generally consisting of horse-drawn vehicles, for many years. However, when automobiles and heavy trucks were introduced, totally new requirements became necessary for road and highway construction.

Today, European roads consist of much deeper pavement sections. In southern Germany and Austria, where freeze-thaw conditions in winter are much like those in the upper Midwest of the United States, the typical road may have 2½ inches of high-strength basalt concrete with an exposed-aggregate surface placed over 7½ inches of unreinforced concrete. These layers are placed on top of a 6-inch lean concrete base supported by 16 inches of frost-resistant aggregate subbase and a two-layer subgrade of stiff, silty clay compacted thoroughly. Underdrains are installed in the aggregate layer to complete the design. These roads—at least 32 inches thick—are built for long service life and low maintenance, and they can withstand higher axle loads than major U.S. highways are designed to withstand. Although these roads are more expensive initially, the life-cycle costs are lower.

An experimental adaptation of this type of European roadway has been built on a Detroit expressway alongside a new segment built to the current U.S. standard (see Reference 6). It will be quite interesting to compare the two roads over time, and make an in-depth analysis.

Perhaps the Romans had the right idea after all. Their deep, well-designed pavement sections—built with the best materials available at the time—have left an enduring legacy.

drainage ditches on either side and leveled the roadbed. Heavy rollers, hauled by hand, compacted the subsoil.

Roman concrete mix. Roman concrete was, when practical, made of lime mixed with volcanic rock or sand called *pozzolana*, named after the place where it was first found, Pozzuoli, near Mount Vesuvius. The pozzolana contained an aluminum silicate from which silica was readily liberated by caustic alkalies, such as calcium hydroxide. Silica combined with the lime to form a solid cementing material that would harden in water. Today, industrial byproducts such as fly ash and silica fume—referred to now as pozzolans—serve to enhance concrete in a similar way.

There is no evidence that the Romans understood the reason for the superiority of the pozzolana mix over plain lime mortar, but they did know there was a difference, and they used the mix with considerable ability to construct their roads. Where pozzolana was not available, or too far from the source to transport, they mixed the lime with powdered bricks that furnished the silica required. The amazing endurance of many of these ancient Roman roads can be attributed to this lime-silica mortar as well as to the favorable climate.

The Roman Road-building Legacy

Following the collapse of the Roman Empire in A.D. 455, Roman roads fell into disrepair, and in many places the stones were dug up and used for building purposes. In spite of this, many of the roads still exist and are used daily.

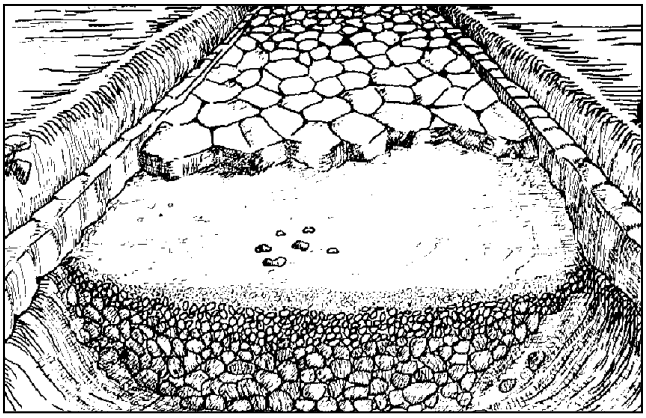

Figure 3. Typical cross section of a Roman road constructed on dry ground. Having four main courses built upon a sand-and-mortar bed, Roman roads were as thick as 5 feet.

It was not until 1716 that a central administration for the upkeep of roads and bridges was formed in France. A training school for young engineers was established in 1747. This was the beginning of the study of the science of road construction. Roman road-building technology certainly contributed to this effort. And, today, the Romans are considered to have been the best and most scientific road builders the world has yet seen.

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PUBLICATION # C950949