2.2 ENGINEERING IN THE EARLY CIVILIZATIONS: THE MESOPOTAMIANS

Significant engineering achievements must be credited to the ancient dwellers of Mesopotamia, the land between the Tigris and Euphrates Rivers, currently the country of Iraq. In this area, the wheeled cart is said to have first appeared. In southern Mesopotamia, at the beginning of recorded history, the ancient and mysterious Sumerian people constructed canals, temples, and city walls that comprised the world's first engineering works.

Figure 1.6 shows different types of levers, rollers, wooden sledges, earth ramps.

The land of Mesopotamia was open to attack from the north, east, and west, and its history is a confused record of conquests and occupations by neighbouring peoples. The most prominent rulers of ancient Mesopotamia were the Babylonians and the Assyrians.

Records inscribed on clay tablets have been discovered and deciphered, providing an insight into life in that area thousands of years ago. These records show that as early as 2000 B.C., an angle measuring device called the astrolabe was being used for astronomical observations. This instrument, which consisted of a graduated circle and a sighting arm, was based on the 60-unit numerical system used by the Mesopotamians. That system has been retained in time and angle measurements to the present day.

Figure 1.7 shows an angle measuring device called the astrolabe.

The most unusual class of structure left by the Mesopotamians was the ziggurat, a temple tower built in honour of their gods. The ziggurat was a terraced pyramid of brick with staircases, setbacks, and a shrine or chapel at the top.

The Tower of Babel mentioned in the Old Testament is believed to have been this type of structure.


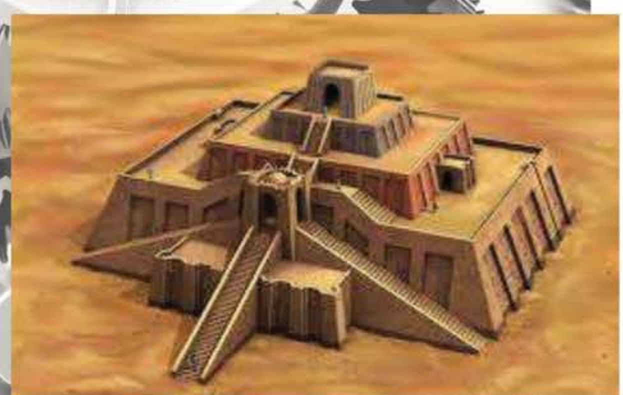

Figure 1.8 shows different types of structures in Babel.

Hammurabi, the great king who ruled Babylonia for 43 years (circa 1850 to 1750 B.C.) compiled a comprehensive new code of law that bears his name. This famous code provided penalties for those who permitted poor construction practices and is considered to be a forerunner of today's building codes.

The Code of Hammurabi provided an important message dealing with quality assurance and professional responsibility and exacted extremely severe penalties for its breach. It read:

1- If a builder build a house for a man and do not make its construction 'firm and the house which he has built collapse and cause the death of the owner of the house—that builder shall be put to death.

2- If it cause the death of the son of the owner of the house—they shall put to death a son of the builder.

3- If it cause the death of the slave of the owner of the house—he shall give to the owner of the house a slave of equal value.

4- If it destroys property, he shall restore whatever it destroyed, and because he did not make the house which he built firm and it collapsed, he shall rebuild the house which collapsed at his own expense.

5- If a builder build a house for a man and do not make its construction meet the requirements and a wall fall in, that builder shall strengthen the wall at his own expense.

It is not surprising that the people who populated the valleys of the Tigris and Euphrates developed significant irrigation and flood control works. Today, in Iraq, evidence of abandoned canals can still be traced by lines of embankments, lakes, and streams. The Nahrwan, a 400-foot wide canal extended generally parallel to the Tigris River over a distance of 200 miles and this irrigates an area averaging 18 miles in width. Imposing masonry dams were used by the Mesopotamians to divert small tributaries into the canal.

Figure 1.9 shows different types of structures in Babel.

During the reign of King Sennacherib, the Assyrians completed (circa 700 B.C.) the first notable example of a public water supply. They built a 30-milelong feeder canal bringing fresh water from the hills of Mount Tas to the existing Khosr River, by which the water flowed an additional 15 miles into Nineveh. At Jerwan, an elevated cut-stone aqueduct was built to carry the open canal over a small stream. This famous structure was 863 feet long, 68 feet wide, and 28 feet at the highest point. It supported a channel that was approximately 50 feet wide and about 5 feet deep. The channel was underlain by a thick layer of concrete, the first known use of this construction material.

Figure 1.10 shows different types of structures in Babel.

2.3 CONTRIBUTIONS OF THE GREEKS

Beginning about 600 B.C., the Greek way of life and thought became dominant in the eastern Mediterranean area. The Greeks are best remembered for their **abstract logic and their ability to theorize and to synthesize the knowledge of the past**.

Their advances in art, literature, and philosophy were great, **tending to overshadow their contributions to engineering**. They tended to focus mainly on theory and placed little value on experimentation and verification and on practical application.

In fact, the great Greek thinkers expressed the viewpoint that any application of the fruits of the mind to material needs was not worthy of dignity or respect.

Nevertheless, the Greek architecton made the first notable advance toward professional stature (العمارة). He was recognized as a master builder and construction expert with knowledge and experience beyond the scope of the average citizen. The Greek peninsula was so cut up by mountain ranges that land communication as difficult. The Greeks turned to the sea to become the first great harbor builders (الكبيرة الموانى).

<u>Herodotus</u> described a great breakwater or mole that was constructed to protect the harbor at Samos.

→The breakwater was 400 yards long and was built in water 120 feet deep (3).

→This represents the first recorded construction of an artificial harbor, and it was to become a prototype in harbor planning even into modern times.

Figure 1.11 shows a breakwater at Samos to protect the harbor.

The Greeks' interest in navigation later led to the building of the first lighthouse (منارة) in the world, the Pharos at the port of

Alexandria. This 370-foothigh structure, built about 300 B.C., was known as one of the Seven Wonders of the Ancient World.

Figure 1.12 The first lighthouse in the world.

Another great work built on the island of Samos was a 3300-foot-long tunnel cut through a 900-foot hill under the direction of the architecton Eupalinus of Megara. The main tunnel, which was hand-chiseled through solid limestone, was about 5.5 feet in width and height.

Figure 1.13 Tunnel cut through a 900-foot hill.

At the bottom of the main tunnel, a trench was cut 30 feet deep and 3 feet wide. In this trench, water was brought through clay pipes to the city. The tunnel construction was carried out from both ends, but the surveying methods used to perform this work are not known.

During the Golden Age of Greece, the ruler **Pericles** undertook a huge building program designed to make Athens the most beautiful city on earth.

He retained the services of leading artists and building experts of the time to build temples, shrines, and statues on the Acropolis, the flat-topped rock overlooking the city.

Figure 1.14 Temples in the Golden Age of Greece.

The ruins of these works today provide one of the world's most remarkable sights. The builders of the Greek temples must have used timber frames and manual hoists that were equipped with capstans and pulleys similar to those used in modern times. By their use of columns and beams, the designers showed a level of structural understanding not demonstrated by builders of the past.

2.4 CONTRIBUTIONS OF THE ROMANS

The most famous engineers of antiquity, the romans (العصور الرومانية القديمة), devoted more of their resources to public works than did their predecessors. With cheap labor, including thousands of slaves, and abundant raw materials, they built arenas(الساحات), roads, aqueducts(مجارى مائية), temples, town halls, baths, and public forums(منتدي).

Scholars divide Roman history into two main periods:

The Republic, which extended from 535 B.C., the legendary date of Rome's founding(تاريخ التأسيس), until 24 B.C. The Republic was an age of conquest (الغزو) and exploitation (الاستعمار)of Rome's extensive colonial possessions, a time when Roman engineering achievements were confined largely to Italy.

➔ **The Empire**, which extended from 24 B.C. until A.D. 476.

The Empire was a relatively peaceful period in which public works were extended into the colonies; remains of some of these engineering facilities can be found today in Spain, France, North Africa, and the Near East.

In contrast to the Greeks, the Romans were practical builders who relied more on experience than on mathematical logic and science.

Their works were simple in design yet impressive in scale and bold (جريئة) in execution. By and large, their works emphasized function rather than the artistic or aesthetic.

Roman builders are credited (تقيد) with making significant contributions to engineering, which include developing improved methods of construction, discovering and using hydraulic cement, and devising a number of construction machines (استنباط عدد البناء) such as pile drivers, treadmill hoists, and wooden bucket wheels.

Figure 1.15 Wooden bucket wheels.

The latter machines, illustrated in Figure 1.15, were used for dewatering mines (ازالة الحواجز) and construction sites.

Some of the most famous of Roman engineering works are briefly described below:

1- **The Circus Maximus** was a race course where games and contests were held. It is believed to have been either built or greatly enlarged by **Tarquinius Priscus**, an ancient king of Etrusean and Greek ancestry (يوناني النسب) who ruled Rome in the sixth century B.C.

2- **The Appian Way** was the first and most famous link in a road network that radiated from Rome. Named for Appius Claudius, the Censor of Rome in 312 B.C., the road was noted for its direct alignment, high embankments (السدود العالية), and superior pavement (رصف) structure.

Figure 1.16 Shows a section of the Appian Way as it appears today.

3- **Aqua Appia**, also named for Appius Claudius, was the first major aqueduct (قناة) built in Rome. It was a low-level, largely underground work built in a tunnel or by cut-and-cover construction.

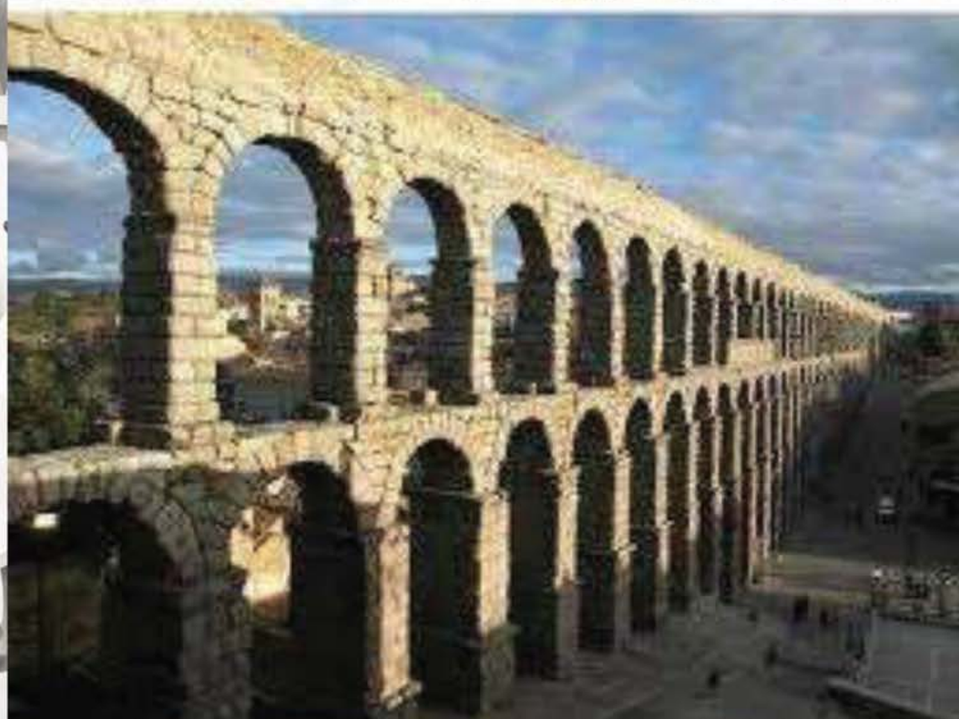

Figure 1.17 Shows the Aqua Appia as it appears today.

4- The Pantheon was a temple of extraordinary stateliness. **Agrippa**, a brilliant engineer and the adopted son of Augustus, built the Pantheon circa 17 B.C. It suffered two fires and was rebuilt by Hadrian who ruled during the period A.D. 117–138. **The internal diameter** of the Pantheon is equal to its height of 141 feet. It is crowned with a coffered semi-spherical concrete vault.

Figure 1.18 Shows the Pantheon as it appears today.

Preserved to the present day, the Pantheon embodies Rome's most imaginative engineering works.

5- **The Alcantara Bridge**, built in Spain by the engineer Gaius Julius Lacer in A.D. 98, is still in use (see Figure 1.19).

It has six arches (اقواس) of dry stone and a total length of 600 feet. The roadway is 175 feet above the river.

Figure 1.19 Shows The Alcantara Bridge in Spain, built in the year A.D. 98, is still in use.

6- **The Pont du Gard** was part of an ancient aqueduct that supplied water to Nimes in the south of France. Built under the direction of Agrippa during the reign of Augustus (circa 27 B.C. to A.D. 14), this imposing structure was built of dry masonry construction (بناء جاف), except for the water channel on top. It is about 160 feet high, and its larger arches have a span of approximately 80 feet. The Pont du Gard is illustrated in Figure 1.20.

Figure 1.20 Shows The Pont du Gard.

2.5 ENGINEERING IN THE MIDDLE AGES

Approximately eight centuries following the fall of the Roman Empire, relatively few advances in engineering.

There was, however, some engineering progress during this period, notably in **structural design** and in the development of **energy saving** and **power-enhancing machines** and devices.

1- **The Gothic cathedrals:** These structures have been called some *"of the lightest, most daring 'skeleton stone' construction ever attempted by man"*.

These tall and elegant structures, with *stained glass windows*, *pointed central arches*, and *high thin walls supported along the side* by half arches called flying buttresses, evidence a high level of structural competence for the engineer/architects who designed them and the master craftsmen who built them.

Figure 1.21 shows stained glass windows, pointed central arches, and high thin walls supported along the side by half arches called flying buttresses.

2- **Large landowners:** sought to protect themselves and their properties, *massive fortress homes* (حصون) or *castles* were built.

The fortress-home was characterized by *thick walls*, *tall protective towers*, and *an encircling wide ditch* spanned by a *single bridge* (خندق به جسر واحد).

With the invention of gunpowder and cannons (البارود والمدافع) (circa A.D. 1500), the construction of medieval castles came to an end.

Figure 1.22 shows The fortress-home was characterized by <u>thick walls</u>, <u>tall protective towers</u>, and <u>an encircling wide ditch</u> spanned by a <u>single bridge</u>.

During the middle Ages, engineers sought to strengthen or supplement the productive powers of humans and animals by devising and improving labour saving machines. The wind mill was developed during this era, and water mills were improved and used in new ways. Water wheels for mill drive were in use all over Europe by A.D. 700.

Other mechanical advances that appeared in Europe during medieval times include the spinning wheel and a hinged rudder for ships (الدفة)(1). By A.D. 00, the Vikings had developed the art of shipbuilding (فن بناء السفن)and discovered Greenland (14).

Figure 1.23 shows the wind mill and water mills.