2 Importance of Civil Engineering

UNIT SPECIFICS

Through this unit we have discussed the following aspects:

- ***The importance of Civil Engineering in shaping and impacting the world***
  - *Responsibilities and Role in reaching SDGs*
  - *Direct and indirect impact with respect to SDGs*
- ***The ancient Marvels and modern Wonders in the field of Civil Engineering***
  - *Ancient Civilizations [4000 – 900 BCE]*
  - *Classical Period [1000 BCE – 1000 CE]*
  - *Renaissance & Age of Enlightenment [1400 – 1750 CE]*
  - *Modernism & Industrial Era [1750 - 1950 CE]*
  - *Contemporary style & Digital Era [1950 - present]*
- ***Future Vision for Civil Engineering***

Besides giving a large number of multiple choice questions as well as questions of short and long answer types marked in two categories following lower and higher order of Bloom's taxonomy, a list of references and suggested readings are given in the unit so that one can go through them for practice.

There is a "Know More" section, which has been carefully designed so that the supplementary information provided in this part becomes beneficial for the users of the book. It is important to note that for getting more information on various topics of interest some QR codes have been provided which can be scanned for relevant supportive knowledge This section mainly highlights applications of the subject matter for our day-to-day real life or/and industrial applications on variety of aspects, case study related to environmental, sustainability, social and ethical issues whichever applicable, and finally inquisitiveness and curiosity topics of the unit.

RATIONALE

This unit establishes the importance of the profession and practice of Civil engineering in the context of Sustainable development and future trends and needs. It further emphasizes the roles and responsibility of the civil engineer.

UNIT OUTCOMES

List of outcomes of this unit is as follows:

U2-O1: Knowledge on the role, impact/relevance, and importance of Civil Engineering

U2-O2: Knowledge on the outstanding Civil Engineering feats of ancient and modern times

U2-O3: Knowledge on the future trends in the field

Unit-2 Outcomes	***EXPECTED MAPPING WITH COURSE OUTCOMES*** *(1- Weak Correlation; 2- Medium correlation; 3- Strong Correlation)*						
	CO-1	***CO-2***	***CO-3***	***CO-4***	***CO-5***	***CO-6***	***CO-7***
U2-O1	*3*		*2*	*3*	*1*	*1*	*3*
U2-O2	*3*	*2*	*2*	*1*	*2*	*1*	
U2-O3	*2*		*1*	*2*			*3*

The Civil Engineering discipline encompasses various specialisations, like, Construction Engineering, Structural Engineering, Geotechnical Engineering, Transportation Engineering, Environmental Engineering, Materials Engineering, Marine Engineering, Irrigation Engineering, Highway Engineering, Bridge Engineering, Hydraulic Engineering, etc. The built-environment, comprising of buildings, bridges, railways and roads, sewers and dams, power pants and transmission towers and lines, tunnels, canals, and waterways, are all results of these sub-domains. As discussed earlier, the built-environment, along with the inhabitants and social ecosystem it supports, has profound impact on the world and is a critical determinant of sustainable development. Hence, not only is civil engineering of importance for present needs of shelter, sanitation, transportation, and connectivity, but plays a significant role in addressing the issues and concerns arising due to the unmitigated urbanisation and economic development.

In the following Sections, a brief discussion on the importance of the discipline in shaping and impacting the world is followed by tracing the evolution and development of civil engineering practice through examples across time – from ancient era to present society. These ancient Marvels and modern Wonders reflect the society in which it thrived, with respect to the events and context discussed earlier in Unit 1, and paves way for the innovations of the future.

2.1 CIVIL ENGINEERING: SHAPING AND IMPACTING THE WORLD

The civil engineering market is expected to grow 25% each year (2022) up to 11.7 trillion US Dollars by 2025 (Global Market Insights, Inc.) due to the ever-increasing demand for infrastructure. In turn, increasing the need of competent engineers possessing sound knowledge of engineering fundamentals, and software and technical proficiency. In addition, a Civil engineer must hone skills as identified as the **Top Skills for 2025**, such critical thinking and creative problem-solving skills, the ability to communicate and collaborate effectively, coupled with strong leadership required for project management (World Economic Forum). Beyond the core activities of designing, i.e., conceptualise novel solutions, develop layouts and perform design calculations, and On-site supervision, civil engineers are **responsible** for;

- Oversee or perform soil tests, surveying operations, materials test, etc., and Analyse survey reports, maps, and other data to plan projects.
- Design and communicate ideas upon interacting with all stakeholders and identify possible design improvements, as well as incorporate Building codes, standards and guidelines into the design as required.
- Develop Project scope and timeline, and manage and monitor each stage of project,
- Assess environmental impact and risks, and ensure job site meets all legal guidelines and health and safety rules.
- Assist with staging, testing, and shipping of equipment prior to deployment.

- Prepare and present technical reports, analysis reports, cost estimates, Bill of Materials (BOM) and Bill of Quantities (BOQ), environmental impact statements.
- Submit permit applications to local or national agencies, and mitigate conflict.

Civil Engineering plays a **significant role** in offering methodologies, approaches, assessments of risks and impacts, as well as technologies and tools to assist decision-makers and technicians to achieve the Sustainable Development Goals (SDGs), in the following ways;

(i) ***Planning measures to mitigate and adapt*** to climate change, extreme weather events, earthquakes, droughts, floods, and other natural disasters.

(ii) ***Developing efficient and sustainable strategies*** for resource utilization while minimizing environmental impact and addressing unequal distributions.

(iii) ***Enhancing the safety of structures and infrastructures*** against exceptional loads and deterioration over their lifecycle.

(iv) ***Implementing a comprehensive risk management*** approach and appropriate technologies to reduce pollution and environmental degradation, thereby reducing vulnerability.

(v) ***Establishing safe drinking water and sanitation systems*** to safeguard human health.

A huge responsibility of achieving the SDGs lies on the shoulders of Civil engineers and the need for creative and sustainable solutions is the need of the hour. Most of the 17 SDGs are in some way connected to the discipline of Civil engineering, directly or indirectly, as illustrated below, highlighting the importance of the discipline.

- The **direct impact** that Civil engineering interventions can have, are on *SDGs 6 – Clean water and sanitation, 7 – affordable and clean energy, 9 – Industry, innovation and infrastructure, 11 – sustainable cities and communities, and 12 – Responsible consumption and production*.
- Under *SDG 1 – Eradicate Poverty*, its associated Target 1.4 focuses on "*access to basic services, ownership and control over land and other forms of property, inheritance, natural resources*", and civil engineers play an active role in planning land use.
- Under *SDG 2 – Zero Hunger*, Target 2.3 outlines "*By 2030, double the agricultural productivity*" and Target 2.4 stresses on "*By 2030, ensure sustainable food production systems and implement resilient agricultural practices*", which requires civil engineering interventions in form of irrigation, water and waste management, transportation, etc.
- SDGs *3 – Health and Well-being, 4 – Quality Education, 8 – Decent work and economic growth, 13 – Climate Action, 14- Life below water, and 15 – Life on Land* can all be improved by Civil engineering, through infrastructural solutions with reduced environmental impacts that are socio-economically respondent.
- Further, civil engineering projects and practice can become a potent medium to create awareness and statements, inspire change and imbibe best practices in the society towards *SDGs 5 - Gender Inequality, 6 – Reduced Inequalities, 16 – Peace, justice and strong institutions*.

2.2 ANCIENT WONDERS AND MODERN MARVELS

The prowess of a civilisation can be contemplated through the tangible and intangible cultural heritage, and the feats of design, engineering and construction of the ancient world indicates the advancement and creativity of these long-gone people. While events and aspirations dictated the progress of the civil engineering practice, the ancient wonders and modern marvels showcase the importance and impact of the discipline on mankind.

2.2.1 Ancient Civilizations [4000 – 900 BCE]

One of the first, most formidable, examples of civil engineering and urban planning maybe noted in the Indus Valley, with the city of Harappa being built during the Bronze Age, in the 4th millennium BC. Sanitation and wastewater systems were uncovered dating back to 2550BCE in the cities of Mohenjo-daro, Harappa and Lothal, and well planned urban housing made of strong *leeves* or earthen walls, with private toilets and drainage, networks of reservoirs and canals for irrigation, granaries with air ducts raised on high platforms, and designated public baths (refer Fig. 1), are some of the remnants of civil engineering of these flourishing cultures in the valley.

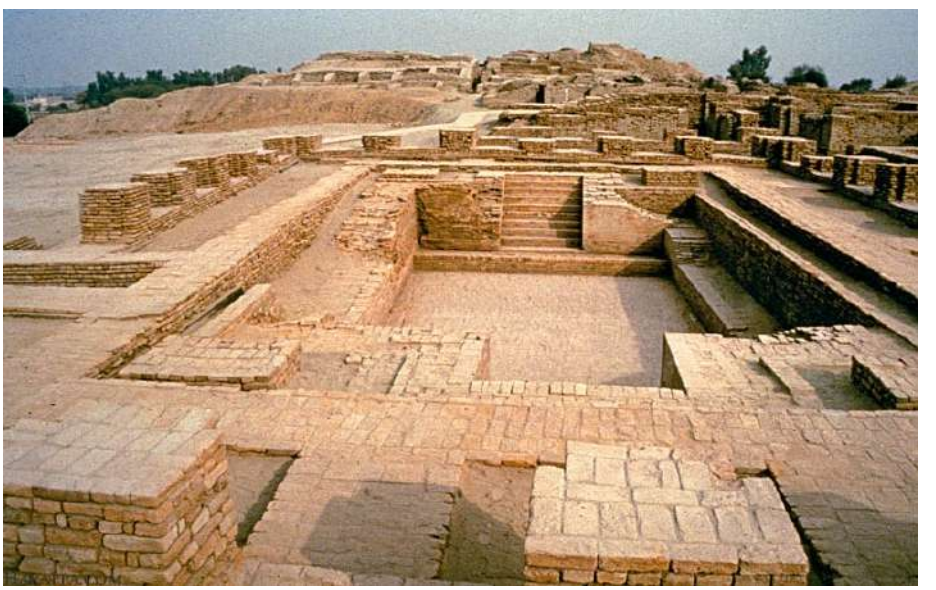

Fig. 2.1 : Great Bath at Mohenjo-Daro
(source : https://www.harappa.com/sites/default/files/slides/bath-indus.jpg)

In parallel, in ancient Mesopotamia (Iraq) along the rivers of Tigris and Euphratyes, the stepped pyramidal structure referred as **Ziggurat, at Ur** dates to 4000 BCE, with the 'White Temple' on

top of it being built in circa 3500 BCE. Underwater channel systems, called '*qanats*', were constructed to route water from aquifers and wells to the surface for consumption and irrigation.

Civil engineering and architecture were at a peak in ancient Egypt. The **stepped pyramid** dedicated to King Djoser, of the 3rd Dynasty, located at Saqqara Necropolis in Egypt, was erected around 2700 BCE. Designed and build by architect-turned-God Imhotep, documents reveal his profound contribution of using shaped stones to create mammoth monuments with simple tools and mathematics. Shortly after, between 2575–c. 2465 BCE, Pharaoh Khufu of the 4th Dynasty, commissioned the building of the **three principal pyramids of Giza** - Khufu or the Great Pyramid (originally 481 feet); Khafre (471 feet); and Menkaure (213 feet), on the west bank of the Nile. These two sites, along with the ancient ruins of Memphis, are collectively recognised as a UNESCO World Heritage site.

Whilst in Europe, the **Stonehenge**, United Kingdom, was being completed approximately around 2,400 BCE. It comprises of two rings of standing stones with horizontal lintels on connecting them, arranged in a ditch with earthen embankments, with a trilithon – a structure of two large vertical stones with a horizontal resting across them, at the centre. The outer ring has vertical sarsen standing stone measuring 13 feet high, 7 feet wide and weighing roughly 25 tonnes, and the inner ring has smaller blue stones. The Stonehenge in Amesbury, Silbury Hill – a manmade earthen mound with pits and tunnels, and other henges at Avesbury, all are recognised as **UNESCO World Heritage sites**.

2.2.2 Classical Period [1000 BCE – 1000 CE]

What followed was an era of superlative design and construction, characterised by their architectural styles, hand in hand with the rise and fall of empires. From 1st millennium BC to 1st millennium AD, the Greco-Roman style dominated and was termed as 'Classical'. The Greek, and later the Roman, primarily military-oriented, focussed on expansion of their empires and hence, heavily invested on development of infrastructure. **Cities** emerged, such as, the capital Rome in Italy; Persepolis in Greece; Marseille in France; ports at Nucratis and later Alexandria, named after Alexander the Great, in Egypt; and Antioch in modern day Turkiye, once the seat of both the Byzantime and Roman empire. The Roman's championed road building and the first known roadway, the **Appian Way** or the 'queen of the roads', was constructed in 312BCE, connecting Rome with its allies in Capua. The Romans were also the first civilization of built permanent bridges or *Ponte,* as it not only played a strategic role in connecting the vast ends of the ever-growing empire traversing various rivers, but also was perfected in design to behave as aqueducts to carry water. **Pons Amelius**, the oldest stone bridge; Ponte Milvio, the second bridge; and Pons Fabricius, the oldest bridge still standing, all plied over the river Tiber, while the **Pont du Gard,** the tallest Roman bridge, carried water over 50km across southern France to the colony of Nimes.

Temples, urban settlements, such as cities and ports, and Universities were constructed, offering a broader picture of the priorities and wealth of the empires of the time. However, it is interesting to note that there was a strong underlying religious belief system in the Greco-Roman Pantheon and was a centric theme of construction. The **Temple of Artemis** at Ephesus, the **Statue of Zeus**

at Olympia, **the Collosus** of Rhodes, **the Pharos** (lighthouse) at Alexandria, and the **Mausoleums at Halicarnassus**, all built at the time, are recognised as amongst the Seven Wonders of the Ancient World (other two being, the Great Pyramids of Giza and the Hanging Gardens of Babylon). Other notable religious structures built at the time are, the **Parthenon** dedicated to Goddess Athena at the Acropolis, a dedicated site atop Athens; **Temple of Jupiter Optimus Maximus** in Rome and those by Herod in the Judea, modern day Jerusalem.

In parallel, between the 10th - 5th century BCE, one of the first universities of the world was established at **Takshashila**, near the bank of the Indus River, India. It was a centre of great learning under the Indo-Greeks, with many scholars from all over the world. Chanakya, the noted scholar and Prime Minister of emperor Chadragupta Maurya, was a key figure at the university.

Further north, under the vision of the first emperor of united China, of the Qin dynasty, several existing piecemeal defensive wall structures were connected in the 3rd century BCE to develop a singular system of fortification, consisting of river dikes, bulwarks, and natural terrain, extending form the eastern Hebei province to the Gulf of Chihli. The early '**Great Wall**' was built with rammed earth, stones and wood, and later fortified with bricks and tiles with lime mortar, having passageways blocked by wooden gates. The construction of the Wall flourished under the Ming dynasty and continued till 17th century CE.

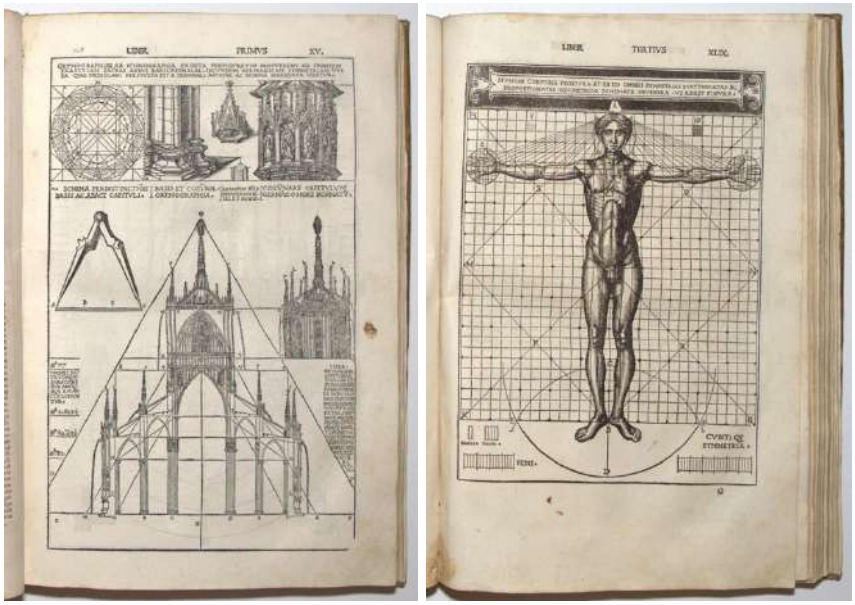

Fig. 2.2 : Pages from De Architectura [1475-1543], first vernacular edition, translated by Cesare di Lorenzo Cesariano (source : https://www.bada.org/object/first-vernacular-edition-de-architectura-vitruvius)

The development and eventual documentation of the **Classical style** can be traced to the earliest temples in Greece, such as that at Samos, built in timber framing. With change in material, from timber to stone, the scale and proportions grew, whilst retaining and refining the design elements and principles, that are still seen prevalent today. This was later composed as a ten-book treatise named, '*De Architectura*' (refer *Fig. 2*), authored by architect and military engineer, Marcus Vitruvius Pollio around 15c. BC, under the patronage of Caesar Augustus. It covered building materials, construction techniques and machines, guidelines on design of temples, civil and domestic buildings, common facilities, such as, pavements, water supply, aqueducts, as well as discussed, scientific and aesthetic principles, such as, geometry, measurement, buoyancy (Archimedes' principle), astronomy for sundials, and '***Orders of architecture***'. In addition, the first book opened with discourse on Town planning, architecture, and civil engineering, and elucidated the qualifications of an architect-engineer. Vitruvius proposed the triad of '*utilitas, firmitas, venustas'* (utility, strength, and beauty), as aesthetic characteristics of a good design and further developed the terms, order, arrangement, fit and proportion, which inspired Leonardo da Vinci to later illustrate the '*Vitruvian Man*'.

The 1st millennium AD saw the loss of Antiquity, as it gave way to political ambitions and philosophical schools of thoughts, led by thinkers such as, Plato and Socrates, leading to a shift from building of religious centres and temples to that of political and social interests, such as, the **Colosseum in Rome** (refer *Fig. 3*) and various triumphal monuments, such as, **Arch of Titus** and **Trajan's column**. But in the second half of the millennium, civil infrastructure continued to be built, such as, **Alcantara bridge** and **baths of Caracalla**; the rise of Christianity once again piqued interest in religious buildings. While several existing Greco-Roman temples and grottoes were converted in Christian churches, the new Roman Christian emperors took upon themselves tasks to build several basilica across their kingdom, from the **Basilica of Maxentius and Catacomb of the Via Latina** in Rome, and the **Papal basilicas** in present day Vatican City; to the *Aula Palatina* or Basilica of Constantine at Trier, Germany, and the **Hagia Sophia** (today known as the Grand Mosque) in Istanbul, Turkiye.

In 5th century CE, another profound institute of education - **Nalanda University,** in present day Bihar, India, came into establishment under the vision of the Gupta empire; and monolithic, rock-carved artistry and construction thrived under the patronage of the Pallava Kingdom in the southern state of Tamil Nadu. The famed Shore Temple, the *rathas* or temple-chariots dedicated to the Pandavas, several *mandapas* or pavilions, and noteworthy rock reliefs, such as '*Arjuna's penance*', at **Malappuram** (or Mahabalipuram), has earned recognition as a UNESCO World Heritage Site. Meanwhile in China, the world's oldest open-spandrel segmental arch-bridge of stone, fondly called Ānjì, meaning 'safe crossing' or **Zhaozhou Qiáo,** was constructed in the Hebei Province between 595-605 CE. In the 8th century CE, the **Seokguram grotto**, as part of Bulguksa Temple complex, in South Korea, was built and is recognised as National treasure 24 and as a UNESCO World Heritage site.

Thence onwards, the story of civil engineering runs hand in hand with architecture, largely responding to the human condition and the social context, with respect to, the visual language and aesthetics, structural layouts and buildings elements, construction techniques and materials, and the artist-engineer's creativity. This led to the development of styles categorised into 'periods' or 'movements'.

Following the Classical period, and before the next grand period of the Renaissance, which translates to 'rebirth', where two shorter styles that were found across Europe, namely;

Romanesque, found mostly across Medieval Europe between 1050-1170, retained several features of the Roman style and is characterized by thick, heavy piers, narrow windows, stained glass, semi-circular arches, and towers, as in the Tower of Pisa; and **Gothic**, or *Opus Francigenum*, meaning "French work", was prevalent in the Late Middle Ages in France, between 900-1300, could be distinguished by pointed arches, high vaulted ceilings, flying buttresses, and vibrant interiors with stained glass windows, gables, colourful tapestries, etc. Noteworthy examples are, the **Cathédrale Notre Dame** in Paris**,** France, a UNESCO world heritage site and the Milan Cathedral or ***Duomo di Milano***, Milan, Italy.

Fig. 2.3 : Different Architectural styles across Italy (*Left*) Colosseum, Rome, Italy (source : photographed by Author, 2015), (*Right*) Tower of Pisa, Italy

Fig. 2.4 : Examples of Gothic Architecture across Europe : (*Left*) A model of Notre Dame Church exhibited inside the premise, Paris, 2019; (*Right*) A picture of the Duomo di Milano, Milan, Italy, during restoration in 2015

(source: photographed by Author)