2.2.3 Renaissance & Age of Enlightenment [1400 – 1750 CE]

Renaissance, emerged as a response to the over-embellished previous styles drawing inspiration from the Classical in the early 15th century at Florence, Italy, and spread across rest of Italy, France, Germany, Russia, Spain and England. It was characterised by use of arched openings, hemispherical domes, vaulted ceilings, orderly arrangement of columns, and formal landscaped gardens, exemplifying proportion, symmetry, and order. Several artist-architect-engineers, such as, Bruneslleschi, Boticelli, Michelangelo, Alberti, Palladio, Bramante, Bruni and Leonardo da Vinci, and great men of science and philosophy, such as, Copernicus, Galileo, Francis Bacon, Newton, Keplar, Machiavelli and More, flourished in this period. This age of discovery paved the path to several scientific and technological advancements of today.

Filippo **Brunelleschi**, popularly known as the ‘Father of Renaissance’, designed the *Basilica di San Lorenzo*, housing the pulpit and tondo works by **Donatella**; and engineered the world’s largest brick vaulted dome, measuring 45.5m width and 116m height, for the *Santa Maria del Fiore* or Florence Cathedral. Another important advent of the Early Renaissance was the first theoretical ten-book compilation ‘on the Art of Building’, *De re aedificatoria*, by Leon Battista **Alberti**. It is also the first printed book on architecture, dated 1485, followed by the first edition print of Vitruvius’ *De Architectura* (refer Fig. 2).

In the following High Renaissance period, Bramante, under the patronage of the Duke of Milan, incorporated classical styles in contemporary buildings bringing about a unique character to this period. Two noted examples are, the abbey church of *Santa Maria delle Grazie*, where he introduced the choir and a hemispherical dome with arched classical openings, rooted within an octagonal drum. He also worked on the cathedral of Pavia, the cloister of San Pietro in Montorio, and the *Cortille del Belvedere*, Vatican. In 1506, his design of the rebuilding of St. Peter’s Basilica was selected, however, owing to his death the new chief Architect and noted artist, **Michaelangelo**, stayed true to the original proposal of the Greek-cross plan by Bramante. Another master builder of the time, **Andrea Palladio**, titled the “most influential architect of the Renaissance”, adopted the Classical elements in a less grandiose manner and developed from it unique features, such as, the Palladian Arch - a scaled triumphal arch with square-topped opening for windows, the symmetric domed hall with identical four facades with orders supporting triangular pediments, as in the Villa Capra, famously called ‘La Rotonda’. He also authored the “*I Quattro Libri dell'Architettura*" or Four Books on Architecture, published in 1570.

During the Late Renaissance, also called **Mannerism**, the trend continued where classical elements were reinterpreted as is seen by Michelangelo in the **St. Peter’s Basilica.** The cupola of the basilica was designed as two masonry shells, one sitting into another, held by ribs which supported a massive roof lantern, and the exterior boasted a ‘giant order’ (see Fig. 5), defining the external square, held together by a wide cornice – creating a timeless masterpiece.

Following Renaissance, two styles emerged – the **Baroque**, and later, more flamboyant, **Roccoco**, between 1600-1755 as a sharp contrast to Renaissance. With an attempt to apply certain classical elements to regional architecture, without regard for the fundamentals of composition characterising Classical, these two styles are characterised by geometrically exaggerated, ornate and colourful structures, such as the **Palace of Versailles in France**, and **St. Paul's Cathedral in London**, and were seen in conjunction with the Counter Reformation movement.

Fig. 2.5 : St. Peter's Square, Vatican, boasting Michelangelo's 'giant order'
(source : photograph by Author, 2015)

2.2.4 Modernism & Industrial Era [1750 - 1950 CE]

Civil engineering remained at the helm during the **First Industrial Revolution**, with industries springing up and connectivity, transportation and sanitation became a dire requirement. Several bridges, canals and sewers were commissioned to carry effluents, goods and people, to and fro from industries. Noteworthy designs include *Bridgewater canal*, built by engineer Brindley in 1761, having several tunnels allowing direct travel to coal mines; and the world's first cast-iron, arch bridge over the River Severn at Coalbrookedale in 1776, where Pritchard used the brittle metal to construct a semi-circular structure that transfers load onto abutments, while held in compression to counter cracks from propagating – a first of its kind.

In 1771, John Smeaton the first self-proclaimed civil engineer, formed the **Smeatonian Society of Civil Engineers**. He constructed the Eddystone Lighthouse, off Cornwall, England, and developed 'hydraulic lime' and techniques of dovetail joints and dowels for securing blocks.

Road maintenance also became a priority in the 18th century, with the establishment of turnpikes trusts and toll roads. **Design and construction details of roads** saw significant improvement, with new methods proposed by Pierre Tresaguet in 1764 and later, improved by his mentee, John Metcalf who proposed convex shaped surface to allow rainwater to drain. Thomas Telford suggested small stones on the rock foundation further covered with a mixture of stone and gravel, having elevated pavements on either sides, known as 'Telford pitching', and John McAdam developed the '**macadamisation**' where soil foundation is layed with aggregate layers of angular stones and gravel. This design was later patented as the 'Tar Mc Adam road' by civil engineer, Hooley 1901, as is used today.

Soon railways spread rapidly and took over as the preferred mode of heavy goods transportation, with engineer Stephenson designing the **first steam locomotive** in 1825, and later improving it under the *Liverpoool and Manchester railway* (L&MR) in 1830.

A prolific civil engineer of the time, **Isambard Brunel,** pushed the boundaries of engineering and expanded his role as engineer-architect and designer. By 1833, the *Great Western Railway* (GWR) was commissioned under the able guidance of who had assisted on the *Thames Tunnel* project which has been incorporated today as part of the London Underground. Brunel, also has to his credit, design of several remarkable bridges, with the *Cliffton Suspension bridge* over Avon spanning 702 m - the longest at the time, as well as for, the world's longest steamship of the time, '*Great Western'*, constructed of wood and reinforced with iron diagonals and bolts, with improved surface condenser incorporated. He continued his experiments and further designed the first modern ship, *Great Britain*, which was propeller-driven and iron-hulled. The *Great Eastern*, his third transatlantic ship design, was the most technologically-advanced and luxurious ship of the time and is famed as one of the seven wonders of the Industrial Revolution. However, it aided the laying of oceanic telegraph cables rather than plying passengers, and proved to be pivotal in connecting America and Europe. He also designed the '*Three bridges'*, London, that allowed the routes of Great Western and Brentford Railway, Grand Junction canal and Windmill Lane; and the Renkioi Hospital, a first of its kind hospital in 1845, comprised of pre-fabricated wood and canvas that could be shipped and assembled on-site, far away in Tukiye, where the Crimean War was underway.

During the **Second Industrial Revolution**, when the spotlight was on the new nation of United States of America (USA), the **Neoclassical style,** as the name suggests, a revival of Classical style, was adopted to communicate a grand and powerful aesthetic in Gilded Age. Characterised by triangular pediments, free-standing columns, balustraded balconies, pronounced cornices, and symmetry, the White House and overall, the Capitol complex in Washington DC, it is reminiscent of Palladian architecture. Neoclassicalism also spread to England, France and Russia, with some of its outstanding advocates being, Robert Adam, John Soane and Claude-Nicolas Ledoux.

Modern design as understood today, epitomized by metal construction**,** first sprouted its presence with the **first two exhibition pavilions of the World Fairs** or the "*Exposition Universelle*". The two were, the **Crystal Palace** in Hyde Park, London, a cast-iron and plate-glass structure housing 92,000 sqm exhibition space designed by Joseph Paxton in 1851; and the **Eiffel Tower**, Paris, locally referred to as "*La dame de fer*" (Iron Lady), a wrought-iron lattice tower designed by architect, Stephen Stauvestre, along with structural engineers, Maurice Koechlin and Emile Nouguier. With further industrialisation supporting mass production of steel and glass, these materials became vastly employed as they imbibed a sense of never-before appeal, and further motivated futuristic styles.

Fig. 2.6 : The Great Exhibition pavilions - (*Left*) Crystal Palace, London, (*Right*) Eiffel Tower, Paris

Fig. 2.7 : Examples of Art Nouveau (*Left*) Sagrada Familia, Barcelona, and
Art Deco style (*Right*) Chrysler Building, Chicago

Between 1890-1910, aversive to historicism and enthusiastic of modern life, the unique style of **Art Nouveau** developed characterised by organic lines and sinuous forms, achievable by steel frames and exaggerated by glass panes. The style was called *Jugendstil* in Germany, *Sezessionstil* in Austria, *Stile Floreale* (or Stile Liberty) in Italy, and *Modernismo* (or Modernista) in Spain; and was employed in building design by architects, Louis Sullivan across Chicago and further accentuated by artist-architect, Antoni Gaudi in Spain. Sullivan advocated the development of original forms and ornamentation, and is identified as '**Father of skyscrapers'**, exemplified in his design of the Wainwright Building in Chicago. In his firm worked a young civil engineer and aspiring architect, Frank Llyod Wright, who later was called the '**Father of modern architecture'** and like his mentor, developed a style unique to America

– the Prairie style, illustrated through large cantilevers and use of glass held with metal, like the Robie house or 'Fallingwater' – the most famous house in the world.

It was followed by **Art Deco style**, also referred to as style modern, which exhibited an affinity with machines as a reflection of modernity. While a short-lived movement between the 1920's and 30's, it had an indelible mark on the skyline of the emerging nation of USA, with iconic structures, such as, the Empire State Building, Rockefeller Center and Chrysler Building. This style was characterised by stepped gables, sculptured panels, ornate geometry, and cubic forms, along with use of unorthodox materials like, exposed steel and aluminium, decorative glass, ceramic and even, stucco and terracotta. In contrast, Europe saw the development of the '**International style**' characterised by rectangular forms, cantilevered projections, flat roof, ribbon windows, curtain glass, asymmetric facades and lack of ornamentation, as practiced by Le Corbusier in France, and Walter Gropius and Mies van der Rohe in Germany.

Various other styles such as, *Futurism, Constructivism, Brutalism, De Stijl, and Bauhaus*, all encompassed under the term **'Modernism'**, prevalent during the early 20th century, were grounded on the principle of '*Form follows Function'* as stated by Louis Sullivan. Fuelled by the abundant availability of mass-produced modern materials; they were a stark deviation from the traditional styles, characterised by functionalism, lack of ornamentation, and rational use of modern materials true to their nature, with a keenness for structural innovation. Philip Johnson's Glass House is an exquisite example.

2.2.5 Contemporary style & Digital Era [1950 - present]

Post-World War II, the international style flourished in the US for commercial buildings, as evident in the Seagram Building designed by Mies van der Rohe, a champion of minimalism famous for his aphorism "*less is more*".

But soon, in the 1960's, there was an antagonism towards the bleakness of modernism, and newer trends, such as, the introduction of the principles of **Beaux Arts style** by Louis Kahn and Eero Saarinen; and the need to focus on placemaking, with the local conditions and contexts through incorporation of vernacular by Robert Venturi, who published '*Complexity and Contradiction in Architecture'*, gave rise to the **Post-Modernism.** It challenged its predecessor with asymmetry, ornamentation, historical details and familiar motifs, and was characterised by eclectic inspirations and kitsch aesthetics, with focus more on form over function. Some of the notable examples are, the Lotus Temple in New Delhi, the Sydney Opera House, and the Guggenheim Museum, Bilbao, by pioneer Frank O'Gehry.

The concept of modularity was also catching on, with Archigram collective proposing a mega-scale modular concept called Plug-in City in 1964 and Shafie Moshdie designing the Habitat 67, a modular experimental housing. In Japan, the '***Metabolism' style*** developed, focusing on modularity, flexibility and interchangeable units, as exemplified by the Nagakin Capsule Tower designed by Kisha Kurokawa in 1972.

Fig. 2.8 : Examples of Modernism - (*Left*) Frank Llyod Wright's *Fallingwater*, Pennsylvania,
(*Right*) Philip Johnson's *The Glass House*, Connecticut

Fig. 2.9 : Examples of Contemporary Style - (*Top Left)* Frank O'Gehry's Guggenheim Museum, Bilbao,
(*Top Right*) Nagakin Capsule Tower Kisho Kurokawa's *Nagakin Capsule Tower*, Tokyo,
(*Bottom Left*) Mies van der Rohe's *Seagram Building*, New York City,
(*Bottom Right*) Renzo Piano and Richard Roger's *Centre de Pompiduo*, Paris

Meanwhile in India, between 1950's-70's, the young nation also felt the ripples of these movements, with the vision of setting up a model city – Chandigarh. The task of designing a modern yet culturally sensitive aesthetic, Le Corbusier devised the city's masterplan by applying the concept of *Unité d'Habitation*. With the Capitol Complex at its heart, clean geometry and concrete facades were interspersed with motifs and symbology, and compositions of colour. And in 1961, the year of completion of the construction of the Capital Complex – a UNESCO World Heritage site, another grand project was in motion. Louis Kahn was commissioned the tasks of designing the IIM Ahmedabad (1962-74), a vision of Dr. Vikram Sarabhai and Kasturbahi Lalbhai, to develop professionals for the country's growing industrial progress.

The introduction and widespread adoption of the use of CAD software between the 1960's – 1990's led to the widening of architectural styles beyond post-modernism to high-tech or **Structural expressionism**, which aimed at showcasing the underlying function-structure of the buildings, from exterior to the interior, through the use of advanced technology and materials. Aluminium, steel, glass and concrete offered a sense of grandiose and honesty, with open plans allowing reconfigurable spaces, large overhangs and lack of load bearing walls. The World Trade Centre (1971) in New York by Yamasaki, the Centre Pompidou (1977) in Paris by Renzo Piano and Richard Rogers, and the Burj al Arab (1991) by Tom Wright are some famous examples. Improved design tools furthered modular construction and led to the development of the **Klip House concept**, designed by Interloop between 1997-2001, where modules could be snapped together to build a unit. Presently, the world's tallest building, the Burj Khalifa (2010) with the height of 830m to the tip, housing 163 floors, is an epitome of contemporary architecture. The three-leafed structure is an abstraction of the desert flower, Hymenocallis, twirling into a spire as it gains height.

Hand in hand, another trend of the present times, propelled by the development of CAD and other design tools, is **Parametricism.** Characterised by the use of algorithmic equations and computational tools leveraged to generate varied and almost impossible forms which are complex yet fluid, can be traced back to 1997. Earlier famed architects, Frei Otto and Antoni Gaudi are often considered inspirations for this style, personified by *Pritzker Awardee, Zaha Hadid*. The Guangzhou Opera House, at Galaxy Soho in Beijing China, and the Hyder Aliyev Centre in Baku, Azerbaijan, are a few of her exemplary works.

While using parametric design not only enables designers to optimise the planning and improve efficiency of the design, attempts to incorporate sustainability factors is currently being pursued by noted firms, such as, Ai Space Factory, Foster & Partners, etc. The OPPO R&D headquarters, named the **'Infinity Loop',** *designed by Bjarke Ingels Group (BIG)*, China, boasts an elegant form that is self-shaded, thereby, it reduces the energy usage and increases natural light. Another remarkable example is the '*Heart of Yong'an*' by TJAD, China, where algorithmic modelling has been used to create a hyperbolic, single slope, curving roof structure, emulating the surrounding mountains, with rammed earth walls and local blue tile roofing.

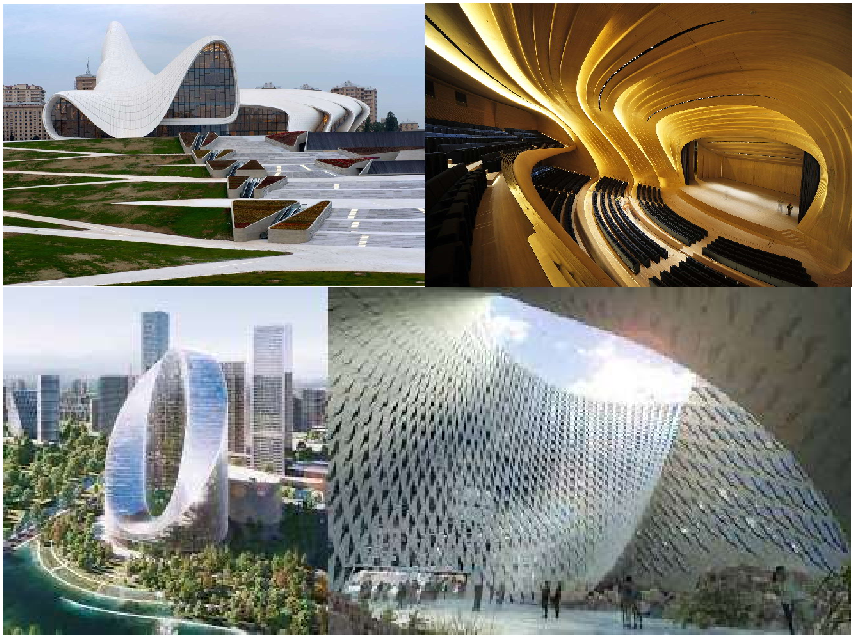

Fig. 2.10 : Examples of Parametricism - (*Top)* Views of Zaha Hadid's *Hyder Aliyev Center,* Baku*,* Azerbaijan, *(Bottom)* of Bjarke Ingels *Group's Infinity Loop,* Hangzhou, China

2.3 FUTURE VISION FOR CIVIL ENGINEERING

With demand for design and construction on the rise, the future holds many propositions. The key themes for civil engineering, at the juncture of **design + technology**, will be:

Sustainable Design & construction: Developing ***Green infrastructure*** that is safe, inclusive, energy efficient, and uses materials and techniques that have low environmental impact; using ***Nanotechnology and use of nano materials***, like, nano-silica, nano-clays, and iron nanoparticles, incorporated into concrete, and copper nanoparticles used in steel beams; and realising ***Futuristic transportation***, such as self-drive and travel pods through hyperloop will improve quality of life.

Cutting-edge technology: Using ***Augmented and Virtual reality*** to model real world construction challenges, as well as provide an immersive experience to visualise concepts via ***Digital Twins***; and leveraging ***AI, Big data and IoT*** to seamlessly harness data for mundane decisions and support collaborative projects with multiple stakeholders, will improve the quality and time of the design and construction.

The importance and profound impact of Civil engineering on society and the world, is undeniable and beckons that formidable and competent civil engineers forge the future.

UNIT SUMMARY

This Unit walks through an aspiring civil engineer on the importance of the profession, its remarkable lineage of breakthroughs across history and the future scope of the profession. Drawing from the knowledge shared in Unit 1, this Unit connects to the importance of the profession and practice as custodians of sustainable development and exemplifies the potential impact of civil engineering on achieving each SDG, either directly or indirectly. It further discusses the skills required for a competent civil engineer and the capabilities expected. The next Section elucidates marvels and breakthroughs in the ancient era up till present times, and continues to highlight in brief the major themes for the future.

EXERCISES

I. Multiple Choice Questions

Q. 2.1 Which of the following is not a Civil Engineering specialisation?

(a) Geotechnical Engineering
(b) Hydraulic Engineering
(c) Environmental Engineering
(d) Urban Planning

Q. 2.2 What are the SDGs that are directly impacted by Civil Engineering?

(a) SDG 11 - Sustainable cities and communities,
(b) SDG 6 - Clean water and sanitation
(c) SDG 16 - Peace, justice and strong institutions
(d) SDG 9 - Industry, innovation and infrastructure

Q. 2.3 Which ancient marvel, recognised as a UNESCO World Heritage site, is the oldest amongst the Seven Wonders of the World?

(a) Three principal pyramids of Giza
(b) Ziggurat with the ‘White Temple’ at Ur
(c) Mohenjo-daro, Harappa and Lothal
(d) The Stonehenge, United Kingdom

Q. 2.4 The Greeks and Roman style of architecture and construction is called?
(a) Renaissance
(b) Ancient
(c) Classical
(d) Gothic

Q. 2.5 Who is the Father of Renaissance?
(a) Leonardo da Vinci
(b) Andrea Palladio
(c) Leon Battista Alberti
(d) Filippo Brunelleschi

Answers of Multiple Choice Questions: 2.1 (d), 2.2 (c), 2.3 (a), 2.4 (c), 2.5 (d)

II. Short and Long Answer Type Questions

Q. 2.6 What are the roles and responsibilities of a Civil Engineer?

Q. 2.7 What were the major periods in design and construction? Write briefly on each with an example of civil engineering.

Q. 2.8 Describe the major future trends in Civil Engineering and elaborate which one is set out to be the most impact full in the days to come.