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HISTORICAL DEVELOPMENT OF CONSTRUCTION TECHNIQUES: FROM ANCIENT ARCHITECTURE TO MODERN ENGINEERING

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SUMMARY

The history of architecture has been molded with the development in modes of construction, reflecting the social, economic, and technological advancement of different civilizations. This paper discusses the chronological development of the various methods of construction from ancient architecture to modern engineering and cites some key milestones shaping today's construction processes. The study embraces developments throughout four major periods: early developments during the era of 'Masters of Structuring Matter', geometric and structural novelties developed during Gothic and then during the Renaissance, revolutionary industrial development throughout the 19th century, and technological and sustainable approaches of the 20th and 21st century. The paper highlights how iconic constructions, like ziggurats, Greek temples, Roman infrastructure, Gothic cathedrals, and modern skyscrapers, specify technology, culture, and architecture as being interdependent because of the characteristics which involve structure and materials. Results show that learning construction practices from the past not only brings new light to today's design but also presents new demands toward sustainable and resilient building techniques in facing challenges during modern times. Future research is likely to be more directed toward integrating traditional methods with advanced technologies for the development of new, environmentally friendly construction solutions.

Key words: *construction techniques, ancient architecture, modern engineering, building materials, building information modeling (BIM).*

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INTRODUCTION

The past is full of lessons that the architecture of their era left behind. The world has been built with many different techniques, long gone and quickly replaced when newer ways emerged. Looking back at them gives us a general understanding of the construction of the time, but it also shows the different social and economic politics that have been at play [5]. The selection of building techniques has always been dependent on the culture, the economic resources, and the latest available technologies. Being able to construct has always been fundamentally necessary in every culture throughout the course of history.

Very basic construction methods were present in the ancient cultures of both the West and the East. The buildings of those early cultures resemble the organization of the societies that built them, but altogether, they lack an easily perceivable historical journey between them. Most of the noteworthy advancements have happened in the relatively recent past of today's history. This essay explores those aspects of the historical development of construction techniques that ultimately led to our contemporary approach to building. Primarily, the paper will focus on four different periods that witnessed substantial advancements in building methods. These have been identified as: the time of the 'Masters of Structuring Matter', where the most important activation of the built environment developed in the Western world; the Gothic and Renaissance period, where the first and astonishingly cutting-edge ways of creating geometry were defined; the time of the Industrial Revolution, when the most important aspect of the modern approach to manufacturing was created; and finally, the first half of the 20th century, where engineering as we perceive it today was formed. The text will be constructed by analyzing the built environment of chosen buildings, all of which belong to one of those periods considered [2].

ANCIENT CONSTRUCTION TECHNIQUES

Since the dawn of history, mankind has always strived to satisfy not only its basic housing needs but also its aspiration to achieve greatness. The two are obviously interrelated. Therefore, the historical development of architectural and construction techniques is always tightly bound with the aspiration and spirit of the times that form the cultural context. Architecture has always been an attempt to introduce human beings into the ordered harmony of the cosmos, humble parts of a meaningful and solemn whole. No matter if it adopted figurative imagery and the use of specific symbols, or, apart from the attributes of form, it expressed wealth, power, and refinement. In the last instance, there was still a similar complicity, understood differently of course: it was replaced by the pride and the joy of man in doing something good for himself and for the coming generations; it was also the reciprocal complicity of those who shared the same spiritual and cultural heritage absorbed not only instinctively but also through innumerable historical experiences [1].

Before we analyze various specialized construction techniques together with their typological responses, it is very important that we examine, speculatively and in a very simplified manner, the basic construction and architectural behavior of historical construction as an important introduction to both the ancient and modern technical responses. This perspective does not pretend that historical construction exhibitions especially provide a first relevant base for setting up correct critical analysis in the field of pre-seismic and post-seismic interventions. On the other hand, precise original and authentic preventive strategies for each specific situation that reflect creative and scholarly synthesis of such scientific considerations and common sense in respect to traditional historical cultural identity are required [3].

Stone Age and Neolithic Construction

Historically, it is almost impossible to investigate the very first construction activities. The earliest people and their wooden huts have long decomposed. The progress from an essentially non-construction culture into a highly developed building industry has left only archaeological traces. What we have is evidence of the simple log huts of the earliest settlers. The first houses of stone, which later formed towns and cities, can still be seen in the form of medieval castles and ruins. Although it is difficult to pinpoint the first appearance of rudimentary habitations, it is relatively easy to show that the construction of a house was regarded as a simple, quite ordinary task. The first construction workers were the elementary farmer-builders, who used the oddly shaped logs, twigs, and reeds around them to construct simple dwellings. Predominantly characterized by natural materials such as wood and animal hides, the very early houses served to protect the people against adverse weather and the wild animal world. Although few social groups actually lived in caves or simple shelters, the precondition for any natural life is physical protection through the construction of a "shelter".

Initially, early humans depended on their physical surroundings and lived as nomads without any fixed residence. Many were hunters who killed wild animals for food or skins for clothing. Some began tentatively to cultivate the land and took to agriculture. Gradually, herding sheep and goats and farming probably displaced hunting alone as the main economy of the human family. With the ownership of land came the settlement, and this is the time when the real significance of the term "construction" began. For some seven thousand to eight thousand years ago, humans began slowly to transition to settled community living, and this is where the first major change in the early architectural world was noted [4]. Below the table 1 explain Key Innovations and Cultural Impact of Construction Techniques Across Historical Periods.

Table 1. Key Innovations and Cultural Impact of Construction Techniques Across Historical Periods

	Historical Period	**Key Innovations**	**Significant Structures**	**Cultural Impact**
1	Ancient Civilization	Stone consruction, mudbrick, early use of geometry	Ziggurats, Egyptian pyramids	Reflected religious and cosmic order, early societal organization
2	Gothic & Renaissance	Flying buttresses, vaulted ceilings, architectural symmetry	Gothic cathedrals, St. Peter,s Basilica	Symbolized religious power, advances in artistic axpression
3	Industrial Revolution	Iron and steel structures, mass production, concrete	Eiffel Tower, Brooklyn Bridge	Industrial growth, urbanization, public infrastructure
4	20th Century	Skyscrapers, reinforced concrete, digital tools (BIM)	Empire State Building, Modern skyscrapers	Symbol of modernity, technological advancement, global cities

Ancient Mesopotamian and Egyptian Architecture

In Mesopotamia, the construction of houses and public buildings was equally dependent on local circumstances and resources, characterized by the use of materials such as different species of wood, stone, adobe, mudbrick, and fired bricks. Nonetheless, the supply of clay compared to the relative structural scarcity of wood made mudbrick the most common building material for domestic architecture. Ziggurats, the stepped "holy" towers with their pyramidal volumes built in brick and adobe, represent a beautiful synthesis of Mesopotamian construction techniques and the ideological and cosmological world of the time. The entire structure of a ziggurat refers to a sacred mountain where the gods had their dwelling. The more important the temple on the top of the ziggurat was, the more the structure's basic design principles had to be developed.

Moreover, the construction of the ziggurat should be seen in relation to the entire layout of the Mesopotamian cities where the well-structured places and sanctuaries were mostly dedicated to the principal cult of the city, dedicated to the supreme god of the town. In Egypt, from the end of the 3rd millennium BC onwards, builders could count on natural stone, which was more durable and endowed with greater constructive possibilities than the ancient materials available up to that time. This opening to new technological resources allowed for the largest-scale architectural projects, still unparalleled in the number of stones used and in their weight. Preceded only by the obelisk, the monumental statuary, erected from the New Kingdom onwards in the free area around the temple's first courtyard, had a purely propagandistic function, and there is no correspondence between the site of the statue, which has a celebratory function, and the sarcophagus of the pharaoh [6]. Figure 1 shows the History of Architecture: Megaliths, Mesopotamia, and Ancient Egypt Plan of Palace of Sargon Khosrabad Reconstruction.

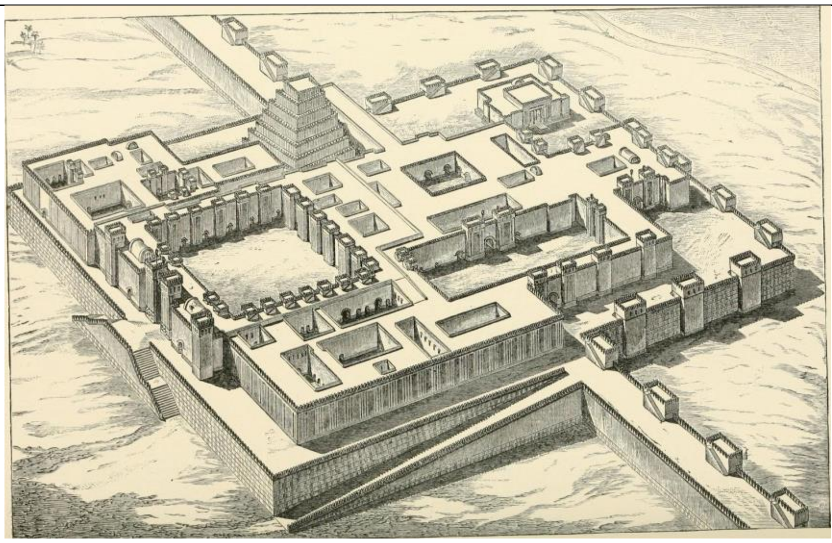

Figure 1. History of Architecture: Megaliths, Mesopotamia, and Ancient Egypt Plan of Palace of Sargon Khosrabad Reconstruction. Image via Wikimedia Commons 6 / 11

Greek and Roman Construction Methods

The Ancient Greeks made significant contributions to architecture, defining the column orders in temple construction. The Doric, Ionic, and Corinthian orders developed in the 8th and 7th centuries BC. It is the first written document discussing a comprehensive plan for the actual building process and was used as a manual by construction practitioners for many years. In ancient Greece, architecture was a form of art, and buildings were not merely seen as pragmatic shelters. The Greeks invested a great deal of work, talent, and money to create aesthetically pleasing manifestations of their ideals. Although a few materials such as concrete, brick, and an early form of steel were used in some temple walls, the Greek temple remains a mostly wooden structure.

The Romans constructed with brick, concrete, and stone, producing walls that were typically around 1 meter thick. The use of concrete as a main construction material in buildings was the most important advance in building technology at the time. Tall buildings with thick concrete walls have the gravity load carried vertically to the ground, which leads to a squat, small-base building to resist overturning. The Romans used massive concrete piers at the ground floor and arches to span a large space in an effort to protect buildings from earthquakes with a great deal of structural redundancy. The innovative use of curved structures helped the Romans engineer larger and more stable buildings. With integrated concrete walls and a domed ceiling, the Pantheon becomes a dark, intimate space that radiates a sense of defectlessness, even within the seeming randomness of structural redundancy on the outside. The purpose of the construction and the grand statement it makes suggest that its starting point is the ancient Greek temple. Construction of public amenities not only benefits the population but also speaks a great deal about governing capability. With a large number of sophisticated public building plans, Greek and Roman civilization's urban planning, public works, and construction methods were and still are widely influential [7].

MEDIEVAL AND RENAISSANCE CONSTRUCTION

Architecture of the period known as the Middle Ages and the Renaissance is characterized by a conjunction of style and techniques. As these historical periods were highly transformative, we can deduce that many architectural developments appeared as the result of the evolution of construction techniques and knowledge. But the changing architectural scene probably originated such advances as well. We shall thus present architecture and construction at times considered crucial, such as the age of scholasticism and the repertory from Ancient Times. In medieval architecture, these developments appear in the vaulted halls of abbey churches and cathedrals, most notably in the large fourteenth-century octagonal chapter halls. Multiparty and available light in Gothic churches reduced the walls to fill up the space between the piers and allowed the glazing of large windows around the building, but the continuity between the interior principle and the exterior appearance went far beyond the classical repertory. On the one hand, the friable stone of Ghent enabled an extremely elegant relief work. The ensemble of the work displayed the split between craftsmen and corporations that characterized the Middle Ages, fostered by the fact that the masons and the enlightened craftsmen did not work in the same rooms. The end of the medieval period corresponds to the birth of the Renaissance in Italy, which lasted until the sixteenth century. It was several times delayed from being imported to France, but now it doesn't seem possible for the Renaissance to incorporate a popular evocation of its Roman roots. In 1506, Julius II was building a huge, new Saint Peter's under the direction of Bramante, who proposed using a new design with a central octagonal plan for the revised church. However, Bramante died before 1514, and then Raphael and Michelangelo both made changes to the previous plan of Saint Peter's while they oversaw the restructuring. At the death of Michelangelo in 1564, the dome of the basilica was completed and St. Peter's was shown as it appears today [8].

Gothic Architecture and Cathedrals

Gothic Architecture: Few styles in the history of architecture have generated such a strong reaction in their times and outlives it than the so-called Gothic architecture, which flourished from the 12th to the end of the 16th century. Gothic design was inspired by the earlier Romanesque architecture, but of the three styles invented by the Europeans, the Gothic evolved to be the most distinctive and pervasive all over Europe. Many of the characteristics that set it apart followed the advantage in calculation and developments in structural systems that facilitated the construction of larger and lighter edifices than the Romanesque. Among these, the use of flying buttresses to support the arched vaults from the nave walls to the arches over the side aisles, the separation of the transverse nave from the light canted pointed arches of the barrel vaults above, and openings up the walls to extravagant displays of vital light and richly colored stained glass.

The combination of these elements was only enhanced by the large walls with very little fenestration on the first level, titan-like proportions, and an assortment of geological details that were simply unseen in the history of Western architecture. A central element in the appearance of a Gothic cathedral marks the massive flying buttresses that push with their hefty structural force the weight of the vaults directly on the ground; the pier arch that emerged marks the shapes of a disembodied arc located outside of the cathedral, continuing and suggesting themselves as solid chapels. Somehow, the limited and continuous connection of structural stone voussoirs became some unified impalpable point-line-circle that amazed the middle-aged inhabitants of medieval European cities. Many were drawn into the cathedral as a single historic context [9].

Medieval Fortifications and Castles

One response to the pervasive warfare that characterized much of the medieval period was the construction of fortified strongholds by the nobility and others who considered themselves the power brokers of the time. A study of medieval architecture cannot, therefore, overlook these structures, largely exterior or in some cases integrated with ecclesiastical establishments, built for defense. They are the product of necessity at a time when differences between adversaries were often settled by force of arms rather than by reasoned argument. Structural design also evolved in response to the nature of war, and discussion of the elements and external features should be read in the context of military developments. In addition, these fortifications create a link between the built world and the medieval psyche, providing a bridge between a mundane daily life for the vast majority and a world of higher aspirations occupied by a privileged few. Throughout the medieval period, fortifications were a vital, but often contentious and deadly, part of the medieval world. Medieval life abounded with reminders in the form of the parapets that adorn holy images, the dramatic ruins that grace landscapes, and the heritage of place names such as names derived from castle types or field works that indicate their military significance. They were both the engines of war and the sources of sublime beauty. In part because of their symbolic importance, castles continue to be the subject of studies and dissertations in multiple disciplines in college settings around the world. Throughout the course of the medieval period, the value of buildings changed, often because of their association and adaptation with war, becoming monastic sites, royal homes, or feudal strongholds hundreds of years after their original purpose was intended [10].

Renaissance Innovations in Building Techniques

This is the time when the classical architectural principles of the ancient Greeks and Romans, such as axiality and symmetry, came to the forefront again and were integrated into contemporary design. Much influence was exercised by the advanced techniques of painting, such as the use of a vanishing point and perspective, a mathematical proportion, and a method to construct and perceive space. The very idea of a rational and mathematical order in creation led to buildings with a harmonious, symmetrical, and proportional plan. The constructed buildings had a clear geometric shape, and the ideal shape was the circle, based on which the centralized plan was developed. Several basic elements of architecture were strengthened during the Renaissance.

One of the major leaps in architecture starts with the innovative building techniques of Florence, a city of the Italian Renaissance, by the architect Filippo Brunelleschi. Brunelleschi, along with several other architects and scholars, was of the opinion that an absolute geometric method could lead to an understanding of the harmony of nature and divine laws. Though he showed great interest in applying the principle of proportion of classical geometry, a critic pointed out that his carefully and delicately, almost interactive, proportional method was rather original. The construction of the dome at the Florence Cathedral can be considered a famous piece of architecture from this period. The main dome of the church was constructed without any additional scaffolding, and the roof tiles of the dome were arranged in a two-skinned herringbone pattern that ensures stability. This large circular-shaped dome, standing 375 feet high, is built with a self-supporting technique. The dome remains the fourth largest and tallest in the world, and it was constructed after the design laid down by Brunelleschi [11].

INDUSTRIAL REVOLUTION AND TECHNOLOGICAL ADVANCEMENTS

The Industrial Revolution marked a transformation from ancient building techniques rooted in long-lasting traditions of craftsmanship to supply the demands of an increasing population. Technological advancements in the production of iron and steel enabled engineers to significantly push the boundaries of traditional building types. This influence quickly materialized in the form of new building typologies that changed the architectural landscape and city forms around the world. The new materials and techniques gave way to experimental constructions and the elimination of historic architectural ornaments from the product offering. The back-to-basics approach, where visual and form expression complements building functionality, emerged from the produced typologies.

The development of skyscrapers introduced and defined modern visual urban forms of Western cities for most of the 20th century. The use of a newly emerged material, concrete, further enhanced the palette of tools available to constructors. The discovery of concrete and improvements in piling dirt were used to create an even firmer bond of buildings to the earth in the process of foundation making. The shift toward concrete as a structural material gradually opened the door to more capable and modern architectural design. Advances in building materials and engineering principles brought improvements to how buildings, factories, bridges, and other elements of the human environment are constructed. Factories emerged in Europe in large numbers as a substitute for craftsmen's facilities. This period also activated the construction of railways and long-span bridges, as well as river improvements with lock chambers that increased the ship's carrying capacity, speed, and safety.

Iron and Steel Structures: Industrial Revolution

The rise of iron and steel as materials of choice for construction during the Industrial Revolution changed the processes of construction and the aesthetics of architecture alike. Iron utilized in frame structures saw rapid development early in the Industrial Revolution, particularly in warehouses, factories, trains, and bridges. Iron frame structures supported by cast-iron columns and beams made for robust and flexible systems that could support larger loads over wider spans. The development of inductive furnaces allowed for the mass production of high-strength wrought iron, greatly increasing this metal's production and the ability to create larger and taller structures.

The development of the wrought-iron lattice structure as a stairway for all parts of the Eiffel Tower in 1889 announced a new aesthetic associated with wrought iron, in which the iron structure appears as lacework. The Eiffel Tower was built as a temporary structure for the Paris World Exhibition, and early in its construction, it was disparaged for its apparent deformity and coldness. Moreover, the 19th century also saw the development of steel into ingots and later rolled sections in the United States and England, increasing the production but also the quality of steel. Steel combines iron with other metals to produce an alloy that has a higher shear strength and malleability over a wider temperature and pressure range. The Brooklyn Bridge, designed by the Austrian-born engineer John Roebling, opened in 1883. Like the Eiffel Tower, it demonstrated the potential of steel as a construction material and engineering material between the late 19th and early 20th centuries [12].

Concrete and Reinforced Concrete

Liquid stone: nearly 2000 years ago, this idea changed from modest first experiments into enormous building activities. But over time, the construction using cement-based materials was replaced by stone construction. The Romans left behind the idea of surrounding Europe with extensive road systems that were hardly taken up again in the almost two millennia that followed. Only in the 19th and 20th centuries were ancient Roman construction units, first provided as mere construction mortar, quickly reinvented into pure construction materials that were set into the minds of architects and builders in Europe, and later in the rest of the world. These massive and ambitious building activities were only possible through a method of construction that must be described as the most elemental expression of construction, by some called 'concrete in the rough': cast concrete.

In particular, back in 1867, wrought iron reinforced concrete had to overcome some technical difficulties and very special design tasks. The reach of new and the extension of old building types was more than what was thought possible in a very short time, as the use of reinforced concrete made it an indispensable basis of construction. Cast iron with concrete made possible the rotary motion of the Cling suspension bridge, which was built at the mouth of the Niagara River, the three largest dams, the construction of the Panama Canal, the method of the Kushtokei concrete road with its new bridges, new borers, and tunnels with access to the Lichtlorenbau, grain silos, the House of the Millionaire in America, the 'palace' in London, and many tall buildings in the world. Viewed in this way, it is really only one of the innumerable good epistemological significances of the World Exposition. The choice of the subject and the promotion of appropriate construction outstandingly contributed to improved living conditions. Today we can say: the engineers face a severe and arduous movement from casting in the rough to the so-called refined building. The third European architecture faced a similar order and drew from the methods to solve the resulting problems out of the art of the architect and the builder.

Skyscrapers and Modern High-Rise Buildings

Skyscrapers are a feature of urban landscapes from New York to Frankfurt. Technological advancements and a need for both efficient use of space and buildings to house a service-based economy drove the development of the skyscraper. The hallmark of a skyscraper is that it must be tall. The ability to build taller buildings was made possible by the development of a number of factors: the use of steel as a frame for a building in place of brick or stone bearing walls, the development of reinforced concrete, and, to aid in the construction of very tall buildings, fireproofing. Advancements in elevator technology, fire safety systems, and structural design have also contributed to the ability to construct the modern skyscraper. As skyscrapers were reliant on economic conditions and were economically risky to develop, the 'first skyscraper' is hard to pin down. Skyscraper development also took place in response to larger scale forces and trends within cities and society.

Skyscrapers and very tall buildings bear not only economic and technological considerations but also hold symbolic meaning. They are seen as icons and representatives of the cities they are a part of. Companies have made attempts to construct the world's tallest or most 'famous' building as a status symbol or to assert a certain image. Cities see skyscrapers as symbols of economic and urban progress, even when construction or financing of the building might be detrimental to its immediate neighbors. Today, society's views on how we build tall are changing. New towers are constructed with a nod to ecological and sustainable principles. Instead of looking at how to build up, they look at how building up will impact the city in 20, 50, or even 100 years. The next wave of extremely tall buildings examines how we can build efficiently and attractively in a sustainable, economically resilient way.

SUSTAINABLE AND GREEN CONSTRUCTION PRACTICES

Historically, construction has been primarily about providing shelter and meeting human functional needs. However, the state of the earth's ecosystem demands attention and has made people think about more sustainable and green alternatives in construction. Consequently, this chapter represents a paradigm shift toward the construction of the future and the various elements and entities affecting building sustainability. Several principles of sustainable construction guide the best practices, emphasizing the construction of energy-efficient, renewable-based, eco-friendly practices to minimize waste and maximize performance, productivity, and environmental quality of indoor and outdoor spaces. Additionally, this chapter incorporates the latest technological developments and innovations that define the future of the profession in the 21st century, including internet- and digitally-based technologies, computations, and renewable energy facilities, performance and monitoring systems, and more. These practices and services define the essence of the architecture and engineering profession as providers of functionally sound facilities that also consider environmental, social, and community factors.

The chapter presents more advanced and in-depth topics bulked into three major factions of sustainable design and construction (green materials, well-being, and indoor air quality), and sustainable systems technologies (heating, cooling, plumbing, lighting, and IT). The chapter suggests that a cradle-to-cradle economic and ecological system in which leftover waste becomes the resource of another industrial entity is destined to emerge on a global scale. This chapter defines sustainable and green building construction, examining conservation of energy—the driving force behind the building's operating systems as a main principle, and renewable materials that include both recyclables and reusables as the second construction design principle. When waste is created, it is our responsibility to minimize and dispose of it reasonably—for instance, using biodegradable materials—thus providing an answer to control and diminish waste. The chapter also discusses the concept of sustainable design and construction as a lifelong and continuous process in order to maintain functionality and quality. The chapter also reviews various materials health-based and environmental assessments as well as global practice certifications and standards for buildings. Finally, it presents a contemporary analysis of identified global environmental and social principles and recent technological advances in future-forward facilities development.

Principles of Sustainable Construction

The principles of sustainable construction encompass best practices in a greener, healthier, and more efficient building. With the growing interest in human health and the economy, the sustainable construction principles address the importance of recognizing the environment in engineering design, education, the economy, and community. Central to sustainable construction are sustainable energy and resource concepts. Currently, buildings use 40% of the energy and materials going into, and 40% of the waste emitted from, daily activities. Sustainable energy includes not only energy efficiency but also environmental justice to reduce waste.

Lifecycle assessment is a way to evaluate the environmental cost of a particular product, material, or building system during the entire time of ownership, from extraction to production to transportation and maintenance, including the energy and environmental costs of waste or demolition at the end of the material's life. Many sustainable buildings are made from sustainable materials, or materials that are considered environmentally friendly because of their carbon footprint or amount of recycled content. They can reduce air pollution, waste going into landfills, reduce chronic health problems, reduce the ill effects of using fossil fuels, and also improve energy conservation. When developing a collaborative process of involving community members and administrative leaders in the development of a sustainable project, it increases the buy-in and would likely result in lower implementation costs because the community would likely be investing into the project. There are many policies and incentives in place to help implement sustainable operations and reduce the impacts of climate change.

Green Building Materials and Technologies

A number of green building materials and technologies have evolved over the last few years in response to sustainable construction goals. In this paper, only the most promising, cost-effective, and reliable materials and technologies are discussed. In this context, green does not refer to a greenish color or material, as in ecological or natural material, nor does it mean a thing made out of plant or wood. Instead, it refers to either renewable and/or recyclable, resource-efficient, less harmful, more energy-efficient, or manufactured in ways that protect the health of workers as well as building occupants. Moreover, green may also mean durable and long-lasting, and thus sustainable. Green may also mean appropriate for contextual or ethical reasons, and fitting well in the community and landscape in terms of use and image. In summary, green building material means one that reduces or eliminates harmful environmental impact, reduces the use of non-renewable resources, and/or reduces the generation of waste. In figure 2 shows the Sustainable Construction methods and benefits.

Figure 2. Sustainable Construction: Methods and Benefits [13]

There are a number of green building materials on the market, which can be used to craft a home of your dreams. Some of them are engineered lumber, halogen and energy-efficient lighting, air-purifying drywall, cement alternatives, recycled construction waste, aerogel, straw bale, bamboo, cork, and wool carpeting, recycled glass tiles, sheep wool, and cellulose insulation. There are a number of modern techniques and materials available to increase the energy efficiency of a residential home or commercial building. Technologies like smart glass, which changes light transmission based on outside temperatures, high-performance window panels, and the use of photocopiers and solar panels to generate energy are some of the current techniques being employed to create more energy-efficient buildings. Moreover, sustainable design or green building are usually the terms that can be used interchangeably. Although in the practical context, green building does indeed refer to environmentally friendly construction, while sustainable design or sustainability involves environmental, economic, and social issues, especially in a larger or long-term developmental context. In this paper, the scope of the materials and technologies discussed will be confined to the green materials consisting of a variety of construction materials that reduce environmental impacts over the life cycle, thus saving resources, and are based on the reduced, recycled, and recyclable content of resources, such as timber, and modified wood products or composites of wood fibers; and on the reduced, reused, and recycled content of non-timber construction materials, particularly metals and plastics, for potentially beneficial construction applications. In this context, the green building technologies will be confined to the innovative materials, the new or modified construction materials. For instance, stone, cement concrete, mortar, grout, lightweight insulating concrete, fire-resistant or fireproof concrete, and color-impregnated or color-stained concrete. However, it will not include the new or innovative technologies that enhance the building or structural performance in a manner that does not necessarily reduce or minimize sustainability or redundancies, but may sometimes contradict the current trend in green building.

LEED Certification and Sustainable Design

Today, the built urban environment consumes 67.5% of the electricity and 48.1% of the water in the United States. Buildings located in the United States are responsible for 35% of CO2 emissions, 35% of electricity consumption, 15% of potable water consumption, and 40% of raw material use. In order to move towards more sustainable practices, a rating system has been created, which seeks to accommodate and classify various strategies to achieve higher performance and lower environmental impact.

LEED certification is a "green building" practice that incorporates strategies in energy efficiency, conservation of water, and sustainable site development. A LEED building can be suited for different sites, which encompass erosion and sedimentation controls, preferred parking for low-emission vehicles, multiple control zones, and various green roofs. Operational savings produced by LEED-certified buildings can offer occupants higher luminance from energy-saving fixtures and greater access to outdoor spaces such as terraces and courtyards. LEED criteria are focused on improving an integrated design process, innovative designs, energy performance, the use of recyclable materials, and the reduction of water use and light pollution. Green buildings are not only leveraged environmentally but also adopt pro-environmental behavior based on promoting environmental sustainability. Investment in new construction and major renovation has been shown to raise the value of the building and optimize the market. Rapid market changes are leading to consumer-driven expectations regarding environmental responsibility. LEED is a certification in the United States that has verified a recent tax status that demands governments to design and execute buildings greater than 5,600 m² in size to be LEED-certified.

DIGITAL TECHNOLOGIES AND BUILDING INFORMATION MODELING

The use of computers has expanded across almost all domains of society and industry, including the construction sector. Computer programs and applications have been developed and adapted to support engineers and architects in their century-long tradition of design, planning, and construction. New tools, as well as completely new methods, currently allow and are needed to make the engineering and construction of today’s architecture and infrastructure. This chapter gives an overview of these developments and research findings in the nexus of digital technologies in construction. It will present the variety of new computer-based methods that allow us to collaborate and model a project.

Digital Tools in Construction

The history of digital tools in construction dates back to the advent of mainframe computers. Researchers in architecture and engineering obtained access to mainframe computer labs and developed software. In 1960, for example, a system was developed that inspired further advancements. These systems were animated, interactive, and far more controlled than anything available today. Since the release of early systems as open source, they should be fully operating public domain systems by the time the reader holds this book. Research centers brought connected graphics to computers, which became commercially available in the 1960s at industry giants. The teaching of computer-aided design and manufacture in the 1980s was the subject of a special issue of a relevant journal. It is no longer acceptable to attempt to teach the sincerity, brilliance, and originality of these initiatives without attributing them to the right parties mentioned. In figure 3 displays the Impact of Digitisation and Digital Transformation Construction.

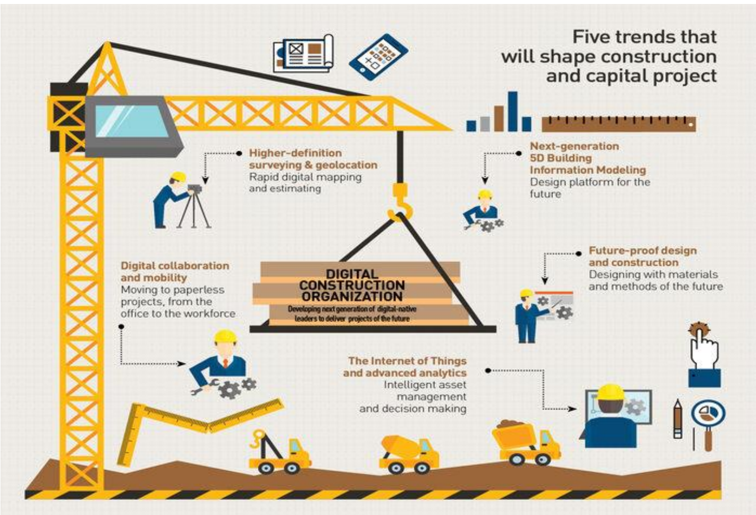

Figure 3. Impact of Digitisation and Digital Transformation Construction

Evolution of Digital Tools in Construction

Since the early days, digital tools have been applied in the architecture field. The first computer-aided design software was primarily used as drafting software, building abstract geometry, which was later printed, transferred to transparent media, and drawn with a pencil. Over time, our understanding of computer-aided design tools expanded to simulate complex geometry, the connectivity between design parameters, and the impact of design decisions. It became unusual to design using software that recreated physical construction. Design software slowly transitioned from being suitable only for describing geometry, structures, and systems, to incorporating simulation engines, broader design parameters, and even collaboration. Furthermore, the data inputted in one software, from a design perspective or a quantitative one, had the potential to be read into an array of other software packages. This ability of software to communicate with each other and potentially form a mesoscopic system was coupled with the term building information management.

BIM initially started as a social and communicative platform, allowing several design team professionals to correlate with each other to avoid spatial conflicts prior to construction. The first construction BIM software hardly comprised any analysis, apart from checking for clashes in terms of spatiality, and subsequently moved to include quantities and a broader aspect of design settings. We have now moved to a stage where software packages are able to provide a feasible view of the construction; display options by considering aesthetic value, cost, and energy efficiency; produce a series of construction drawings and design schedules; and in some cases, directly inform drones and 3D printers to get the building built. From a construction point of view, BIM is allowing several processes to be aggregated and distilled into software, thereby speeding up the construction process and reducing any redundant social interactions. The construction industry has shown multiple interests in technology ranging from building information management to drones. Optics are one example of an emerging technology, including virtual, mixed, and augmented reality. These technologies are reality emulators, simulating digital data into real life. They are applied in the construction field for simulating a project within a site as if a building or structure were already there. They allow contractors to visualize the interaction between the project and the surrounding environment. A well-planned approach to site construction is required, which will follow from improving the flow of the project construction, material deliveries, and results simulation. A vital step towards achieving sustainable construction using virtual reality is planning for the use of a building post-completion.

Building Information Modeling (BIM)

Building Information Modeling (BIM) is a prominently emerging construction technique that has only been used widely in the last 20 years. BIM is defined as a process for generating and managing digital representations of physical and functional characteristics of places, and it focuses particularly on buildings. BIM involves a digital description of every aspect of the facility; it draws upon information assembled in prior phases and adds value to building documentation. It can also facilitate insights into how a facility can be constructed and/or demolished, and by analyzing design and lifecycle concepts, it can direct an investment’s value and speed up the realization of that value. BIM goes beyond conventional CADD by leveraging digital solutions to streamline structure development workflows and facilitate the communication of technical designers. Collaboration and streamlined communication while employing a workflow system are two valuable outcomes of employing BIM. The architect, contractor, engineer, and specialist applications have been devised and applied for BIM in both small, medium, and large practices, and it has now moved to a process of international standardization. Robust BIM integration engages the major tools used by these professionals and allows direct interoperability of datasets in an electronic environment. Combined BIM leverages applications such as 3D computer-aided design tools and engineering analysis tools.

BIM enhances project visualization and improves coordination within a project at its beginning stage. It serves as a life or project cycle management facility responsible for gathering, managing, and disseminating asset lifecycle facts, commonly referred to as asset intelligence. Today, BIM tools can be used for computational sustainability assessments upon proposed building models. The software tools developed to facilitate this embedding of computational sustainability measurement into the building design are Computational BIM. Listings of the BIM software tools employed for the constructor's desired purpose in the construction industry indicate that the Learn Platform features 25 BIM software for construction projects. It includes various software tools. The market share of one of the BIM systems in 2021 was enormous, making it among the most popular BIM systems. In the USA, a significant percentage of the nation's largest architectural companies implementing BIM for design programs for new commercial design projects used this system in 2021. In 2016, a government agency signed a BIM Frame Agreement and deployed 3D BIM technology in several large design and construction projects.

CONCLUSION

In conclusion, all the eras presented are unique in themselves, and techniques developed throughout history contributed significantly to the development of the discipline of architecture. Ancient people explored techniques to work with stone, and Romans adapted effective load-bearing and encasing constructions that could be used in different climatic conditions. Developing structure-inspired architecture was the main advantage of Gothic architecture. At the time of the Renaissance, empirical expertise was replaced by theoretical knowledge in the study of construction, and further technological advancements in material production and construction nurtured the establishment of new materials and forms in construction. In addition, structural theories consequently affected the creative processes in architecture for later generations. Well-being and quality of life, with the help of engineering advancements, approached humanity. Massive towers and impressive spans that could not have been made without such centuries-long theoretical advancements were finally carried out. The spotlight in the 20th-century building processes has transformed to labor efficiency, being dependent upon the characteristics of the systems of production and planning. Moreover, the way of construction has adapted to society's desire through new materials and facilities.

Today's construction industry has laid an important foundation due to the variety of historical buildings, numerous technological achievements, and architectural reforms, and has a duty to protect each of them. The relationship between historical information and contemporary designing techniques has been demonstrated in a less accepted framework. Moreover, the understanding of the roots of engineering disciplines is now as essential as the epistemological background of the huge technological advances and accumulated scientific knowledge that promote today's building culture. Future works should focus on the technological innovation characterizing 21st-century construction. Hence, we suggest a detailed study of construction techniques and technologies associated with the canons in future research. The present technological process is linked to the significance of natural materials with regard to sustainability and energy dissipation resistance. Cultural reactions and habitat formulations are also envisaged in new construction standards for the spread of digital tools. By doing so, the visibility and respect for architectural contributions to the built environment are highlighted from the individual characteristics of technology. Since our environment itself is a scientific subject, it seems that everything is relative, even for frugal modernist processes that keep only the essential ones to live. All the ideas, specifications, and designs may preclude the desire for construction to be a holy refuge and dwelling house. Despite the need for evolution and variability, architecture was taken by time from one shape to the next, rebuilding a society to fall and to stay, to act and to consider new purposes in relation to the old. Even today, society is bringing a series of values of its heritage, which presents a textbook, which is opposite, so as to enable the alter bridge to be an arrow in the future rather than digging its own image of perfection and idealization in the past. Each age in the library of architectural thought leads to new intellectual capabilities that the coming age should not scorn. Architectural knowledge is also the sum of the intellect arrived at on the lands of the historic built spaces of time and place, a lesson that evokes the resonance of forgotten memories.

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