



# General Construction Concepts

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# Table of Contents

Chapter 1 - Construction Engineering and Architectural Engineering

Chapter 2 - Civil Engineering

Chapter 3 - Architecture

Chapter 4 - Building Code

Chapter 5 - Building Material

Chapter 6 - Construction Management

Chapter 7 - Fire Safety

Chapter 8 - Prefabricated Building

Chapter 9 - Others Construction Concepts

## Chapter- 1

# Construction Engineering and Architectural Engineering

## Construction engineering

**Construction engineering** concerns the planning and management of the construction of structures such as highways, bridges, airports, railroads, buildings, dams, and reservoirs. Construction of such projects requires knowledge of engineering and management principles and business procedures, economics, and human behavior. Construction engineers engage in the design of temporary structures, quality assurance and quality control, building and site layout surveys, on site material testing, concrete mix design, cost estimating, planning and scheduling, safety engineering, materials procurement, and cost engineering and budgeting.

## Career

The construction industry in the United States provides employment to millions with all types and levels of education. Construction contributes 14% of the United States Gross National Product. Construction engineering provides much of the design aspect used both in the construction office and in the field on project sites. To complete projects construction engineers rely on plans and specifications created by architects, engineers and other constructors. During most of the 20th century structures have been first designed then engineering staff ensure it is built to plans and specifications by testing and overseeing the construction. Prior to the 20th century and more commonly since the start of the 21st century structures are designed and built in combination allowing for site considerations and construction methods to influence the design process

## Work activities

Construction engineers have a wide range of work areas. Typically, entry level construction engineers analyze topographical information. Construction engineers also have to use computer software to design hydraulic systems and structures while following construction codes. Keeping a workplace safe is key to having a successful construction company. It is the construction engineer's job to make sure that everything is conducted correctly. In addition to safety, the construction engineer has to make sure that the site stays clean and sanitary. They have to make sure that there are no impediments in the

way of the structure's planned location and must move any that exist. Finally, more seasoned construction engineers will assume the role of project management on a construction site and are involved heavily with the construction schedule and document control as well as budget and cost control. Their role on site is to provide construction information, including repairs, requests for information, change orders and payment applications.

Construction engineers should have strong understanding for math and science, but many other skills are required, including critical thinking, listening, learning, problem solving, monitoring and decision making. Construction engineers have to be able to think about all aspects of a problem and listen to other's ideas so that they can learn everything about a project before it begins. During project construction they must solve the problems that they encounter using math and science. Construction engineers must maintain project control of labor and equipment for safety, to ensure the project is on schedule and monitor quality control. When a problem occurs it is the construction engineer who will create and enact a solution.

## **Abilities**

A construction engineer is really a combination of two different fields joined into one concentration. The engineer must be educated with the scientific background to be able to solve various problems and have the ability to have the skills to design and calculate different project. On the other side of the engineer's education is the ability to be able to manage different types of people in the work force. Traditional educations only focus on either the engineering side of the equation or the management side of the equation, but the construction engineering field combines both sides of the equation together, to better educate people to become more well rounded employees.

## **Educational requirements**

A typical construction engineering curriculum is a mixture of engineering mechanics, engineering design, construction management and general science and mathematics. This usually leads to a Bachelor of Science degree. The B.S. degree along with some construction experience is sufficient for most entry level construction engineering jobs. Graduate school may be an option for those who want to go further in depth of the construction and engineering subjects taught at the undergraduate level. In most cases construction engineering graduates look to either civil engineering, engineering management, or business administration as a possible graduate degree. For authority to approve any final designs of public projects (and most any project), a construction engineer must have a professional engineers (P.E.) license. To obtain a P.E. license the Fundamentals of Engineering exam and Principles and Practice in Engineering Exam must be passed and education and experience requirements met.

## **Job prospects**

Job prospects for construction engineers generally have a strong cyclical variation. For example, starting in 2008 - continuing until at least 2011 - job prospects have been poor due to the collapse of housing bubbles in many parts of the world. This sharply reduced demand for construction, and as a result, forced construction professionals towards infrastructure construction and therefore increased the competition faced by established and new construction engineers. This increased competition, and a core reduction in quantity demand is in parallel with a possible shift in the demand for construction engineers due to the automation of many engineering tasks, overall resulting in reduced prospects for construction engineers. In early 2010 the United States construction industry had a 27% unemployment rate, this is nearly three times higher than the 9.7% national average unemployment rate. The construction unemployment rate (including tradesmen) is comparable to the United States 1933 unemployment rate - the lowest point of the Great Depression - of 25%.

## Architectural engineering



César Pelli's Ratner Athletic Center uses cables, counterweights and masts as load-bearing devices.

**Architectural engineering**, also known as **Building engineering**, is the application of engineering principles and technology to building design and construction. Definitions of an **architectural engineer** may refer to:

- An engineer in the structural, mechanical, electrical, construction or other engineering fields of building design and construction.
- A licensed engineering professional in parts of the United States.

- In informal contexts, and formally in some places, a professional synonymous with or similar to an architect. In some languages, "architect" is literally translated as "architectural engineer".

## **Engineering for building**

### **Structural Engineering**

Structural engineering involves the analysis and design of physical objects such as buildings, bridges, equipment supports, towers and walls. Those concentrating on buildings are responsible for the structural performance of a large part of the built environment and are, sometimes, informally referred to as "building engineers". Structural engineers require expertise in strength of materials and in the seismic design of structures covered by earthquake engineering. Architectural Engineers sometimes practice structural as one aspect of their designs; the structural discipline when practiced as a specialty works closely with architects and other engineering specialists.

### **Mechanical, Electrical and Plumbing (MEP)**

Mechanical and electrical engineers are specialists, commonly referred to as "MEP" (mechanical, electrical and plumbing) when engaged in the building design fields. Also known as "Building services engineering" in the United Kingdom, Canada and Australia. Mechanical engineers design and oversee the heating ventilation and air conditioning (HVAC), plumbing, and rain gutter systems. Plumbing designers often include design specifications for simple active fire protection systems, but for more complicated projects, fire protection engineers are often separately retained. Electrical engineers are responsible for the building's power distribution, telecommunication, fire alarm, signalization, lightning protection and control systems, as well as lighting systems.

## **The Architectural engineer (PE) in the United States**

In many jurisdictions of the United States, the architectural engineer is a licensed engineering professional, usually a graduate of an architectural engineering university program preparing students to perform whole-building design in competition with architect-engineer teams; or for practice in one of structural, mechanical or electrical fields of building design, but with an appreciation of integrated architectural requirements.

Formal architectural engineering education, following the engineering model of earlier disciplines, developed in the late 19th century, and became widespread in the United States by the mid-20th century. With the establishment of a specific "architectural engineering" NCEES Professional Engineering registration examination in the 1990s, and first offering in April 2003, architectural engineering became recognized as a distinct engineering discipline in the United States. Architectural engineers are not entitled to practice architecture unless they are also licensed as architects.

# The Architect as Architectural Engineer

In some countries architecture, as a profession providing architectural services, is sometimes referred to as "architectural engineering". In others, such as in Japan, the terms "architecture" and "building engineering" are used synonymously. The practice of architecture includes the planning, designing and overseeing the building's construction.

In some languages, such as Korean and Arabic, "architect" is literally translated as "architectural engineer". In some countries, an "architectural engineer" (such as the *ingegnere edile* in Italy) is entitled to practice architecture and is often referred to as an architect. These individuals are often also structural engineers. In other countries, such as Germany, Austria and most of the Arabic countries, architecture graduates receive an engineering degree (*Dipl.-Ing. - Diplom-Ingenieur*).

In Brazil, architects and engineers currently share the same accreditation process (CREA - Regional Council of Engineers and Architects). Besides traditional architecture design training, Brazilian architecture courses also offer complementary training in engineering disciplines such as structural, electrical, hydraulic and mechanical engineering. After graduation, architects can be fully responsible for most engineering design and construction, except highly specialized tasks such as road design and high voltage electrical.

## Education

The architectural, structural, mechanical and electrical engineering branches each have well established educational requirements that are usually fulfilled by completion of a university program.

### **Architectural Engineering as a single integrated field of study**

What differentiates Architectural Engineering as a separate and single, integrated field of study, compared to other engineering disciplines, is its multi-disciplined engineering approach. Through training in and appreciation of architecture, the field seeks integration of building systems within its overall building design. Architectural Engineering includes the design of building systems including Heating, ventilation and air conditioning (HVAC), plumbing, fire protection, electrical, lighting, transportation, and structural systems. In some university programs, students are required to concentrate on one of the systems; in others, they can receive a generalist Architectural or Building Engineering degree.

## Chapter- 2

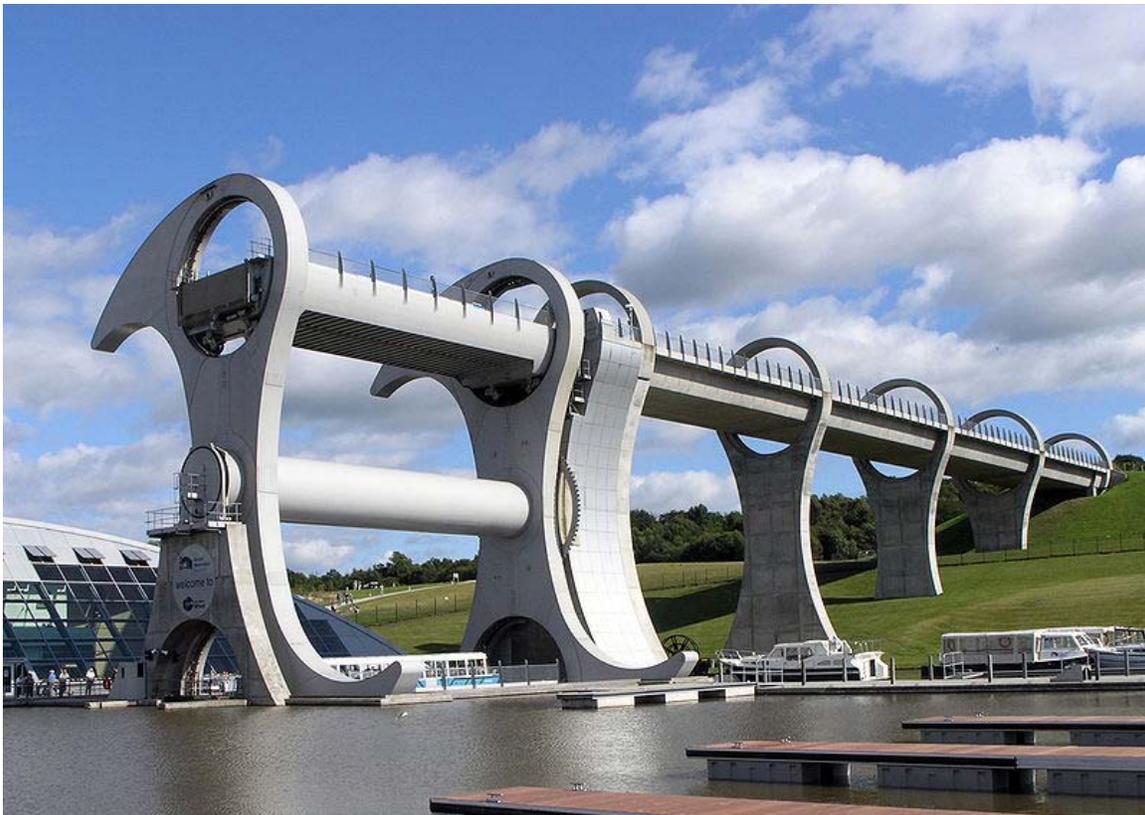
# Civil Engineering



The Petronas Twin Towers, designed by architect Cesar Pelli and Thornton-Tomasetti and Ranhill Bersekutu Sdn Bhd engineers, were the world's tallest buildings from 1998 to 2004.

**Civil engineering** is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like bridges, roads, canals, dams and buildings. Civil engineering is the oldest engineering discipline after military engineering, and it was defined to distinguish non-military engineering from military engineering. It is traditionally broken into several sub-disciplines including environmental engineering, geotechnical engineering, structural engineering, transportation engineering, municipal or urban engineering, water resources engineering, materials engineering, coastal engineering, surveying, and construction engineering. Civil engineering takes place on all levels: in the public sector from municipal through to federal levels, and in the private sector from individual homeowners through to international companies.

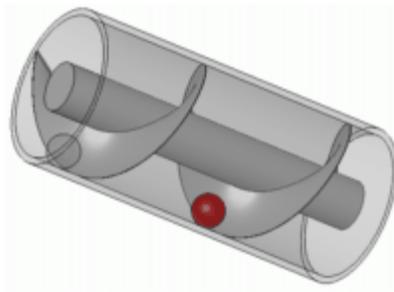
## History of the civil engineering profession



The Falkirk Wheel in Scotland

Engineering has been an aspect of life since the beginnings of human existence. The earliest practices of Civil engineering may have commenced between 4000 and 2000 BC in Ancient Egypt and Mesopotamia (Ancient Iraq) when humans started to abandon a nomadic existence, thus causing a need for the construction of shelter. During this time, transportation became increasingly important leading to the development of the wheel and sailing.

Until modern times there was no clear distinction between civil engineering and architecture, and the term engineer and architect were mainly geographical variations referring to the same person, often used interchangeably. The construction of Pyramids in Egypt (circa 2700-2500 BC) might be considered the first instances of large structure constructions. Other ancient historic civil engineering constructions include the Parthenon by Iktinos in Ancient Greece (447-438 BC), the Appian Way by Roman engineers (c. 312 BC), the Great Wall of China by General Meng T'ien under orders from Ch'in Emperor Shih Huang Ti (c. 220 BC) and the stupas constructed in ancient Sri Lanka like the Jetavanaramaya and the extensive irrigation works in Anuradhapura. The Romans developed civil structures throughout their empire, including especially aqueducts, insulae, harbours, bridges, dams and roads.



The Archimedes screw was operated by hand and could raise water efficiently.

In the 18th century, the term civil engineering was coined to incorporate all things civilian as opposed to military engineering. The first self-proclaimed civil engineer was John Smeaton who constructed the Eddystone Lighthouse. In 1771 Smeaton and some of his colleagues formed the Smeatonian Society of Civil Engineers, a group of leaders of the profession who met informally over dinner. Though there was evidence of some technical meetings, it was little more than a social society.

In 1818 the Institution of Civil Engineers was founded in London, and in 1820 the eminent engineer Thomas Telford became its first president. The institution received a Royal Charter in 1828, formally recognising civil engineering as a profession. Its charter defined civil engineering as:

the art of directing the great sources of power in nature for the use and convenience of man, as the means of production and of traffic in states, both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation and docks for internal intercourse and exchange, and in the construction of ports, harbours, moles, breakwaters and lighthouses, and in the art of navigation by artificial power for the purposes of commerce, and in the construction and application of machinery, and in the drainage of cities and towns.

The first private college to teach Civil Engineering in the United States was Norwich University founded in 1819 by Captain Alden Partridge. The first degree in Civil Engineering in the United States was awarded by Rensselaer Polytechnic Institute in

1835. The first such degree to be awarded to a woman was granted by Cornell University to Nora Stanton Blatch in 1905.

## History of civil engineering



Pont du Gard, France, a Roman aqueduct built circa 19 BC.

Civil engineering is the application of physical and scientific principles, and its history is intricately linked to advances in understanding of physics and mathematics throughout history. Because civil engineering is a wide ranging profession, including several separate specialized sub-disciplines, its history is linked to knowledge of structures, materials science, geography, geology, soils, hydrology, environment, mechanics and other fields.

Throughout ancient and medieval history most architectural design and construction was carried out by artisans, such as stone masons and carpenters, rising to the role of master builder. Knowledge was retained in guilds and seldom supplanted by advances. Structures, roads and infrastructure that existed were repetitive, and increases in scale were incremental.

One of the earliest examples of a scientific approach to physical and mathematical problems applicable to civil engineering is the work of Archimedes in the 3rd century BC, including Archimedes Principle, which underpins our understanding of buoyancy, and practical solutions such as Archimedes' screw. Brahmagupta, an Indian mathematician, used arithmetic in the 7th century AD, based on Hindu-Arabic numerals, for excavation (volume) computations.

## The civil engineer

### Education and licensure



The Institution of Civil Engineers headquarters in London

Civil engineers typically possess an academic degree with a major in civil engineering. The length of study for such a degree is usually three to five years and the completed degree is usually designated as a Bachelor of Engineering, though some universities designate the degree as a Bachelor of Science. The degree generally includes units covering physics, mathematics, project management, design and specific topics in civil engineering. Initially such topics cover most, if not all, of the sub-disciplines of civil engineering. Students then choose to specialize in one or more sub-disciplines towards the end of the degree. While an Undergraduate (BEng/BSc) Degree will normally provide

successful students with industry accredited qualification, some universities offer postgraduate engineering awards (MEng/MSc) which allow students to further specialize in their particular area of interest within engineering.

In most countries, a Bachelor's degree in engineering represents the first step towards professional certification and the degree program itself is certified by a professional body. After completing a certified degree program the engineer must satisfy a range of requirements (including work experience and exam requirements) before being certified. Once certified, the engineer is designated the title of Professional Engineer (in the United States, Canada and South Africa), Chartered Engineer (in most Commonwealth countries), Chartered Professional Engineer (in Australia and New Zealand), or European Engineer (in much of the European Union). There are international engineering agreements between relevant professional bodies which are designed to allow engineers to practice across international borders.

The advantages of certification vary depending upon location. For example, in the United States and Canada "only a licensed engineer may prepare, sign and seal, and submit engineering plans and drawings to a public authority for approval, or seal engineering work for public and private clients." This requirement is enforced by state and provincial legislation such as Quebec's Engineers Act. In other countries, no such legislation exists. In Australia, state licensing of engineers is limited to the state of Queensland. Practically all certifying bodies maintain a code of ethics that they expect all members to abide by or risk expulsion. In this way, these organizations play an important role in maintaining ethical standards for the profession. Even in jurisdictions where certification has little or no legal bearing on work, engineers are subject to contract law. In cases where an engineer's work fails he or she may be subject to the tort of negligence and, in extreme cases, the charge of criminal negligence. An engineer's work must also comply with numerous other rules and regulations such as building codes and legislation pertaining to environmental law.

## **Careers**

There is no one typical career path for civil engineers. Most people who graduate with civil engineering degrees start with jobs that require a low level of responsibility, and as the new engineers prove their competence, they are trusted with tasks that have larger consequences and require a higher level of responsibility. However, within each branch of civil engineering career path options vary. In some fields and firms, entry-level engineers are put to work primarily monitoring construction in the field, serving as the "eyes and ears" of senior design engineers; while in other areas, entry-level engineers perform the more routine tasks of analysis or design and interpretation. Experienced engineers generally do more complex analysis or design work, or management of more complex design projects, or management of other engineers, or into specialized consulting, including forensic engineering.

## Sub-disciplines

In general, civil engineering is concerned with the overall interface of human created fixed projects with the greater world. General civil engineers work closely with surveyors and specialized civil engineers to fit and serve fixed projects within their given site, community and terrain by designing grading, drainage, pavement, water supply, sewer service, electric and communications supply, and land divisions. General engineers spend much of their time visiting project sites, developing community consensus, and preparing construction plans. General civil engineering is also referred to as site engineering, a branch of civil engineering that primarily focuses on converting a tract of land from one usage to another. Civil engineers typically apply the principles of geotechnical engineering, structural engineering, environmental engineering, transportation engineering and construction engineering to residential, commercial, industrial and public works projects of all sizes and levels of construction.

### Coastal engineering

Coastal engineering is concerned with managing coastal areas. In some jurisdictions the terms sea defense and coastal protection are used to mean, respectively, defence against flooding and erosion. The term coastal defence is the more traditional term, but coastal management has become more popular as the field has expanded to include techniques that allow erosion to claim land.



Building construction for several apartment blocks

## **Construction engineering**

Construction engineering involves planning and execution of the designs from transportation, site development, hydraulic, environmental, structural and geotechnical engineers. As construction firms tend to have higher business risk than other types of civil engineering firms, many construction engineers tend to take on a role that is more business-like in nature: drafting and reviewing contracts, evaluating logistical operations, and closely-monitoring prices of necessary supplies.

## **Earthquake engineering**

Earthquake engineering covers ability of various structures to withstand hazardous earthquake exposures at the sites of their particular location.



Earthquake-proof and massive pyramid El Castillo, Chichen Itza

Earthquake engineering is a sub discipline of the broader category of Structural engineering. The main objectives of earthquake engineering are:



Testing base-isolated (right) and regular (left) building model

- Understand interaction of structures with the shaky ground.
- Foresee the consequences of possible earthquakes.
- Design, construct and maintain structures to perform at earthquake exposure up to the expectations and in compliance with building codes.

## Environmental engineering



A filter bed, a part of sewage treatment

Environmental engineering deals with the treatment of chemical, biological, and/or thermal waste, the purification of water and air, and the remediation of contaminated sites, due to prior waste disposal or accidental contamination. Among the topics covered by environmental engineering are pollutant transport, water purification, waste water treatment, air pollution, solid waste treatment and hazardous waste management. Environmental engineers can be involved with pollution reduction, green engineering, and industrial ecology. Environmental engineering also deals with the gathering of information on the environmental consequences of proposed actions and the assessment of effects of proposed actions for the purpose of assisting society and policy makers in the decision making process.

Environmental engineering is the contemporary term for sanitary engineering, though sanitary engineering traditionally had not included much of the hazardous waste management and environmental remediation work covered by the term *environmental engineering*. Some other terms in use are public health engineering and environmental health engineering.

## Geotechnical engineering



Construction of an Embankment Dam in Navarra, Spain

Geotechnical engineering is an area of civil engineering concerned with the rock and soil that civil engineering systems are supported by. Knowledge from the fields of geology, material science and testing, mechanics, and hydraulics are applied by geotechnical engineers to safely and economically design foundations, retaining walls, and similar structures. Environmental concerns in relation to groundwater and waste disposal have spawned a new area of study called geoenvironmental engineering where biology and chemistry are important.

Some of the unique difficulties of geotechnical engineering are the result of the variability and properties of soil. Boundary conditions are often well defined in other branches of civil engineering, but with soil, clearly defining these conditions can be impossible. The material properties and behavior of soil are also difficult to predict due to the variability of soil and limited investigation. This contrasts with the relatively well defined material properties of steel and concrete used in other areas of civil engineering. Soil mechanics, which describes the behavior of soil, is also complicated because soils exhibit nonlinear (stress-dependent) strength, stiffness, and dilatancy (volume change associated with application of shear stress).

## **Water resources engineering**



Hoover dam

Water resources engineering is concerned with the collection and management of water (as a natural resource). As a discipline it therefore combines hydrology, environmental science, meteorology, geology, conservation, and resource management. This area of civil engineering relates to the prediction and management of both the quality and the quantity of water in both underground (aquifers) and above ground (lakes, rivers, and streams) resources. Water resource engineers analyze and model very small to very large areas of the earth to predict the amount and content of water as it flows into, through, or out of a facility. Although the actual design of the facility may be left to other engineers.

Hydraulic engineering is concerned with the flow and conveyance of fluids, principally water. This area of civil engineering is intimately related to the design of pipelines, water supply network, drainage facilities (including bridges, dams, channels, culverts, levees, storm sewers), and canals. Hydraulic engineers design these facilities using the concepts of fluid pressure, fluid statics, fluid dynamics, and hydraulics, among others.

### **Materials engineering**

Another aspect of Civil engineering is materials science. Material engineering deals with ceramics such as concrete, mix asphalt concrete, metals Focus around increased strength, metals such as aluminum and steel, and polymers such as polymethylmethacrylate (PMMA) and carbon fibers.

Materials engineering also consists of protection and prevention like paints and finishes. Alloying is another aspect of material engineering, combining two different types of metals to produce a stronger metal.

## Structural engineering



Burj Khalifa, the world's tallest building, in Dubai



Clifton Suspension Bridge, designed by Isambard Kingdom Brunel, in Bristol, UK

Structural engineering is concerned with the structural design and structural analysis of buildings, bridges, towers, flyovers, tunnels, off shore structures like oil and gas fields in the sea, and other structures. This involves identifying the loads which act upon a structure and the forces and stresses which arise within that structure due to those loads, and then designing the structure to successfully support and resist those loads. The loads can be self weight of the structures, other dead load, live loads, moving (wheel) load, wind load, earthquake load, load from temperature change etc. The structural engineer must design structures to be safe for their users and to successfully fulfill the function they are designed for (to be *serviceable*). Due to the nature of some loading conditions, sub-disciplines within structural engineering have emerged, including wind engineering and earthquake engineering.

Design considerations will include strength, stiffness, and stability of the structure when subjected to loads which may be static, such as furniture or self-weight, or dynamic, such as wind, seismic, crowd or vehicle loads, or transitory, such as temporary construction loads or impact. Other considerations include cost, constructability, safety, aesthetics and sustainability.

## Surveying



US Navy Surveyor at work with a leveling instrument.

Surveying is the process by which a surveyor measures certain dimensions that generally occur on the surface of the Earth. Surveying equipment, such as levels and theodolites, are used for accurate measurement of angular deviation, horizontal, vertical and slope distances. With computerisation, electronic distance measurement (EDM), total stations, GPS surveying and laser scanning have supplemented (and to a large extent supplanted) the traditional optical instruments. This information is crucial to convert the data into a graphical representation of the Earth's surface, in the form of a map. This information is then used by civil engineers, contractors and even realtors to design from, build on, and trade, respectively. Elements of a building or structure must be correctly sized and positioned in relation to each other and to site boundaries and adjacent structures. Although surveying is a distinct profession with separate qualifications and licensing arrangements, civil engineers are trained in the basics of surveying and mapping, as well as geographic information systems. Surveyors may also lay out the routes of railways, tramway tracks, highways, roads, pipelines and streets as well as position other infrastructures, such as harbors, before construction.

### Land Surveying

In the United States, Canada, the United Kingdom and most Commonwealth countries land surveying is considered to be a distinct profession. Land surveyors are not considered to be engineers, and have their own professional associations and licencing requirements. The services of a licenced land surveyor are generally required for boundary surveys (to establish the boundaries of a parcel using its legal description) and

subdivision plans (a plot or map based on a survey of a parcel of land, with boundary lines drawn inside the larger parcel to indicated the creation of new boundary lines and roads), both of which are generally referred to as cadastral surveying.

### **Construction Surveying**

Construction surveying is generally performed by specialised technicians. Unlike land surveyors, the resulting plan does not have legal status. Construction surveyors perform the following tasks:

- Survey existing conditions of the future work site, including topography, existing buildings and infrastructure, and even including underground infrastructure whenever possible;
- Construction surveying (otherwise "lay-out" or "setting-out"): to stake out reference points and markers that will guide the construction of new structures such as roads or buildings for subsequent construction;
- Verify the location of structures during construction;
- As-Built surveying: a survey conducted at the end of the construction project to verify that the work authorized was completed to the specifications set on plans.

### **Transportation engineering**

Transportation engineering is concerned with moving people and goods efficiently, safely, and in a manner conducive to a vibrant community. This involves specifying, designing, constructing, and maintaining transportation infrastructure which includes streets, canals, highways, rail systems, airports, ports, and mass transit. It includes areas such as transportation design, transportation planning, traffic engineering, some aspects of urban engineering, queueing theory, pavement engineering, Intelligent Transportation System (ITS), and infrastructure management.

### **Municipal or urban engineering**

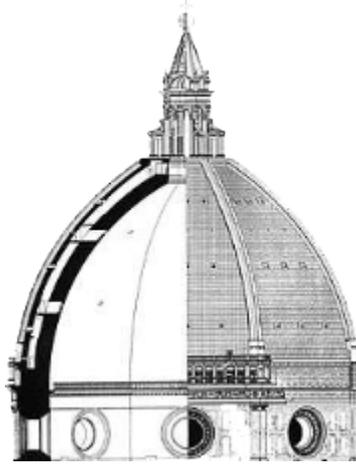
Municipal engineering is concerned with municipal infrastructure. This involves specifying, designing, constructing, and maintaining streets, sidewalks, water supply networks, sewers, street lighting, municipal solid waste management and disposal, storage depots for various bulk materials used for maintenance and public works (salt, sand, etc.), public parks and bicycle paths. In the case of underground utility networks, it may also include the civil portion (conduits and access chambers) of the local distribution networks of electrical and telecommunications services. It can also include the optimizing of waste collection and bus service networks. Some of these disciplines overlap with other civil engineering specialties, however municipal engineering focuses on the coordination of these infrastructure networks and services, as they are often built simultaneously, and managed by the same municipal authority.

## Chapter- 3

# Architecture



Brunelleschi, in the building of the dome of Florence Cathedral, not only transformed the cathedral and the city of Florence, but also the role and status of the architect.



Section and elevation of Brunelleschi's dome

**Architecture** (Latin *architectura*, from the Greek ἀρχιτέκτων – arkhitekton, from ἀρχι- "chief" and τέκτων "builder, carpenter") can mean:

- The art and science of designing and erecting buildings and other physical structures.
- The practice of an architect, where architecture means to offer or render professional services in connection with the design and construction of a building, or group of buildings and the space within the site surrounding the buildings, that have as their principal purpose human occupancy or use.
- A general term to describe buildings and other structures.
- A style and method of design and construction of buildings and other physical structures.

A wider definition may comprise all design activity, from the macro-level (urban design, landscape architecture) to the micro-level (construction details and furniture). Architecture is both the process and product of planning, designing and constructing form, space and ambience that reflect functional, technical, social, and aesthetic considerations. It requires the creative manipulation and coordination of material, technology, light and shadow. Architecture also encompasses the pragmatic aspects of realizing buildings and structures, including scheduling, cost estimating and construction administration. As documentation produced by architects, typically drawings, plans and technical specifications, architecture defines the structure and/or behavior of a building or any other kind of system that is to be or has been constructed.

Architectural works are often perceived as cultural and political symbols and as works of art. Historical civilizations are often identified with their surviving architectural achievements.

Architecture sometimes refers to the activity of designing any kind of system and the term is common in the information technology world.

## The architect

Architects plan, design and review the construction of buildings and structures for the use of people. Architects also coordinate and integrate engineering design, which has as its primary objective the creative manipulation of materials and forms using mathematical and scientific principles.

## Theory of architecture

### Historic treatises



The Parthenon, Athens, Greece, "the supreme example among architectural sites." (Fletcher).

The earliest surviving written work on the subject of architecture is *De architectura*, by the Roman architect Vitruvius in the early 1st century CE. According to Vitruvius, a good building should satisfy the three principles of *firmitas*, *utilitas*, *venustas*, which translate roughly as -

- Durability - it should stand up robustly and remain in good condition.
- Utility - it should be useful and function well for the people using it
- Beauty - it should delight people and raise their spirits.

According to Vitruvius, the architect should strive to fulfill each of these three attributes as well as possible. Leone Battista Alberti, who elaborates on the ideas of Vitruvius in his treatise, *De Re Aedificatoria*, saw beauty primarily as a matter of proportion, although ornament also played a part. For Alberti, the rules of proportion were those that governed

the idealised human figure, the Golden mean. The most important aspect of beauty was therefore an inherent part of an object, rather than something applied superficially; and was based on universal, recognisable truths. The notion of style in the arts was not developed until the 16th century, with the writing of Vasari. The treatises, by the 18th century, had been translated into Italian, French, Spanish and English.



Unite d'Habitation by Le Corbusier at Briey, France

In the early nineteenth century, Augustus Welby Northmore Pugin wrote *Contrasts* (1836) that, as the titled suggested, contrasted the modern, industrial world, which he disparaged, with an idealized image of neo-medieval world. Gothic architecture, Pugin believed, was the only “true Christian form of architecture.”

The 19th century English art critic, John Ruskin, in his *Seven Lamps of Architecture*, published 1849, was much narrower in his view of what constituted architecture. Architecture was the "art which so disposes and adorns the edifices raised by men ... that the sight of them" contributes "to his mental health, power, and pleasure".

For Ruskin, the aesthetic was of overriding significance. His work goes on to state that a building is not truly a work of architecture unless it is in some way "adorned". For Ruskin, a well-constructed, well-proportioned, functional building needed string courses or rustication, at the very least.

On the difference between the ideals of "architecture" and mere "construction", the renowned 20th C. architect Le Corbusier wrote: "You employ stone, wood, and concrete, and with these materials you build houses and palaces: that is construction. Ingenuity is at

work. But suddenly you touch my heart, you do me good. I am happy and I say: This is beautiful. That is Architecture".



The National Congress of Brazil, designed by Oscar Niemeyer.

## **Modern concepts of architecture**

The great 19th century architect of skyscrapers, Louis Sullivan, promoted an overriding precept to architectural design: "Form follows function".

While the notion that structural and aesthetic considerations should be entirely subject to functionality was met with both popularity and skepticism, it had the effect of introducing the concept of "function" in place of Vitruvius' "utility". "Function" came to be seen as encompassing all criteria of the use, perception and enjoyment of a building, not only practical but also aesthetic, psychological and cultural.



Sydney Opera House, Australia designed by Utzon.

Nunzia Rondanini stated, "Through its aesthetic dimension architecture goes beyond the functional aspects that it has in common with other human sciences. Through its own particular way of expressing values, architecture can stimulate and influence social life without presuming that, in and of itself, it will promote social development."

To restrict the meaning of (architectural) formalism to art for art's sake is not only reactionary; it can also be a purposeless quest for perfection or originality which degrades form into a mere instrumentality".

Among the philosophies that have influenced modern architects and their approach to building design are rationalism, empiricism, structuralism, poststructuralism, and phenomenology.

In the late 20th century a new concept was added to those included in the compass of both structure and function, the consideration of sustainability. To satisfy the contemporary ethos a building should be constructed in a manner which is environmentally friendly in terms of the production of its materials, its impact upon the natural and built environment of its surrounding area and the demands that it makes upon non-sustainable power sources for heating, cooling, water and waste management and lighting.

# History



Vernacular architecture in Denmark.

## Origins and vernacular architecture

Building first evolved out of the dynamics between needs (shelter, security, worship, etc.) and means (available building materials and attendant skills). As human cultures developed and knowledge began to be formalized through oral traditions and practices, building became a craft, and "architecture" is the name given to the most highly formalized and respected versions of that craft.

It is widely assumed that architectural success was the product of a process of trial and error, with progressively less trial and more replication as the results of the process proved increasingly satisfactory. What is termed vernacular architecture continues to be produced in many parts of the world. Indeed, vernacular buildings make up most of the built world that people experience every day. Early human settlements were mostly rural. Due to a surplus in production the economy began to expand resulting in urbanization thus creating urban areas which grew and evolved very rapidly in some cases, such as that of Çatal Höyük in Anatolia and Mohenjo Daro in the Indian subcontinent (now modern-day Pakistan).



The Pyramids at Gizah

### **Ancient architecture**

In many ancient civilizations, such as the Egyptians' and Mesopotamians', architecture and urbanism reflected the constant engagement with the divine and the supernatural, and many ancient cultures resorted to monumentality in architecture to represent symbolically the political power of the ruler, the ruling elite, or the state itself.

The architecture and urbanism of the Classical civilizations such as the Greek and the Roman evolved from civic ideals rather than religious or empirical ones and new building types emerged. Architectural styles developed.

Texts on architecture have been written since ancient time. These texts provided both general advice and specific formal prescriptions or canons. Some examples of canons are found in the writings of the 1st-century BCE Roman military engineer Vitruvius, the *Kao Gong Ji* of ancient China and Vaastu Shastra of ancient India and Manjusri Vasthu Vidya Sastra of Sri Lanka. Some of the most important early examples of canonic architecture are religious.



Kinkaku, (Golden Pavilion), Kyoto, Japan

### **Asian architecture**

The architecture of different parts of Asia developed along different lines from that of Europe; Buddhist, Hindu and Sikh architecture each having different characteristics. Buddhist architecture, in particular, showed great regional diversity. In many Asian countries a pantheistic religion led to architectural forms that were designed specifically to enhance the natural landscape.



The Taj Mahal (1632-1653), in India

### **Islamic architecture**

Islamic architecture began in the 7th century CE, developing from a blend of architectural forms from the ancient Middle East and from Byzantium but also developing features to suit the religious and social needs of the society. Examples can be found throughout the Middle East, North Africa and Spain, and were to become a significant stylistic influence on European architecture during the Medieval period.

## The medieval builder



Notre Dame de Paris, France

In Europe, in both the Classical and Medieval periods, buildings were not attributed to specific individuals and the names of the architects frequently unknown, despite the vast scale of the many religious buildings extant from this period.

During the Medieval period guilds were formed by craftsmen to organize their trade and written contracts have survived, particularly in relation to ecclesiastical buildings. The role of architect was usually one with that of master mason, or *Magister lathomorum* as they are sometimes described in contemporary documents.



*La Rotonda* (1567), Italy by Palladio

### **Renaissance and the architect**

With the Renaissance and its emphasis on the individual and humanity rather than religion, and with all its attendant progress and achievements, a new chapter began. Buildings were ascribed to specific architects - Brunelleschi, Alberti, Michelangelo, Palladio - and the cult of the individual had begun.

There was still no dividing line between artist, architect and engineer, or any of the related vocations, and the appellation was often one of regional preference. At this stage, it was still possible for an artist to design a bridge as the level of structural calculations involved was within the scope of the generalist.

## Early modern and the industrial age



Paris Opera by Charles Garnier (1862), France

With the emerging knowledge in scientific fields and the rise of new materials and technology, architecture and engineering began to separate, and the architect began to concentrate on aesthetics and the humanist aspects, often at the expense of technical aspects of building design. There was also the rise of the "gentleman architect" who usually dealt with wealthy clients and concentrated predominantly on visual qualities derived usually from historical prototypes, typified by the many country houses of Great Britain that were created in the Neo Gothic or Scottish Baronial styles. Formal architectural training in the 19th century, for example at Ecole des Beaux Arts in France, gave much emphasis to the production of beautiful drawings and little to context and feasibility. Effective architects generally received their training in the offices of other architects, graduating to the role from draughtsmen or clerks.

Meanwhile, the Industrial Revolution laid open the door for mass production and consumption. Aesthetics became a criterion for the middle class as ornamented products, once within the province of expensive craftsmanship, became cheaper under machine production.

Vernacular architecture became increasingly ornamental. House builders could use current architectural design in their work by combining features found in pattern books and architectural journals.

## **Modernism and reaction of architecture**



The Bauhaus Dessau architecture department from 1925 by Walter Gropius

The dissatisfaction with such a general situation at the turn of the twentieth century gave rise to many new lines of thought that served as precursors to Modern Architecture. Notable among these is the Deutscher Werkbund, formed in 1907 to produce better quality machine made objects. The rise of the profession of industrial design is usually placed here. Following this lead, the Bauhaus school, founded in Weimar, Germany in 1919, redefined the architectural bounds prior set throughout history, viewing the creation of a building as the ultimate synthesis—the apex—of art, craft, and technology.

Other architects such as Frank Lloyd Wright developed Organic architecture in which the form was defined by its environment and purpose, with an aim to promote harmony between human habitation and the natural world.



*Fallingwater*, Organic architecture by Frank Lloyd Wright.

When Modern architecture was first practiced, it was an avant-garde movement with moral, philosophical, and aesthetic underpinnings. Immediately after World War I, pioneering modernist architects sought to develop a completely new style appropriate for a new post-war social and economic order, focused on meeting the needs of the middle and working classes. They rejected the architectural practice of the academic refinement of historical styles which served the rapidly declining aristocratic order. The approach of the Modernist architects was to reduce buildings to pure forms, removing historical references and ornament in favor of functionalist details. Buildings displayed their functional and structural elements, exposing steel beams and concrete surfaces instead of hiding them behind decorative forms.



The Crystal Cathedral, California, by Philip Johnson,(1980)

Architects such as Mies van der Rohe, Philip Johnson and Marcel Breuer worked to create beauty based on the inherent qualities of building materials and modern construction techniques, trading traditional historic forms for simplified geometric forms, celebrating the new means and methods made possible by the Industrial Revolution, including steel-frame construction, which gave birth to high-rise superstructures. By mid-century, Modernism had morphed into the International Style, an aesthetic epitomized in many ways by the Twin Towers of New York's World Trade Center.

Many architects resisted Modernism, finding it devoid of the decorative richness of ornamented styles. Yet as the founders of that movement lost influence in the late 1970s, Postmodernism developed as a reaction against the austerity of Modernism. Robert Venturi's contention that a "decorated shed" (an ordinary building which is functionally designed inside and embellished on the outside) was better than a "duck" (a building in which the whole form and its function are tied together) gives an idea of this approach.

## Architecture today



Postmodern design at Gare do Oriente, Lisbon, Portugal, by Santiago Calatrava.

Part of the architectural profession, and also some non-architects, responded to Modernism and Postmodernism by going to what they considered the root of the problem. They felt that architecture was not a personal philosophical or aesthetic pursuit by individualists; rather it had to consider everyday needs of people and use technology to give a livable environment.

The *Design Methodology Movement* involving people such as Christopher Alexander started searching for more people-oriented designs. Extensive studies on areas such as behavioral, environmental, and social sciences were done and started informing the design process. As the complexity of buildings began to increase (in terms of structural systems, services, energy and technologies), architecture started becoming more multi-disciplinary. Architecture today usually requires a team of specialist professionals, with the architect being one of many, although usually the team leader.



Green roof planted with native species at L'Historial de la Vendée, a new museum in western France

During the last two decades of the twentieth century and into the new millennium, the field of architecture saw the rise of specializations by project type, technological expertise or project delivery methods. In addition, there has been an increased separation of the 'design' architect from the 'project' architect. Moving the issues of environmental sustainability into the mainstream is a significant development in the architecture profession. Sustainability in architecture was pioneered in the 1960s by architects such as Sim Van der Ryn, in the 1970s Ian McHarg in the US and Brenda and Robert Vale in the UK and New Zealand. There has been an acceleration in the number of buildings which seek to meet green building sustainable design principles. Sustainable practices that were at the core of vernacular architecture increasingly provide inspiration for environmentally and socially sustainable contemporary techniques. The U.S. Green Building Council's LEED (Leadership in Energy and Environmental Design) rating system has been instrumental in this. An example of an architecturally innovative green building is the Dynamic Tower which will be powered by wind turbines and solar panels.

## Chapter- 4

# Building Code



Code Violation: This concrete block wall is penetrated by cable trays and cables. The hole should be firestopped to restore the fire-resistance rating of the wall. Instead, it is filled with flammable polyurethane foam.

A **building code**, or **building control**, is a set of rules that specify the minimum acceptable level of safety for constructed objects such as buildings and nonbuilding structures. The main purpose of building codes are to protect public health, safety and general welfare as they relate to the construction and occupancy of buildings and structures. The building code becomes law of a particular jurisdiction when formally enacted by the appropriate authority.

Building codes are generally intended to be applied by architects and engineers although this is not the case in the UK where Building Control Surveyors act as verifiers both in the public and private sector (Approved Inspectors), but are also used for various

purposes by safety inspectors, environmental scientists, real estate developers, contractors and subcontractors, manufacturers of building products and materials, insurance companies, facility managers, tenants, and others.

There are often additional codes or sections of the same building code that have more specific requirements that apply to dwellings and special construction objects such as canopies, signs, pedestrian walkways, parking lots, and radio and television antennas.

## Types of building codes



"Sutyagin's skyscraper" (Небоскрёб Сутягина) - supposedly world's tallest wooden single-family house - found to be in violation of fire codes by the city of Arkhangelsk, Russia, and was demolished.

The practice of developing, approving, and enforcing building codes varies considerably among nations. In some countries building codes are developed by the government agencies or quasi-governmental standards organizations and then enforced across the country by the central government. Such codes are known as the **national building codes** (in a sense they enjoy a mandatory nation-wide application).

In other countries, where the power of regulating construction and fire safety is vested in local authorities, a system of model building codes is used. Model building codes have no legal status unless adopted or adapted by an authority having jurisdiction. The developers of model codes urge public authorities to reference model codes in their laws, ordinances, regulations, and administrative orders. When referenced in any of these legal instruments, a particular model code becomes law. This practice is known as *adoption by reference*. When an adopting authority decides to delete, add, or revise any portions of the model code adopted, it is usually required by the model code developer to follow a formal adoption procedure in which those modifications can be documented for legal purposes.

There are instances when some local jurisdictions choose to develop their own building codes. At some point in time all major cities in the United States had their own building codes. However due to ever increasing complexity and cost of developing building regulations, virtually all municipalities in the country have chosen to adopt model codes instead. For example, in 2008 New York City abandoned its proprietary *1968 New York City Building Code* in favor of a customized version of the International Building Code. The City of Chicago remains the only municipality in America that continues to use a building code the city developed on its own as part of the *Municipal Code of Chicago*.

Similarly, in India, each municipality and urban development authority has its own building code, which is mandatory for all construction within their jurisdiction. All these local building codes are variants of a National Building Code, which serves as model code providing guidelines for regulating building construction activity.

## Scope

Building codes generally include:

- Rules regarding parking and traffic impact
- Fire code rules to ensure safe evacuation in the event of a fire
- Requirements for earthquake, hurricane, tornado, flood, and tsunami resistance, especially in disaster prone areas or for very large buildings where a failure would be catastrophic
- Drainage, green space, and fence-building rules
- Requirements for specific building uses (for example, storage of flammable substances, or housing a large number of people)
- Energy provisions and consumption
- Grandfathering provisions: Unless the building is being renovated, the building code usually does not apply to existing buildings.
- Specifications on components

- Allowable installation methodologies
- Minimum and maximum room and exit sizes and location
- Qualification of individuals or corporations doing the work
- For high structures, anti-collision markers for the benefit of aircraft

Building codes are generally separate from zoning ordinances, but exterior restrictions (such as setbacks) may fall into either category.

## **Prescriptive vs. performance**

These requirements are usually a combination of prescriptive requirements that spell out exactly how something is to be done, and performance requirements which just outline what the required level of performance is and leave it up to the designer how this is achieved. Historically they are very reactive in that when a problem occurs the building codes change to ensure that the problem never happens again. In recent years there has been a move amongst most of the building codes to move to more performance requirements and less prescriptive requirements.

Traditionally building codes were generally short non complex interrelated sets of rules. They generally included reference to hundreds of other codes, standards and guidelines that specify the details of the component or system design, specify testing requirements for components, or outline good engineering practice. These detailed codes required a great deal of specialization to interpret, and also greatly constrained change and innovation in building design. In recent years several countries, beginning with Australia, have moved to much shorter objective based buildings codes. Rather than prescribing specific details, objective codes lists a series of objectives all buildings must meet while leaving open how these objectives will be met. When applying for a building permit the designers must demonstrate how they meet each objective.

## **History**

### **Antiquity**

Building codes have a long history. What is generally accepted as the first building code was in the Code of Hammurabi which specified:

- 229. If a builder builds a house for someone, and does not construct it properly, and the house which he built falls in and kills its owner, then that builder shall be put to death.
- 230. If it kills the son of the owner, the son of that builder shall be put to death.
- 231. If it kills a slave of the owner, then he shall pay, slave for slave, to the owner of the house.
- 232. If it ruins goods, he shall make compensation for all that has been ruined, and inasmuch as he did not construct properly this house which he built and it fell, he shall re-erect the house from his own means.

- 233. If a builder builds a house for someone, even though he has not yet completed it; if then the walls seem toppling, the builder must make the walls solid from his own means.

The Law of Moses stipulated a specific construction requirement which is also an early form of a building code. The Bible book of Deuteronomy, chapter 22 verse 8, states:

- "In case you build a new house, you must also make a parapet for your roof, that you may not place bloodguilt upon your house because someone falling might fall from it."

## **Nineteenth-century building laws**

The great changes in societies in Europe, the Industrial Revolution, the end of slavery in the United States, and immigration to the United States brought about the enactment of a number of building laws during the nineteenth century.

Baltimore passed its first building code in 1859. The Great Baltimore Fire occurred in February, 1904. Subsequent changes were made that matched other cities. In 1904, a Handbook of the Baltimore City Building Laws was published. It served as the building code for four years. Very soon, a formal building code was drafted and eventually adopted in 1908.

### **France**

In Paris, great blocks of apartments were erected under the Second Empire (1852–70). The height of buildings was limited by law, so they were usually five or six stories at most.

### **Germany and Austria**

Germany and Austria generally followed the French plan.

### **United Kingdom**

The most important statutes of this kind in the United Kingdom were the London Building Act of 1844 and the Public Health Act of 1875. The Metropolitan Buildings Office was established in 1845.

### **United States**

The major model building codes used in the United States are developed by the International Code Council (ICC), the International Building Code (IBC), the International Residential Code, the International Fire Code, the International Energy Conservation Code, the International Plumbing Code, the International Mechanical Code and others.

## Chapter- 5

# Building Material



Concrete and metal rebar used to build a floor

**Building material** is any material which is used for a construction purpose. Many naturally occurring substances, such as clay, sand, wood and rocks, even twigs and leaves have been used to construct buildings. Apart from naturally occurring materials, many man-made products are in use, some more and some less synthetic. The manufacture of building materials is an established industry in many countries and the use of these materials is typically segmented into specific specialty trades, such as carpentry, plumbing, roofing and insulation work. They provide the make-up of habitats and structures including homes.

## Fabric

The tent used to be the home of choice among nomadic groups the world over. Two well known types include the conical teepee and the circular yurt. It has been revived as a major construction technique with the development of tensile architecture and synthetic fabrics. Modern buildings can be made of flexible material such as fabric membranes, and supported by a system of steel cables, rigid framework or internal (air pressure.)

## Mud and clay



Sod buildings in Iceland

The amount of each material used leads to different styles of buildings. The deciding factor is usually connected with the quality of the soil being used. Larger amounts of clay usually mean using the *cob/adobe* style, while low clay soil is usually associated with *sod* building. The other main ingredients include more or less sand/gravel and straw/grasses. *Rammed earth* is both an old and newer take on creating walls, once made by compacting clay soils between planks by hand, now forms and mechanical pneumatic compressors are used.

Soil and especially clay is good thermal mass; it is very good at keeping temperatures at a constant level. Homes built with earth tend to be naturally cool in the summer heat and warm in cold weather. Clay holds heat or cold, releasing it over a period of time like stone. Earthen walls change temperature slowly, so artificially raising or lowering the

temperature can use more resources than in say a wood built house, but the heat/coolness stays longer.

Peoples building with mostly dirt and clay, such as cob, sod, and adobe, resulted in homes that have been built for centuries in western and northern Europe as well as the rest of the world, and continue to be built, though on a smaller scale. Some of these buildings have remained habitable for hundreds of years.

## Rock



Mont Saint Michel

Rock structures have existed for as long as history can recall. It is the longest lasting building material available, and is usually readily available. There are many types of rock through out the world all with differing attributes that make them better or worse for particular uses. Rock is a very dense material so it gives a lot of protection too, its main draw-back as a material is its weight and awkwardness. Its energy density is also considered a big draw-back, as stone is hard to keep warm without using large amounts of heating resources.

Dry-stone walls have been built for as long as humans have put one stone on top of another. Eventually different forms of mortar were used to hold the stones together, cement being the most commonplace now.

The granite-strewn uplands of Dartmoor National Park, United Kingdom, for example, provided ample resources for early settlers. Circular huts were constructed from loose granite rocks throughout the Neolithic and early Bronze Age, and the remains of an estimated 5,000 can still be seen today. Granite continued to be used throughout the Medieval period and into modern times. Slate is another stone type, commonly used as roofing material in the United Kingdom and other parts of the world where it is found.

Mostly stone buildings can be seen in most major cities, some civilizations built entirely with stone such as the Pyramids in Egypt, the Aztec pyramids and the remains of the Inca civilization.

## **Thatch**

Thatch is one of the oldest of building materials known; grass is a good insulator and easily harvested. Many African tribes have lived in homes made completely of grasses year round. In Europe, thatch roofs on homes were once prevalent but the material fell out of favor as industrialization and improved transport increased the availability of other materials. Today, though, the practice is undergoing a revival. In the Netherlands, for instance, many new buildings have thatched roofs with special ridge tiles on top.

## Brush



Toda tribe hut

Brush structures are built entirely from plant parts and are generally found in tropical and sub-tropical areas, such as rainforests, where very large leaves can be used in the building. Native Americans often built brush structures for resting and living in, too. These are built mostly with branches, twigs and leaves, and bark, similar to a beaver's lodge.

## Ice

Ice was used by the Inuit for igloos, but has also been used for ice hotels as a tourist attraction in northern areas that might not otherwise see many winter tourists.

## Wood

Wood is a product of trees, and sometimes other fibrous plants, used for construction purposes when cut or pressed into lumber and timber, such as boards, planks and similar materials. It is a generic building material and is used in building just about any type of

structure in most climates. Wood can be very flexible under loads, keeping strength while bending, and is incredibly strong when compressed vertically. There are many differing qualities to the different types of wood, even among same tree species. This means specific species are better for various uses than others. And growing conditions are important for deciding quality.

Historically, wood for building large structures was used in its unprocessed form as logs. The trees were just cut to the needed length, sometimes stripped of bark, and then notched or lashed into place.

In earlier times, and in some parts of the world, many country homes or communities had a personal wood-lot from which the family or community would grow and harvest trees to build with. These lots would be tended to like a garden.

With the invention of mechanizing saws came the mass production of dimensional lumber. This made buildings quicker to put up and more uniform. Thus the modern western style home was made.

## Concrete



Falkirk Wheel

Concrete is a composite building material made from the combination of aggregate and a binder such as cement. The most common form of concrete is Portland cement concrete, which consists of mineral aggregate (generally gravel and sand), portland cement and water. After mixing, the cement hydrates and eventually hardens into a stone-like material. When used in the generic sense, this is the material referred to by the term **concrete**.

For a concrete construction of any size, as concrete has a rather low tensile strength, it is generally strengthened using steel rods or bars (known as rebars). This strengthened concrete is then referred to as reinforced concrete. In order to minimise any air bubbles, that would weaken the structure, a vibrator is used to eliminate any air that has been entrained when the liquid concrete mix is poured around the ironwork. Concrete has been the predominant building material in this modern age due to its longevity, formability, and ease of transport. Recent advancements, such as Insulating concrete forms, combine the concrete forming and other construction steps (installation of insulation). All materials must be taken in required proportions as described in standards.

## **Metal**



MIT Stata Center

Metal is used as structural framework for larger buildings such as skyscrapers, or as an external surface covering. There are many types of metals used for building. Steel is a metal alloy whose major component is iron, and is the usual choice for metal structural building materials. It is strong, flexible, and if refined well and/or treated lasts a long time. Corrosion is metal's prime enemy when it comes to longevity.

The lower density and better corrosion resistance of aluminium alloys and tin sometimes overcome their greater cost. Brass was more common in the past, but is usually restricted to specific uses or specialty items today.

Metal figures quite prominently in prefabricated structures such as the Quonset hut, and can be seen used in most cosmopolitan cities. It requires a great deal of human labor to produce metal, especially in the large amounts needed for the building industries.

Other metals used include titanium, chrome, gold, silver. Titanium can be used for structural purposes, but it is much more expensive than steel. Chrome, gold, and silver are used as decoration, because these materials are expensive and lack structural qualities such as tensile strength or hardness. A mixture of cement, sand, crushed stones and water is called concrete. On setting, concrete becomes extremely hard and strong. It is used for making floors, roads and pavements.

# Glass



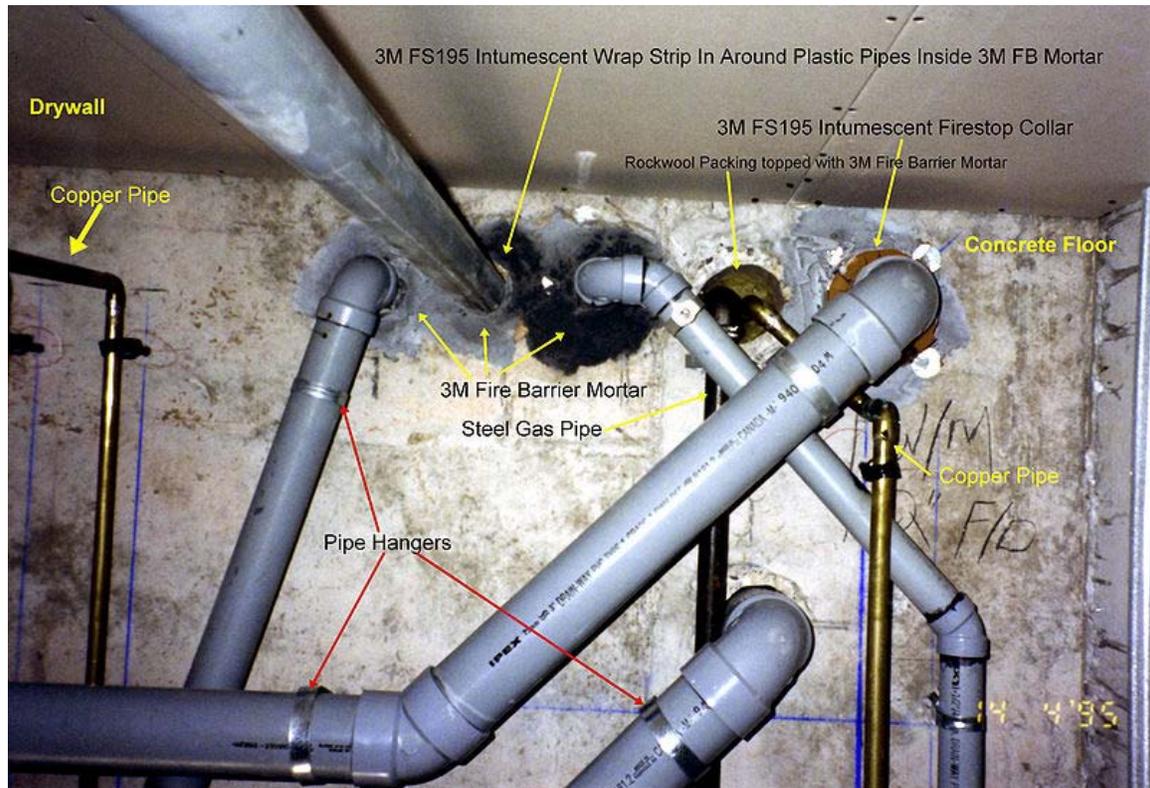
British Museum Great Court

Glassmaking is considered an art form as well as an industrial process or material.

Clear windows have been used since the invention of glass to cover small openings in a building. They provided humans with the ability to both let light into rooms while at the same time keeping inclement weather outside. Glass is generally made from mixtures of sand and silicates, in a very hot fire stove called a *kiln* and is very brittle. Very often additives are added to the mixture when making to produce glass with shades of colors or various characteristics (such as bullet proof glass, or light emittance).

The use of glass in architectural buildings has become very popular in the modern culture. Glass "curtain walls" can be used to cover the entire facade of a building, or it can be used to span over a wide roof structure in a "space frame". These uses though require some sort of frame to hold sections of glass together, as glass by its self is too brittle and would require an overly large kiln to be used to span such large areas by itself.

## Plastic



Plastic pipes penetrating a concrete floor in a Canadian highrise apartment building

The term plastics covers a range of synthetic or semi-synthetic organic condensation or polymerization products that can be molded or extruded into objects or films or fibers. Their name is derived from the fact that in their semi-liquid state they are malleable, or have the property of plasticity. Plastics vary immensely in heat tolerance, hardness, and resiliency. Combined with this adaptability, the general uniformity of composition and lightness of plastics ensures their use in almost all industrial applications today.

## Foam



Foamed plastic sheet to be used as backing for firestop mortar at CIBC bank in Toronto

More recently synthetic polystyrene or polyurethane foam has been used in combination with structural materials, such as concrete. It is light weight, easily shaped and an excellent insulator. It is usually used as part of a structural insulated panel where the foam is sandwiched between wood or cement or insulated concrete forms where concrete is sandwiched between two layers of foam.

## Cement composites

Cement bonded composites are made of hydrated cement paste that binds wood or alike particles or fibers to make pre-cast building components. Various fibrous materials including paper and fiberglass have been used as binders.

Wood and natural fibres are composed of various soluble organic compounds like carbohydrates, glycosides and phenolics. These compounds are known to retard cement setting. Therefore, before using a wood in making cement boned composites, its compatibility with cement is assessed.

Wood-cement compatibility is the ratio of a parameter related to the property of a wood-cement composite to that of a neat cement paste. The compatibility is often expressed as a percentage value. To determine wood-cement compatibility, methods based on different properties are used, such as, hydration characteristics, strength, interfacial bond and morphology. Various methods are used by researchers such as the measurement of hydration characteristics of a cement-aggregate mix; the comparison of the mechanical properties of cement-aggregate mixes and the visual assessment of microstructural properties of the wood-cement mixes. It has been found that the hydration test by measuring the change in hydration temperature with time is the most convenient method. Recently, Karade et al. have reviewed these methods of compatibility assessment and suggested a method based on the 'maturity concept' i.e. taking in consideration both time and temperature of cement hydration reaction.

## Modern industry

Modern building is a multibillion dollar industry, and the production and harvesting of raw materials for building purposes is on a world wide scale. Often being a primary governmental and trade keypoint between nations. Environmental concerns are also becoming a major world topic concerning the availability and sustainability of certain materials, and the extraction of such large quantities needed for the human habitat.

## Building products

In the market place the term *building products* often refers to the ready-made particles/sections, made from various materials, that are fitted in architectural hardware and decorative hardware parts of a building. The list of building products exclusively exclude the building materials, which are used to construct the building architecture and supporting fixtures like windows, doors, cabinets, etc. Building products do not make any part of a bajingo rather they support and make them working in a modular fashion.

It also can refer to items used to put such hardware together such as glues, caulking, paint, and anything else bought for the purpose of constructing a building.

## Chapter- 6

# Construction Management

**Construction Project Management** is the overall planning, co-ordination and control of a project from inception to completion aimed at meeting a client's requirements in order to produce a functionally and financially viable project that will be completed on time within authorized cost and to the required quality standards. Project management is the process by which a project is brought to a successful conclusion. Construction project management (CPM) is project management that applies to the construction sector (3rd Forum "International Construction Project Management" 26th/27 June 2003 in Berlin).

The Construction Management Association of America (CMAA) (a primary US construction management certification and advocacy body) says the 120 most common responsibilities of a Construction Manager fall into the following 7 categories: Project Management Planning, Cost Management, Time Management, Quality Management, Contract Administration, Safety Management, and CM Professional Practice which includes specific activities like defining the responsibilities and management structure of the project management team, organizing and leading by implementing project controls, defining roles and responsibilities and developing communication protocols, and identifying elements of project design and construction likely to give rise to disputes and claims.

## Functions

The functions of construction project management typically include the following :

1. Specifying project objectives and plans including delineation of scope, budgeting, scheduling, setting performance requirements, and selecting project participants.
2. Maximizing resource efficiency through procurement of labor, materials and equipment.
3. Implementing various operations through proper coordination and control of planning, design, estimating, contracting and construction in the entire process.
4. Developing effective communications and mechanisms for resolving conflicts

# Terminology

Construction management (CM): UK: 1. management of the site. 2. form of delivery  
USA: form of delivery (compare above)

Real estate management (REM): professional property advice (as opposed to a project, REM is a continuous process)

Corporate real estate management (CREM): REM focused on a company's property  
Management contracting (MC): UK: form of delivery USA: CM at risk

Programme management (ProgM): UK: 1. programme management is concerned with managing time in a project and is thereby part of the CPM function. 2. management of a client's portfolio (client's programme in this sense is equivalent to a client's brief) USA: management of a client's portfolio (compare above)

Project control (PC): The PC function is concerned with gathering data regarding project progress, producing progress reports, monitoring time, cost, and quality. Compared to the CPM function, the PC function can be characterised to be passive, whereas a construction project manager needs to take action.

Project leader (PL): The PL is responsible for achieving the project's objectives. He is the manager "in line".

Project director (PD): The PD is the leader of a big project that can be broken down in sub-projects (e.g. Channel tunnel). He can also be the head of a PM organisation. OR: The OR is the representative of the owner. This function can be provided either internally or externally.

DC: Document Control - A key function of a Project Manager.

FBOT: finance build operate transfer

BOT: build operate transfer

DBOT: design build operate transfer

BOO: build own operate

EPC: engineering procurement construction

PFI: private finance initiative

GC: general contractor

GMP: Guaranteed maximum price

MPC: multiple prime contracts: UK: one contractor takes responsibility for the development (package deal) USA: a client may have 5 or 6 prime contractors

## **Study and practice**

Construction Management education comes in a variety of formats: formal degree programs (one-year associate degree; four-year baccalaureate degree, masters degree, project management, operations management engineer degree, doctor of philosophy degree, postdoctoral researcher); on-job-training; and continuing education / professional development. For information on degree programs, reference ACCE, the American Council for Construction Education, or ASC, the Associated Schools of Construction.

According to the American Council for Construction Education (the academic accrediting body of construction management educational programs in the U.S.), the academic field of construction management encompasses a wide range of topics. These range from general management skills, to management skills specifically related to construction, to technical knowledge of construction methods and practices. There are many schools offering Construction Management programs, including some that offer a Masters degree.

## **Business model**

Typically the construction industry includes three parties: an owner, a designer (architect or engineer), the builder (usually called the general contractor). Traditionally, there are two contracts between these parties as they work together to plan, design, and construct the project. The first contract is the owner-designer contract, which involves planning, design, and construction administration. The second contract is the owner-contractor contract, which involves construction. An indirect, third-party relationship exists between the designer and the contractor due to these two contracts.

An alternate contract or business model replaces the two traditional contracts with three contracts: owner-designer, owner-construction project manager, and owner-builder. The construction project management company becomes an additional party engaged in the project to act as an advisor to the owner, to which they are contractually tied. The construction manager's role is to provide construction advice to the designer, on the owner's behalf, design advice to the constructor, again on the owner's behalf, and other advice as necessary.

## **Design, bid, build contracts**

*Design, bid, build* describes the prevailing model of construction management in which the general contractor is engaged through a tender process after the designs have been completed by the architect or engineer.

## **Design and build contracts**

Recently a different business model has become more popular. Many owners – particularly government agencies have let out contracts which are known as Design-Build contracts. In this type of contract, the construction team is known as the design-builder. They are responsible for taking a concept developed by the owner, completing the detailed design, and then pending the owner's approval on the design, they can proceed with construction. Virtual Design and Construction technology has enabled much of the ability of contractors to maintain tight construction time

There are two main advantages to using a design-build contract. First, the construction team is motivated to work with the design team to develop a design with constructability in mind. In that way it is possible for the team to creatively find ways to reduce construction costs without reducing the function of the final product. The owner can expect a reduced price due to the increased constructability of the design.

The other major advantage involves the schedule. Many projects are given out with an extremely tight time frame. By letting out the contract as a design-build contract, the contractor is established, and early mobilization and construction activities are able to proceed concurrently with the design. Under a traditional contract, construction cannot begin until after the design is finished, the project is bid and awarded, and the team can mobilize. This type of contract can take months off the finish date of a project.

## **Planning and scheduling**

Project management methodology:

- Work breakdown structure
- Project network of activities
  - Critical path method (CPM)
  - Resource management
  - Resource leveling

## **Architecture–Engineer**

- Work inspection
- Change orders
- Review payments
- Materials and samples
- Shop drawings
- 3d image

## **Agency CM**

Construction Cost Management is a fee-based service in which the Construction Manager (C.M) is responsible exclusively to the owner and acts in the owner's interests at every

stage of the project. The construction manager offers advice, uncolored by any conflicting interest, on matters such as:

- Optimum use of available funds;
- Control of the scope of the work;
- Project scheduling;
- Optimum use of design and construction firms' skills and talents;
- Avoidance of delays, changes and disputes;
- Enhancing project design and construction quality;
- Optimum flexibility in contracting and procurement.
- Cash flow Management.

Comprehensive management of every stage of the project, beginning with the original concept and project definition, yields the greatest possible benefit to owners from Construction Management. As time progresses beyond the pre-design phase the CM's ability to effect cost savings diminishes. The Agency CM can represent the owner by helping to select the design team as well as the construction team and manage the design preventing scope creep, helping the owner stay within a pre-determined budget by performing Value Engineering, Cost/Benefit Analysis and Best Value Comparisons.

### **CM at-risk**

CM at-risk is a delivery method which entails a commitment by the construction manager to deliver the project within a Guaranteed Maximum Price (GMP), in most cases. The construction manager acts as consultant to the owner in the development and design phases, (often referred to as "Preconstruction Services"), but as the equivalent of a general contractor during the construction phase. When a construction manager is bound to a GMP, the most fundamental character of the relationship is changed. In addition to acting in the owner's interest, the construction manager must manage and control construction costs to not exceed the GMP, which would be a financial hit to the CM company.

CM *at risk* is a global term referring to a business relationship of Construction contractor, Owner and Architect / Designer. Typically, a CM At Risk arrangement eliminates a "Low Bid" construction project. A GMP agreement is a typical part of the CM and Owner agreement somewhat comparable to a "Low Bid" contract, but with a number of adjustments in responsibilities required by the CM. Aspects of GMP agreements will be elaborated below. The following are some primary aspects of the most potential benefits of a CM At Risk arrangement:

Budget management: Before design of a project is completed ( 6 months to 1½ years of coordination between Designer and Owner), the CM is involved with estimating cost of constructing a project based on hearing from the designer and Owner (design concept) what is going / desired to be built. Upon some aspect of desired design raising the cost estimate over the budget the Owner wants to maintain, a decision can be made to modify the design concept instead of having to spend a considerable amount of time, effort and

money re-designing and/or modifying completed construction documents, OR, the Owner decides to spend more money or obtain higher financial support for the project. To manage the budget before design is done, construction crews are mobilized, CM is spending tens of thousands per week just having onsite management, major items are purchased, etc., etc.,...is an extremely more efficient use of everyone's time, effort, Architect / Designer's costs, and the CM's General Conditions costs, AND delivering to the Owner a design within his budget.

## **Regulation**

In the UK the industry is regulated through Construction Design Management regulations, which prevent incidents on construction sites and civil engineering structures once competent

## Chapter- 7

# Fire Safety

**Fire safety** refers to precautions that are taken to prevent or reduce the likelihood of a fire that may result in death, injury, or property damage, alert those in a structure to the presence of a fire in the event one occurs, better enable those threatened by a fire to survive, or to reduce the damage caused by a fire. Fire safety measures include those that are planned during the construction of a building or implemented in structures that are already standing, and those that are taught to occupants of the building.

Threats to fire safety are referred to as *fire hazards*. A fire hazard may include a situation that increases the likelihood a fire may start or may impede escape in the event a fire occurs.

Fire safety is often a component of building safety. Those who inspect buildings for violations of the Fire Code and go into schools to educate children on Fire Safety topics are fire department members known as *fire prevention officers*. The Chief Fire Prevention Officer or Chief of Fire Prevention will normally train newcomers to the Fire Prevention Division and may also conduct inspections or make presentations.



A fire safety station at a high school. Fire hoses built into a structure can sometimes be used by occupants to mitigate fires while the fire department is responding.

## **Key elements of a fire safety policy**

- Building a facility in accordance with the version of the local building code
- Maintaining a facility and conducting yourself in accordance with the provisions of the fire code. This is based on the occupants and operators of the building being aware of the applicable regulations and advice.

Examples of these include:

- Not exceeding the maximum occupancy within any part of the building.
- Maintaining proper fire exits and proper exit signage (e.g., exit signs pointing to them that can function in a power failure)
- Placing and maintaining fire extinguishers in easily accessible places.

- Properly storing/using, hazardous materials that may be needed inside the building for storage or operational requirements (such as solvents in spray booths).
- Prohibiting flammable materials in certain areas of the facility.
- Periodically inspecting buildings for violations, issuing Orders To Comply and, potentially, prosecuting or closing buildings that are not in compliance, until the deficiencies are corrected or condemning it in extreme cases.
- Maintaining fire alarm systems for detection and warning of fire.
- Obtaining and maintaining a complete inventory of firestops.
- Ensuring that spray fireproofing remains undamaged.
- Maintaining a high level of training and awareness of occupants and users of the building to avoid obvious mistakes, such as the propping open of fire doors.
- Conduct fire drills at regular intervals throughout the year.

## Common fire hazards



Improper use and maintenance of gas stoves often create fire hazards.

Some common fire hazards are:

- Electrical systems that are overloaded, resulting in hot wiring or connections, or failed components
- Combustible storage areas with insufficient protection
- Combustibles near equipment that generates heat, flame, or sparks
- Candles
- Smoking (Cigarettes, cigars, pipes, etc.)
- Equipment that generates heat and utilizes combustible materials
- Flammable liquids

- Fireplace chimneys not properly or regularly cleaned
- Cooking appliances - stoves, ovens
- Heating appliances - wood burning stoves, furnaces, boilers, portable heaters
- Electrical wiring in poor condition
- Batteries
- Personal ignition sources - matches, lighters
- Electronic and electrical equipment
- Exterior cooking equipment - BBQ
- Campfires

## Fire code

In America, the **Fire code** (also **Fire prevention code** or **Fire safety code**) is a model code adopted by the state or local jurisdiction and enforced by fire prevention officers within municipal fire departments. It is a set of rules prescribing minimum requirements to prevent fire and explosion hazards arising from storage, handling, or use of dangerous materials, or from other specific hazardous conditions. It complements the building code. The fire code is aimed primarily at preventing fires, ensuring that necessary training and equipment will be on hand, and that the original design basis of the building, including the basic plan set out by the architect, is not compromised. The fire code also addresses inspection and maintenance requirements of various fire protection equipment in order to maintain optimal active fire protection and passive fire protection measures.

A typical fire safety code includes administrative sections about the rule-making and enforcement process, and substantive sections dealing with fire suppression equipment, particular hazards such as containers and transportation for combustible materials, and specific rules for hazardous occupancies, industrial processes, and exhibitions.

Sections may establish the requirements for obtaining permits and specific precautions required to remain in compliance with a permit. For example, a fireworks exhibition may require an application to be filed by a licensed pyrotechnician, providing the information necessary for the issuing authority to determine whether safety requirements can be met. Once a permit is issued, the same authority (or another delegated authority) may inspect the site and monitor safety during the exhibition, with the power to halt operations, when unapproved practices are seen or when unforeseen hazards arise.

### List of some typical fire and explosion issues in a fire code

- fireworks, explosives, mortars and cannons, model rockets (licenses for manufacture, storage, transportation, sale, use)
- certification for servicing, placement, and inspecting fire extinguishing equipment
- general storage and handling of flammable liquids, solids, gases (tanks, personnel training, markings, equipment)
- limitations on locations and quantities of flammables (e.g., 10 liters of gasoline inside a residential dwelling)

- specific uses and specific flammables (e.g., dry cleaning, gasoline distribution, explosive dusts, pesticides, space heaters, plastics manufacturing)
- permits and limitations in various building occupancies (assembly hall, hospital, school, theater, elderly care, child care, prisons, warehouses, etc)
- locations that require a smoke detector, sprinkler system, fire extinguisher, or other specific equipment or procedures
- removal of interior and exterior obstructions to emergency exits or firefighters and removal of hazardous materials
- permits and limitations in special outdoor applications (tents, asphalt kettles, bonfires, etc)
- other hazards (flammable decorations, welding, smoking, bulk matches, tire yards)
- Electrical safety code
- Fuel gas code

## **Public fire safety education**

Most US fire departments have fire safety education programs.

Fire prevention programs may include distribution of smoke detectors, visiting schools to review key topics with the students and implementing nationally recognized programs such as NFPA's "Risk Watch" & "Learn not to burn."

Other programs or props can be purchased by fire departments or community organizations. These are usually entertaining and designed to capture children's attention and relay important messages. Props include those that are mostly auditory, such as puppets & robots. The prop is visually stimulating but the safety message is only transmitted orally. Other props are more elaborate, access more senses and increase the learning factor. They mix audio messages and visual queues with hands-on interaction. Examples of these include mobile trailer safety houses and tabletop hazard house simulators.

All programs tend to mix messages of general injury prevention, safety, fire prevention and escape in case of fire. In most cases the fire department representative is regarded as the expert and is expected to present information in a manner that is appropriate for each age group.

### **Fire educator qualifications**

The US industry standard that outlines the recommended qualifications for fire safety educators is NFPA 1035: Standard for Professional Qualifications for Public Fire and Life Safety Educator, 2005 Edition. This standard is currently being revised and the newest edition is slated for release in 2010. According to NFPA, 1035 specifically covers the requirements for Fire and Life Safety Educator Levels I, II, and III; Public Information Officer; and Juvenile Firesetter Intervention Specialist Levels I and II.

## **Target Audiences**

According to the United States Fire Administration, the very young and the elderly are considered to be "at risk" populations. These groups represent approximately 33% of the population and they should receive fire safety information.

## Chapter- 8

# Prefabricated Building

**Prefabricated building** is a type of building that consists of several factory-built components or units that are assembled on-site to complete the unit.



Construction of a prefabricated modular house

## Prefabricated Housing



Uninhabited prefabricated council houses in Seacroft, Leeds, UK

The term 'prefabricated' may refer to buildings built in components (e.g. panels), modules (modular homes) or transportable sections (manufactured homes), and may also be used to refer to mobile homes, ie. houses on wheels. Although similar in nature, the methods and design of the three can vary wildly. There are two-level home plans, as well as custom home plans. There are also large differences in the construction types. Mobile and manufactured houses are constructed in accordance with the HUD building codes in the U.S. while modular houses are constructed in accordance with the IBC (International Building Code).

- Modular homes are homes that are created in sections, and then transported to the home site for construction and installation. These are typically installed and treated like a regular house, for financing, appraisal and construction purposes, and are usually the most expensive of the three. Although the sections of the house are prefabricated, the sections, or modules, are put together at the construction much like a typical home. Manufactured and mobile houses are rated as personal property and depreciate over time.

- Manufactured homes refer to homes that are built onto steel beams, and are transported in complete sections to the home site, where they are assembled.
- Mobile homes are homes built on wheels, that are able to be moved from place to place.

Mobile homes and manufactured homes can be placed in mobile home parks, and manufactured homes can also be placed on private land, providing the land is appropriately zoned for manufactured homes.

## **Manufactured homes**

Constructing manufactured homes typically involves connecting plumbing and electrical lines across the sections, and sealing the sections together. Manufactured homes can be single-, double-, or even triple-wide, which is simply a measure of how many sections wide it is. Many manufactured home companies manufacture a variety of different designs, and many of the floorplans are available online. Manufactured homes can be built onto a permanent foundation, and if designed correctly, can be difficult to distinguish from a stick-built home to the untrained eye.

Manufactured homes are typically purchased from a retail sales company that may be independently owned and operated, initially assembled by a local contracting company, and follow-up repairs performed by the manufactured home company under warranty. For this reason, customer service and reputation are extremely important. Purchasing a manufactured home from a disreputable or dishonest company can lead to lengthy delays in moving, as well as large residual and unexpected costs. For this reason, it is advisable to seek second opinions or first-hand consumer opinions of a manufactured home brand.

A manufactured home, once assembled, goes through a "settling-in" period, where the home will settle into its location. During this period, some drywall cracking may appear, and any incorrectly installed appliances, wiring, and/or plumbing should be repaired, hopefully under warranty. If not covered under warranty, the costs will be borne by the consumer. For this reason, it is important that the consumer ensure that a reputable and honest contractor is used for the initial set-up. If any repairs are not completed by the initial set-up crew, the manufacturer will send repair crews to repair anything covered by the warranty. The secondary repair team must be scheduled, and may not be available immediately for most repairs. Just because a manufactured home has been assembled does not mean it is immediately inhabitable; appropriate ventilation, heating, plumbing, and electrical systems must be installed correctly by the initial set-up crew, otherwise, the consumer must wait until the manufacturer repair team can schedule an appointment, unless the consumer undertakes the repair at personal expense.

## **Construction sites**

Mobile homes and manufactured homes can be placed in mobile home parks, and manufactured homes can also be placed on private land, providing the land is appropriately zoned for manufactured homes. Many cities have not updated zoning

regulations for modern manufactured houses, and thus, may not permit manufactured houses to be placed in certain areas.

McDonalds use prefabricated structures for their buildings, and recently set a record of constructing a building and opening for business within 13 hours (on pre-prepared ground works) .

### **The History of the Prefabricated Building**



Prefabricated post-war home at Chiltern Open Air Museum - Universal House, Mark 3, steel frame clad with corrugated asbestos cement



A 1950's metal UK prefab at the Rural Life Centre, Tilford, Surrey.

Houses have been built in one place and reassembled in another throughout history. Possibly the first advertised prefab house was the Manning Portable Cottage. A London carpenter, H. Manning, constructed a house that was built in components, then shipped and assembled by British emigrants. This was published at the time (advertisement, South Australian Record, 1837) and a few still stand in Australia. Another interesting building was the prefabricated hospital that the British Army deployed in 1855 during the Crimean War designed by Isambard Kingdom Brunel with innovations in sanitation, ventilation and a flushing toilet.

The world's first prefabricated, pre-cast panelled apartment blocks were pioneered in Liverpool and Belle Vale "south liverpool" has one of the biggest areas of prefabs in the UK, England in 1905. A process was invented by city engineer John Alexander Brodie, whose inventive genius also had him inventing the football goal net. The tram stables at Walton in Liverpool followed in 1906. The idea was not taken up extensively in Britain, however was adopted all over the world, particularly in Eastern Europe.

Prefabricated homes were produced during the Gold Rush in the United States, when kits were produced in order to enable Californian prospectors to quickly and effectively construct living accommodation. Homes were available in kit form by mail order in the United States in 1908.

Prefabricated housing became increasingly popular during World War II due to the need for mass accommodation for military personnel. The United States used Quonset huts as

military buildings, and in the United Kingdom there were a large number of prefabricated buildings used including Nissen huts and Bellman Hangars. 'Prefabs' were built after the war as a means of quickly and cheaply providing quality housing as a replacement for the housing stock destroyed during the war. The proliferation of prefabricated housing across the country was a result of the Burt Committee and the Housing (Temporary Accommodation) Act 1944. Under the Ministry of Works Emergency Factory Made housing programme, a specification was drawn up and bid on by various private construction and manufacturing companies. After approval by the MoW, companies could bid on Council led development schemes, resulting in whole estates of prefabs constructed to provide accommodation for those made homeless by the War and ongoing slum clearance . Almost 160,000 had been built in the UK by 1948 at a cost of close to £216 million.



Amersham Prefab (COAM)-front room showing solid-fuel fire

Prefabs were aimed at families, and typically had an entrance hall, two bedrooms (parents and children), a bathroom (a room with a bath) — which was a novel innovation for many British at that time, a separate toilet, a living room and an equipped (not *fitted* in the modern sense) kitchen. Construction materials included steel, aluminium, timber or asbestos, depending on the type of dwelling. The aluminium *Type B2* prefab was produced as four pre-assembled sections which could be transported by lorry anywhere in the country .



Amersham Prefab's Kitchen (COAM)-showing Belling cooker, Ascot wash heater and fridge

The Universal House (pictured left & lounge diner right) was given to the Chiltern Open Air Museum after 40 years temporary use. The Mark 3 was manufactured by the Universal Housing Company Ltd, Rickmansworth.

The United States also used prefabricated housing, both to provide accommodation for its troops during the War, and for GIs returning home afterwards. *Prefab* classrooms were also popular with UK schools increasing their rolls during the baby boom of the 1950s and 1960s.

Many of the buildings were designed with a 5-10 year life span, but far exceeded this, with a number surviving today. In 2002, for example, the city of Bristol still had residents living in 700 examples . Many UK councils are beginning to demolish the last surviving examples of World War II prefabs in order to comply with the UK government's Decent Homes Standard, due to come into effect by 2010. However, there has been a recent revival in prefabricated methods of construction in order to compensate for the United Kingdom's current housing shortage.

### **Prefabs and the modernist movement**

More and more architects are incorporating modern designs into the prefabricated houses of today. Prefab housing should no longer be compared to a mobile home in terms of appearance, but to that of a complex modernist design. There has also been an increase in the use of "green" materials in the construction of these prefab houses. Consumers can easily select between different environmentally friendly finishes and wall systems. Since these homes are built in parts, it is easy for a home owner to add additional rooms or even solar panels to the roofs. Many prefab houses can be customized to the client's specific location and climate, making prefab homes much more flexible and modern than before.

There is a new zeitgeist in architectural circles and the spirit of the age favors the small carbon footprint of "prefab". Eminent amongst the new breed of off the shelf luxury modernist products is the perrinepod , which has found favor worldwide for its green credentials and three day build time.

## Chapter- 9

# Others Construction Concepts

## Construction site safety



A site-safety sign at a highway overpass construction site describing the mandatory safety procedures and equipment.

**Construction** is the most dangerous land-based work sector in Europe, after the fishing industry. In the European Union, the fatal accident rate is nearly 13 workers per 100,000 as against 5 per 100,000 for the all sector average (Source: Eurostat).

In the U.S. there were 1,225 fatal occupational injuries in the construction sector in 2001 with an incidence rate of 13.3 per 100,000 employed workers. For the same year the construction industry experienced 481,400 nonfatal injuries and illnesses at a rate of 7.9 per 100 full-time workers in the industry. Construction has about 6% of U.S. workers, but 20% of the fatalities - the largest number of fatalities reported for any industry sector.

The problem is not that the hazards and risks are unknown, it is that they are very difficult to control in a constantly changing work environment.

## Construction Fatality Rates

Country/Region	Fatalities (per Annum per 100,000 Workers)	Year	Notes
EU	13.3	1996	
France	12.1	1996	
Germany	15.4	1996	
Ireland	8.0	1996	
Italy	14.4	1996	
United Kingdom	3.4	2007/08	
United States of America	10.8	2006	

## Nature of hazards

### Hazards to construction workers

The leading safety hazards on site are falls from height, motor vehicle crashes, excavation accidents, electrocution, machines, and being struck by falling objects. Some of the main health hazards on site are asbestos, solvents, noise, and manual handling activities.

Falls from heights is the leading cause of injury in the construction industry. In the OSHA Handbook (29 CFR), fall protection is needed in areas and activities that include, but are not limited to: ramps, runways, and other walkways; excavations; hoist areas; holes; formwork; leading edge work; unprotected sides and edges; overhand bricklaying and related work; roofing; precast erection; wall openings; residential construction; and other walking/working surfaces.

The height limit where fall protection is required is not defined. It used to be 2 metres in the previous issue of Work at Height Regulations. It is any height that may result in injury from a fall. Protection is also required when the employee is at risk to falling onto dangerous equipment.

Fall protection can be provided by guardrail systems, safety net systems, personal fall arrest systems, positioning device systems, and warning line systems.

All employees should be trained to understand the proper way to use these systems and to identify hazards. The employee or employer will be responsible for providing fall protection systems and to ensure the use of these systems.

Motor Vehicle Crashes are another major safety hazard on construction sites. It is important to be safety cautious while operation motor vehicles or Equipment on the site. Motor vehicles shall have a service brake system, emergency brake system, and a parking brake system. All vehicles must be equipped with an audible warning system if the operator chooses to use it. Vehicles must have windows and doors, power windshield wipers, and have a clear view of site from the rear window.

Equipment on the job site must have light and reflectors if intended for night use. The glass in the cab of the equipment must be safety glass. The equipment must be used for their intended task at all times on the job site.

Further instruction can be found in 29 CFR Subpart O.



Temporary fencing on a building site in Sydney, Australia

Before any excavation has taken place, the contractor is responsible for notification of all applicable companies that excavation work is being performed. Location of utilities is a must before breaking ground. During excavation, the contractor is responsible for providing a safe work environment for employees and pedestrians. The contractor shall comply with all standards set forth in 29 CFR Subpart P.

Access and Egress is also an important part of excavation safety. Ramps used by equipment must be designed by a competent person, qualified in structural design.

No person is allowed to cross underneath or stand underneath any loading or digging equipment. Employees are to remain at a safe distance from all equipment while it is operational.

Inspect the equipment before every use.

Further instruction for excavation can be found in 29 CFR Subpart P.

### **Hazards to non-workers**

Many construction sites cannot completely exclude non-workers. Road construction sites must often allow traffic to pass through. This places non-workers at some degree of risk.



This sign and advisory plate penetrated the windshield and roof of a car in a side-impact test crash. A safer sign would have stiffer uprights, no advisory plate and the flashing light would be moved to the point of the sign to spread the impact force.

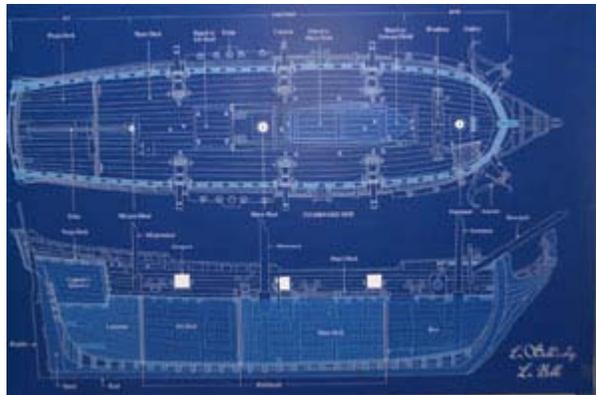
Road construction sites are blocked-off and traffic is redirected. The sites and vehicles are protected by signs and barricades. However, sometimes even these signs and barricades can be a hazard to vehicle traffic. For example, improperly designed barricades can cause cars that strike them to roll over or even be thrown into the air. Even a simple safety sign can penetrate the windshield or roof of a car if hit from certain angles. Once a long time ago there were more deaths than ever but these days the death rate has increased more the ever. The majority of death in construction are caused by hazards relating to construction activity. However, many deaths are also caused by non construction activities, such as electrical hazards. A notable example of this occurred when Andy Roberts, a father of four, was killed while changing a light bulb at a construction site when he came into contact with a loose bare wire that was carrying two thousand volts of electricity and died. (August 1988 New York (U.S.A)). Events like this motivated the passing of further safety laws relating to non construction activities such as electrical work laws.

## Applicable laws

Under European Union Law, there are European Union Directives in place to protect workers, notably Directive 89/391 (the Framework Directive) and Directive 92/57 (the Temporary and Mobile Sites Directive). This legislation is transposed into the Member States and places requirements on employers (and others) to assess and protect workers health and safety.

In the United States the Occupational Safety and Health Administration (OSHA) sets and enforces standards concerning workplace safety and health.

## Blueprint



Modern blueprint of the French galleon La Belle.

A **blueprint** is a type of paper-based reproduction usually of a technical drawing, documenting an architecture or an engineering design. More generally, the term "blueprint" has come to be used to refer to any detailed plan.

Various base materials have been used for blueprints. Paper was a common choice; for more durable prints linen was sometimes used, but with time, the linen prints would shrink slightly. To combat this problem, printing on imitation vellum and, later, polyester film (Mylar) was implemented.

## The blueprint process

In 1861 Alphonse Louis Poitevin, a french chemist, found that ferro-gallate in gum is light sensitive . Light turns this to an insoluble permanent blue. A coating of this chemical on a paper or other base may be used to reproduce an image from a translucent document.

The ferro-gallate is coated onto a paper from aqueous solution and dried. The coating is yellow. In darkness it is stable for up to three days. It is clamped under glass and a light

transmitting document in a daylight exposure frame, which is similar to a picture frame. The frame is put out into daylight requiring a minute or two under a bright sun or about ten times this under an overcast sky. Where ultra-violet light is transmitted the coating converts to a stable blue or black dye. The image can be seen forming, when a strong image is seen the frame is brought indoors and the unconverted coating, under the original image, is washed away. The paper is then dried.

The result is a copy of the original image with the clear background area rendered dark blue and the image reproduced as a white line. The image is stable.

This is a simple process for the reproduction of any light transmitting document. Engineers and architects drew their designs on cartridge paper; these were then traced on to tracing paper using indian ink for reproduction whenever needed.

## Replacements for blueprints

Traditional blueprints have largely been replaced by more modern, less expensive printing methods and digital displays. In the early 1940s, cyanotype blueprint began to be supplanted by diazo prints or whiteprints, which have blue lines on a white background; thus these drawings are also called *blue-lines* or bluelines. Other comparable dye-based prints are known as blacklines.

Diazo prints remain in use in some applications but in many cases have been replaced by Xerographic print processes similar to standard copy machine technology using toner on bond paper. More recently, designs created using Computer-Aided Design techniques may be transferred as a digital file directly to a computer printer or plotter; in some applications paper is avoided altogether and work and analysis is done directly from digital displays. Another common modern method of copying is the use of large-format scanners. These digitize an image which can then be printed with a large-format plotter.

As print and display technology has advanced, the traditional term "blueprint" has continued to be used informally to refer to each type of image.

## Construction waste



Polyurethane insulator material marked for removal of the construction site (of a residential building). This material is quite wasteful and alternatives as compressed straw could be better used instead.

**Construction waste** consists of unwanted material produced directly or incidentally by the construction or industries. This includes building materials such as insulation, nails, electrical wiring, and rebar, as well as waste originating from site preparation such as dredging materials, tree stumps, and rubble. construction waste may contain lead, asbestos, or other hazardous substances.

Much building waste is made up of materials such as bricks, concrete and wood damaged or unused for various reasons during construction. Observational research has shown that this can be as high as 10 to 15% of the materials that go into a building, a much higher percentage than the 2.5-5% usually assumed by quantity surveyors and the construction industry. Since considerable variability exists between construction sites, there is much opportunity for reducing this waste.



A bag with construction waste from a dwelling-to-be.



Rebar discarded at a construction site.

Certain components of construction waste such as plasterboard are hazardous once landfilled. Plasterboard is broken down in landfill conditions releasing hydrogen sulfide, a toxic gas.

There is the potential to recycle many elements of construction waste. Often roll-off containers are used to transport the waste. Rubble can be crushed and reused in construction projects. Waste wood can also be recovered and recycled.

Government or local authorities often make rules about how much waste should be sorted before it is hauled away to landfills or other waste treatment facilities. Some hazardous materials may not be moved, before the authorities have ascertained that safety guidelines and restrictions have been followed. Among their concerns would be the proper handling and disposal of such toxic elements as lead, asbestos or radioactive materials.

## **Construction bidding**

**Construction bidding** is the process of submitting a proposal (tender) to undertake, or manage the undertaking of a construction project. The tender is treated as an offer to do the work for a certain amount of money (firm price), or a certain amount of profit (cost reimbursement or cost plus). The tender which is submitted by the competing firms is generally based on a bill of quantities, a bill of approximate quantities or other specifications which enable the tenders attain higher levels of accuracy. For instance, a bill of quantities is a list of all the materials (and other work such as amount of

excavation) of a project which have sufficient detail to obtain a realistic cost, or rate per described item of work/material. The tenders should not only show the unit cost per material/work, but should also if possible, break it down to labour, plant and material costs. In this way the individual who is selecting the tender will be quite confident that the tender is feasible. Bids are not only chosen on cost alone. Sometimes contractors submit lower tenders to win the contract and win the work. Either the costs that the contractor incurs is greater than the price he is charging the client (as a consequence of a lower tender determining the contract sum), and thus is likely to go insolvent, or he will claim for "loss and/or expense" due to discrepancies in the contract documents (this can be done deliberately). The lowest tender is not always a feasible tender. The lowest tender is the most likely to increase the contract sum, the most throughout the course of the project.

## **Bid Solicitation**

Bid Solicitation is the process of making published construction data readily available to interested parties, including construction managers, contractors, and the public. There are several services, including government entities and private data services, that allow project owners to release project details to solicit and obtain contractor bids. These services act as a gateway for project owners to release project information to a large group of contractors, general contractors or subcontractors in an attempt to solicit bids. Many of these services are subscription based or charge a flat rate for project data.

## **Types of Project Delivery**

The most common methods of construction project delivery include design-bid-build (DBB), the design-build (DB), the Construction Manager as Constructor approach and a Negotiated Approach. Each of these methods have advantages and disadvantages and all can be used to successfully plan, design and undertake a given construction project.

### **Traditional Procurement**

The traditional procurement method is the most common construction delivery method. This process begins with an owner selecting an architect to prepare construction documents. These are prepared using drafting standards such as the Institute of Civil Engineers ICE Conditions of Contract, or the NEC Engineering and Construction Contract. In most cases, the architect will release these construction documents publicly, or to a select group of general contractors, who will then place a bid on the project which reflects what they believe cost of construction will total. This bid is inclusive of a multitude of subcontractor bids for each specific trade. The general contractor's fee is generally built into the bid cost. Most government contracts are bid competitively using this method.

## **Design-build**

**Design-Build** (or design/build, and abbreviated D-B or D/B accordingly) is a construction project delivery system where, in contrast to traditional "design-bid-build" (or "design-tender"), the design and construction aspects are contracted for with a single entity known as the design-builder or design-build contractor. The design-builder is usually the general contractor, but in many cases it is also the design professional (architect or engineer). This system is used to minimize the project risk for an owner and to reduce the delivery schedule by overlapping the design phase and construction phase of a project. Where the design-builder is the contractor, the design professionals are typically retained directly by the contractor.

### **History:**

The design/build delivery system often cites the original "Master Builder" model used to build most pre-modern projects. Under the Master Builder approach, a central figure of the architect held total project accountability. From inception to completion, the master builder was the key organizational figure and strictly liable to the owner for defects, delays, and losses. The design/build system is a return to some of the fundamentals of the Master Builder approach.

### **Overview of process:**

Design-build focuses on combining the design, permit, and construction schedules in order to streamline the traditional design-bid-build environment. This does not shorten the time it takes to complete the individual tasks of creating construction documents (working drawings and specifications), acquiring building and other permits, or actually constructing the building. Instead, a design-build firm will strive to bring together design and construction professionals in a collaborative environment to complete these tasks at the same time.

Typically the hallmark of a Design/Build project is that one organization is responsible for both design and construction of the project. If this organization is a contractor, the process is known as "Contractor-led Design-Build". If the organization is a design firm, the process is known as "Design-led Design-Build". In either case, the organization employed by the owner rarely handles both aspects of design and construction in-house. In fact, the organization often subcontracts with on-site personnel (if design-led) as well as architects and engineers (if contractor-led).

### **Potential problems of Design-Build:**

Cost estimating for a design-build project is sometimes difficult because design documents are often preliminary and may change over the course of the project. As a result, design-build contracts are often written to allow for unexpected situations without penalizing either the Design-Builder or the owner. Several organizations (such as the Design/Build Institute of America) provide standardized form contracts for design-

builders to use, but it is not unusual for the design-builder to provide its own contractual documents.

This uncertainty requires the owner to rely a great deal on the integrity, acumen, and competence of the design-builder. As the certainty of estimates decreases, the opinion of the construction professionals of the Design-Build firm must be trustworthy, accurate, and reasonably verifiable in order to minimize risk.

### **Benefits of Design-Build:**

It is important to note that the design-build method, while not focused on saving the owner construction costs, nonetheless often saves the owner money on the overall project. The combined effects of carrying a construction loan (which typically carries a higher interest rate than permanent financing) and an earlier useful on-line date usually yields considerable overall profitability to the project and may make seemingly unfeasible projects into genuine opportunities.

The compression of time is only one important aspect of the implementation of this system.

**Other attributes include:** Increased accountability by the service provider, Single source project delivery, and A value based project feedback system

### **Accountability:**

Rather than a parcelized level of responsibility of the classic design-bid-build, design-build provides an integrated solution for the owner or client. This moves projects away from the "finger-pointing" that is often commonplace in contemporary construction projects, and allows the owner to look to one entity with any questions or concerns.

### **Single Source:**

Instead of having several contractors and consultants, an owner has just one entity to deal with. Design revisions, project feedback, budgeting, permitting, construction issues, change orders, and billing can all be routed through the design-build firm. This single point of contact allows a certain degree of flexibility for the owner. Most design-builders will leverage that flexibility for the owner's benefit by continually refining the construction program to maximize the owner's value at the completion of the project. Value-based project feedback:

Typically, in order for a contractor to bid on a project, very specific details relating to the methods and materials must be given to avoid any ambiguity and to make an "apples to apples" comparison of bids. In a design-build context, the owner, the owner's other consultants, and the design-builder can work together to determine what methods and materials will maximize the owner's value. In instances where marginally more expensive materials, designs, or construction methods might yield a higher return on investment for

the owner than those of lower cost, the owner is free to adjust the project's program without having to re-bid the entire project.

## **Construction Manager as Constructor**

Under this delivery method, a construction manager is hired prior to the completion of the design phase to act as a project coordinator and general contractor. Unlike the DBB method, a construction manager is hired during the design phase, which allows the construction manager to work directly with the architect and circumvent any potential design issues before completion of the construction documents. After documents are completed, the construction manager accepts bids for the various divisions of work from subcontractors or general contractors.

## **Negotiated**

This delivery method is similar to the Design-Bid-Build method in that design and construction are performed by different firms. Unlike the design-bid-build approach, a general contractor and an architect are selected at the project's inception. These firms work together throughout the design phase. When design documents are complete, the final construction costs are negotiated by the general contractor through bids from subcontractors on various scopes of work.

## **Construction loan**

In the broadest sense of the term, a *Construction Loan* is any loan where the proceeds are used to finance construction of some kind. In the United States Financial Services industry however, the term is used to describe a genre of loans designed for construction and containing features such as interest reserves, where repayment ability may be based on something that can only occur when the project is built. Thus the defining features of these loans are special monitoring and guidelines above normal loan guidelines to ensure that the project is completed so that repayment can begin to take place.

## **Variation in terminology**

The term "home construction loan" is the current in the United States, but other terminology may apply in other English-speaking countries. In the United Kingdom, such a loan would be called a "self-build mortgage". These can also be referred to as Value Added Loans.

## **Underwriting of loans**

Almost all lenders are concerned that their money lent is repaid, so underwriting of construction loans usually focuses on how that might occur.

In the most basic situation, that of an individual building a home for themselves, a business building a property for business use, or an investor building a property to rent out, the fundamental guideline is for the lender to imagine once the loan has been fully extended and converted into a normal mortgage and the building is occupied, whether the individual, business, or investor can afford to pay back the loan on a monthly basis. In the case of the individual, where the lender attempts to predict whether the individual can pay each month the loan payment that would occur once the person moves into the house, the lender would be primarily looking at the amount of income the individual receives. In the case of the business, a similar analysis would occur. In the case of an investor building rental property, a special appraisal would be ordered which would attempt to predict what the rents will be and whether they will be enough to pay back the loan, plus all expenses and still give the renter a certain minimum amount of income. The key point here is that no matter how valuable the building might be once completed, almost no lender would extend a loan for more than what the occupier could afford, because even though they will not have to make any payments during construction they would have to make monthly payments once completed and there can be no assurance that the owner would pay down the loan enough to make the monthly payments affordable once the project is completed.

Beyond this guideline, the next most common rule is a minimum cash injection requirement. Even if, for example, a business might be able to afford a monthly payment of a loan high enough to pay for the entire construction project, many lenders would require them to instead use a certain minimum portion of their own cash to complete the project. The reason for this is both to psychologically and economically tie in the owner with the project (hopefully making it less likely that they would walk away from the project if something goes wrong), and to give the lender a cushion whereby if something goes wrong they are more likely to be able to sell the real estate at a value that would better cover the loan amount. This guideline is often termed a "loan to cost" requirement, ie. the lender will only loan up to 85% of the project costs.

The final major guideline is the maximum loan amount the lender will allow relative to the completed value of the project. This rule is designed to help ensure that, after the project is completed, if the borrower stops paying the payment, the lender can sell the property and hopefully recoup all the funds loaned.

Construction Loans are often extended for developers who are seeking to build something but sell it immediately after building it. In this case, a special appraisal is ordered to attempt to predict the future sales value of the project. The first guideline above, affordability, is usually not used because the owner would immediately attempt to sell the property. However, it is used sometimes for example when a developer is building condominiums, the lender might evaluate whether if the project was changed from condominiums to apartments if the rents received would more than repay the loan each month. Cash injection requirements are often higher due to the added risk (the immediate need to sell). The loan to value requirements however are often the most impactful. This is because the value is often calculated differently than how people might assume. For example, if a developer is building a 20 unit condominium project, a lender might not just

loan a certain percentage of the predicted future total value of the condominiums, but only a certain percentage of the value of the condominium project if, because of an emergency or unforeseen circumstance, the entire building had to be sold at once to one buyer (known as a bulk sale). Since the realizable sales price in this case might be much lower, the maximum loan many lenders would extend would be much lower.

## Usual arrangements

Funds are taken from the loan through a process referred to as a "draw". A draw is the method by which funds are taken from the construction budget to pay material suppliers and contractors. Each lender has different requirements for processing a draw. For example, some allow the borrower to request draws online, while others require paperwork and periodic inspections. This process helps ensure that the loan proceeds are actually used for the construction and that the construction process is moving smoothly. The borrower is only charged interest on the amount borrowed at any one point.

Instead of paying each month during construction, almost all construction loans in the United States have extra funds borrowed right away and stored in a locked account known as an "interest reserve". Each month the monthly payments are taken from the account so that the borrower does not have to start paying out of pocket until the project is completed.

## Construction Management

Besides the underwriting guidelines detailed above, most lenders attempt to mitigate their risk in a variety of ways. The first involves due diligence on the general contractor, architect, soil upon which the property is to be built, environmental inspections, and appraisals. Then, while the construction process is ongoing, the lenders carefully inspect progress both to ensure construction is proceeding smoothly, as well as to ensure that all workers are being paid so that the security of the loan by the real estate is not violated by a "mechanics lien".

## Design-bid-build

**Design-bid-build** (or **design/bid/build**, and abbreviated **D-B-B** or **D/B/B** accordingly), also known as **Design-tender** (or "design/tender") and **Traditional Method**, is a project delivery method in which the agency or owner contracts with separate entities for each the design and construction of a project.

Design-bid-build is the traditional method for project delivery and differs in several substantial aspects from design-build.

There are three main sequential phases to the design-bid-build delivery method:

- The design phase

- The bidding (or tender) phase
- The construction phase

## **Design phase**

In this phase the owner retains an architect (or engineer for infrastructure works) to design and produce tender documents on which various general contractors will in turn bid, and ultimately be utilized to construct the project. For building projects, the architect will work with the owner to identify the owners needs, develop a written program documenting those needs and then produce a conceptual or schematic design. This early design is then developed, and the architect will usually bring in other professionals including mechanical, electrical, and plumbing engineers (MEP engineers), a fire engineer, structural engineer, sometimes a civil engineer and often a landscape architect to complete documents (drawings and specifications). These documents are then coordinated by the architect and put out for tender to various general contractors.

## **Bid (or tender) phase**

Bids (tenders) can be "open", in which any qualified bidder may participate, or "select", in which a limited number of pre-selected contractors are invited to bid.

The various general contractors bidding on the project obtain copies of the tender documents, and then put them out to multiple subcontractors for bids on sub-components of the project. Sub-components include items such as the concrete work, structural steel frame, electrical systems, and landscaping. Questions may arise during the tender period, and the architect will typically issue clarifications or addenda. From these elements, the contractor compiles a complete "tender price" for submission by the closing date and time. Tender documents can be based on the quantities of materials in the completed construction such as in the UK with Bills of quantities, or the operations needed to build it as in Operational bills.

Once bids are received, the architect typically reviews the bids, seeks any clarifications required of the bidders, ensures all documentation is in order (including bonding if required), and advises the owner as to the ranking of the bids. If the bids fall in a range acceptable to the owner, the owner and architect discuss the suitability of various bidders and their proposals. The owner is not obligated to accept the lowest bid, and it is customary for other factors including past performance and quality of other work to influence the selection process. The project is usually awarded to the lowest bid by a qualified general contractor.

In the event that all of the bids are in excess of the goals of the owner, the owner may elect to reject all bids. The following options become available:

- Abandon the project.

- The architect may revise the design at no cost to the owner, making the project smaller or more efficient, or reduce features or elements of the project to bring the cost down. The revised documents can then be re-tendered.
- The owner may elect to select the lowest qualified bid's general contractor to join the architectural team to assist with cost reduction. This process is often referred to as value engineering.

## **Construction phase**

After the project has been awarded, the construction documents may be updated to incorporate addenda or changes and they are issued for construction. The necessary approvals (such as the building permit) must be achieved from all jurisdictional authorities for the construction process to begin.

In most instances, almost every component of a project is supplied and installed by sub-contractors. The general contractor often provides work with its own forces, but it is not uncommon for a general contractor to limit its role to management of the construction process and daily activity on a construction site.

The architect acts as the owner's agent to review the progress of the work and to issue site instructions, change orders or other documentation necessary to the construction process.

## **Potential problems of design-bid-build**

- Failure of the design team to be current with construction costs, and any potential cost increases during the design phase could cause project delays if the construction documents must be redone to reduce costs.
- Redesign expense can be disputed should the architect's contract not specifically address the issue of revisions required to reduce costs.
- Development of a "cheaper is better" mentality amongst the general contractors bidding the project so there is the tendency to seek out the lowest cost sub-contractors in a given market. In strong markets, general contractors will be able to be selective about which projects to bid, but in lean times, the desire for work usually forces the low bidder of each trade to be selected. This usually results in increased risk (for the general contractor) but can also compromise the quality of construction. In the extreme, it can lead to serious disputes involving quality of the final product, or bankruptcy of a sub-contractor who was on the brink of insolvency desperate for work.
- As the general contractor is brought to the team post design, there is little opportunity for input on effective alternates being presented.
- Pressures may be exerted on the design and construction teams, which may lead to disputes between the architect and the general contractor.
- System development life cycle is known as SDLC

## Benefits of design-bid-build

- The design team is impartial and looks out for the interests of the Owner.
- The design team prepares documents on which all general contractors place bids. With this in mind, the "cheaper is better" argument is rendered invalid since the bids are based on complete documents. Incomplete, incorrect or missed items are usually discovered and addressed during the bid process.
- Ensures fairness to potential bidders and improves decision making by the owner by providing a range of potential options. It also identifies new potential contractors.
- Assists the owner in establishing reasonable prices for the project.
- Uses competition to improve the efficiency and quality for owners.

## Design-build

**Design-build** (or **design/build**, and abbreviated **D-B** or **D/B** accordingly) is a construction project delivery system where, in contrast to "design-bid-build" (or "design-tender"), the design and construction aspects are contracted for with a single entity known as the **design-builder** or **design-build contractor**. The design-builder is usually the general contractor, but in many cases it is also the design professional (architect or engineer). This system is used to minimize the project risk for an owner and to reduce the delivery schedule by overlapping the design phase and construction phase of a project. Where the design-builder is the contractor, the design professionals are typically retained directly by the contractor. The most efficient design-builder has design and construction professionals working directly for the same at-risk entity. This is one of the oldest forms of construction since developing from the "master builder" approach.

## Criticisms of Design-Build

A notable design-build project that received significant criticism, not only for excessive cost but for environmental issues, was the Belmont Learning Center. The scandal involved alleged contaminated soil that caused significant delays and massive cost overruns. In Los Angeles, District Attorney Steve Cooley, who investigated the Los Angeles Unified School District's Belmont project, produced a final investigative report, released March 2003. This report concluded that the design-build process caused a number of issues relating to the Belmont scandal:

- Design-Build does not make use of competitive bidding where prospective builders bid on the same design.
- Criteria to select contractor is subjective and difficult to evaluate and to justify later.
- The design and price selected arouses public suspicion, true or not.
- This can lead to loss of public confidence.

It concluded the “design-build” approach and “mixed-use concept” together caused controversy, uncertainty, and complexity of the Belmont project which helped increased the potential for project failure.

While the Belmont investigation cleared the Los Angeles Unified School District of any criminal wrongdoing, the task force recommends strict oversight, including written protocols, a vigorous Office of the Inspector General, and other recommendations if it decides to continue to use the design-build approach.

As of 2009 and on, the Los Angeles Unified School District has vigorously started a campaign to use design-build approach in many of their projects, led by their Chief of Facilities, James Sohn. It is also important to note that during this time, the Superintendent of LAUSD, Ramon C. Cortines, working with the LAUSD Board of Education, actively tried to cut the Office of Inspector General by 75% (compromising on 25%) and subsequently removed the Inspector General Jerry Thornton after he produced critical audits that showed misuse of construction funds.

## Occupancy

**Occupancy** in building construction and building codes is the use or intended use of a building or part thereof for the shelter or support of persons, animals or property. A closely-related meaning is the number of units in such a building that are rented or leased, or otherwise in-use. The lack of occupancy in this sense is a vacancy.

## Building code

It is possible to have multiple occupancies (or building uses) within one building. For instance, one may have a high-rise building, where the lower levels are occupied by retail stores, whereas the upper levels could be residential. Different occupancies within one building are separated by a fire barrier with a defined fire-resistance rating. It is common for a penetration, such as a fire door, to have a fire protection rating lower than the wall fire resistance rating in which it is installed. For example, a two-hour fire separation normally requires fire doors rated at 90-minutes.

For some high challenge occupancies the code requirements for an occupancy separation are more stringent than for other fire-barriers, even with an identical fire-resistance rating. In this case, an occupancy separation with a two-hour fire-resistance rating may not be able to *de-rate* its *closures*, such fire doors or firestops. For example, a two-hour rated *high challenge fire wall* requires 2 hr rated fire doors.

Firestops in occupancy separations are also more likely to be required not only an equal *fire protection rating* (a fire-resistance rating for closures) but must also provide a temperature rating, such that the components of the firestop systems, including the penetrants, are not permitted to rise in temperature above 140°C (284°F) on average or 180°C (356°F) on any single point, so as to lower the likelihood of auto-ignition on the

unexposed side. In this manner, occupancy separations are treated similarly to fire walls, which are structurally stable in case of a fire, limiting fire-induced building collapse.

In this sense, there are two occupancies in most single-family homes: the garage and the living space of the home. Because automobile gasoline or petrol is flammable, an occupancy separation is often required between the two, should there be a vehicle fire. Water heaters and central heating are often placed in this space as well, for their use of natural gas, propane, or other fossil fuels in combustion. This also helps to prevent carbon monoxide poisoning.

## **Building utilization**



The interior of a vacant building showing signs of vandalism and decay

Occupancy can also refer to the number of units in use, such as hotel rooms, apartment flats, or offices. When a motel is at full (100%) occupancy, a NO VACANCY neon sign is often turned on (though the sign often still says VACANCY at other times). Office buildings and apartments in particular aim for full occupancy, but if too many are built in an area this is often not the case. Completely vacant buildings can also attract crime, and are eventually targeted for redevelopment or at least renovation.

Occupancy can also mean the number of persons using an undivided space, such as a meeting room, ballroom, auditorium, or stadium. As with building codes, fire-protection authorities often set a limit on the number of people that can occupy a space, primarily because they must be able to leave the building through the available number of exits in a reasonable amount of time, without tripping or trampling each other in a panicked stampede, possibly blinded by smoke. The integrity of a structure may also be at stake, because too many people will put excessive weight and other forces, leading in some cases to a collapse.

An occupancy sensor is a device that can tell if someone is in a room, and is often used in home automation and security systems. These are typically more advanced than motion sensors, which can only detect motion.

## **Other meanings**

In transport engineering, occupancy can refer to:

1. The number of passengers occupying a vehicle.
2. The percentage of time in which a detector is occupied by a vehicle.
3. The average number of particles occupying a state.