Construction Handbook

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Construction

In large construction projects, such as this skyscraper in Melbourne, cranes are essential.

In the fields of architecture and civil engineering, **construction** is a process that consists of the **building** or assembling of infrastructure. Far from being a single activity, large scale construction is a feat of human multitasking. Normally, the job is managed by a project manager, and supervised by a construction manager, design engineer, construction engineer, or project architect.

For the successful execution of a project, effective planning is essential. Those involved with the design and execution of the infrastructure in question must consider the environmental impact of the job, the successful scheduling, budgeting, construction site safety, availability of building materials, logistics, inconvenience to the public caused by construction delays, and bidding, etc.

Types of construction projects

Construction of a prefabricated home

In general, there are three types of construction:

1. Building construction
2. Heavy / civil construction
3. Industrial construction

Each type of construction project requires a unique team to plan, design, construct, and maintain the project.

Building construction

A building site for a row of riverside apartment blocks in Cambridge

A large unfinished building

Building construction is the process of adding structure to real property. The vast majority of building construction projects are small renovations, such as addition of a room, or renovation of a bathroom. Often, the owner of the property acts as laborer, paymaster, and design team for the entire project. However, all building construction projects include some elements in common - design, financial, and legal considerations. Many projects of varying sizes reach undesirable end results, such as structural collapse, cost overruns, and/or litigation reason, those with experience in the field make detailed plans and maintain careful oversight during the project to ensure a positive outcome.

Building construction is procured privately or publicly utilizing various delivery methodologies, including hard bid, negotiated price, traditional, management contracting, construction management-at-risk, design & build and design-build bridging.

Residential construction practices, technologies, and resources must conform to local building authority regulations and codes of practice. Materials readily available in the area generally dictate the construction materials used (e.g. brick versus stone, versus timber). Cost of construction on a per square metre (or per square foot) basis for houses can vary dramatically based on site conditions, local regulations, economies of scale (custom designed homes are always more expensive to build) and the availability of skilled tradespeople. As residential (as well as all other types of construction) can generate a lot of waste, careful planning again is needed here.

The most popular method of residential construction in the United States is wood framed construction. As efficiency codes have come into effect in recent years, new construction technologies and methods have emerged. University Construction Management departments are on the cutting edge of the newest methods of construction intended to improve efficiency, performance and reduce construction waste.

Heavy / civil construction

Civil engineering deals with the design, construction and maintenance of the physical and naturally built environment, including works such as bridges, roads, canals, dams and buildings.

Industrial construction

Industrial construction, though a relatively small part of the entire construction industry, is a very important component. Owners of these projects are usually large, for-profit, industrial corporations. These corporations can be found in such industries as medicine, petroleum, chemical, power generation, manufacturing, etc. Processes in these industries require highly specialized expertise in planning, design, and construction. As in building and heavy/highway construction, this type of construction requires a team of individuals to ensure a successful project. Industrial construction is very important.Sometimes it may cause or harm the environment.

Construction processes

Design team

Shasta Dam under construction in June 1942

In the modern industrialized world, construction usually involves the translation of designs into reality. A formal design team may be assembled to plan the physical proceedings, and to integrate those proceedings with the other parts. The design usually consists of drawings and specifications, usually prepared by a design team including surveyors, civil engineers, cost engineers (or quantity surveyors), mechanical engineers, electrical engineers, structural engineers, and fire protection engineers. The design team is most commonly employed by (i.e. in contract with) the property owner. Under this system, once the design is completed by the design team, a number of construction companies or construction management companies may then be asked to make a bid for the work, either based directly on the design, or on the basis of drawings and a bill of quantities provided by a quantity surveyor. Following evaluation of bids, the owner will typically award a contract to the most cost efficient bidder.

The modern trend in design is toward integration of previously separated specialties, especially among large firms. In the past, architects, interior designers, engineers, developers, construction managers, and general contractors were more likely to be entirely separate companies, even in the larger firms. Presently, a firm that is nominally an "architecture" or "construction management" firm may have experts from all related fields as employees, or to have an associated company that provides each necessary skill. Thus, each such firm may offer itself as "one-stop shopping" for a construction project, from beginning to end. This is designated as a "design Build" contract where the contractor is given a performance specification, and must undertake the project from design to construction, while adhering to the performance specifications.

Several project structures can assist the owner in this integration, including design-build, partnering, and construction management. In general, each of these project structures allows the owner to integrate the services of architects, interior designers, engineers, and constructors throughout design and construction. In response, many companies are growing beyond traditional offerings of design or construction services alone, and are placing more emphasis on establishing relationships with other necessary participants through the design-build process.

The increasing complexity of construction projects creates the need for design professionals trained in all phases of the project's life-cycle and develop an appreciation of the building as an advanced technological system requiring close integration of many sub-systems and their individual components, including sustainability. **Building engineering** is an emerging discipline that attempts to meet this new challenge.

Financial advisors

Trump International Hotel and Tower (Chicago)

May 23, 2006

September 14, 2007 (3 months before completion)

Many construction projects suffer from preventable financial problems. **Underbids** ask for too little money to complete the project. Cash flow problems exist when the present amount of funding cannot cover the current costs for labour and materials, and because they are a matter of having sufficient funds at a specific time, can arise even when the overall total is enough. Fraud is a problem in many fields, but is notoriously prevalent in the construction field. Financial planning for the project is intended to ensure that a solid plan, with adequate safeguards and contingency plans, is in place before the project is started, and is required to ensure that the plan is properly executed over the life of the project.

Mortgage bankers, accountants, and cost engineers are likely participants in creating an overall plan for the financial management of the building construction project. The presence of the mortgage banker is highly likely even in relatively small projects, since the owner's equity in the property is the most obvious source of funding for a building project. Accountants act to study the expected monetary flow over the life of the project, and to monitor the payouts throughout the process. Cost engineers apply expertise to relate the work and materials involved to a proper valuation. Cost overruns with government projects have occurred when the contractor was able to identify change orders or changes in the project resulting in large increases in cost, which are not subject to competition by other firm as they have already been eliminated from consideration after the initial bid.

Large projects can involve highly complex financial plans. As portions of a project are completed, they may be sold, supplanting one lender or owner for another, while the logistical requirements of having the right trades and materials available for each stage of the building construction project carries forward. In many English-speaking countries, but not the United States, projects typically use quantity surveyors.

Legal considerations

Construction along Ontario Highway 401, widening the road from six to twelve travel lanes.

A construction project must fit into the legal framework governing the property. These include governmental regulations on the use of property, and obligations that are created in the process of construction.

The project must adhere to zoning and building code requirements. Constructing a project that fails to adhere to codes will not benefit the owner. Some legal requirements come from malum in se considerations, or the desire to prevent things that are indisputably bad - bridge collapses or explosions. Other legal requirements come from malum prohibitum considerations, or things that are a matter of custom or expectation, such as isolating businesses to a business district and residences to a residential district. An attorney may seek changes or exemptions in the law governing the land where the building will be built, either by arguing that a rule is inapplicable (the bridge design will not collapse), or that the custom is no longer needed (acceptance of live-work spaces has grown in the community).

A construction project is a complex net of contracts and other legal obligations, each of which must be carefully considered. A contract is the exchange of a set of obligations between two or more parties, but it is not so simple a matter as trying to get the other side to agree to as much as possible in exchange for as little as possible. The time element in construction means that a delay costs money, and in cases of bottlenecks, the delay can be extremely expensive. Thus, the contracts must be designed to ensure that each side is capable of performing the obligations set out. Contracts that set out clear expectations and clear paths to accomplishing those expectations are far more likely to result in the project flowing smoothly, whereas poorly drafted contracts lead to confusion and collapse.

Legal advisors in the beginning of a construction project seek to identify ambiguities and other potential sources of trouble in the contract structure, and to present options for preventing problems. Throughout the process of the project, they work to avoid and resolve conflicts that arise. In each case, the lawyer facilitates an exchange of obligations that matches the reality of the project.

Interaction of expertise

Apartment complex under construction in Daegu, South Korea

Design, finance, and legal aspects overlap and interrelate. The design must be not only structurally sound and appropriate for the use and location, but must also be financially possible to build, and legal to use. The financial structure must accommodate the need for building the design provided, and must pay amounts that are legally owed. The legal structure must integrate the design into the surrounding legal framework, and enforce the financial consequences of the construction process.

Procurement

Procurement describes the merging of activities undertaken by the client to obtain a building. There are many different methods of construction procurement; however the three most common types of procurement are:

1. Traditional (Design-bid-build)
2. Design and Build
3. Management Contracting

There is also a growing number of new forms of procurement that involve relationship contracting where the emphasis is on a co-operative relationship between the principal and contractor and other stakeholders within a construction project. New forms include partnering such as Public-Private Partnering (PPPs) aka Private Finance Initiatives (PFIs) and alliances such as "pure" or "project" alliances and "impure" or "strategic" alliances. The focus on co-operation is to ameliorate the many problems that arise from the often highly competitive and adversarial practices within the construction industry.

Traditional

This is the most common method of construction procurement and is well established and recognized. In this arrangement, the architect or engineer acts as the project coordinator. His or her role is to design the works, prepare the specifications and produce construction drawings, administer the contract, tender the works, and manage the works from inception to completion. There are direct contractual links between the architect's client and the main contractor. Any subcontractor will have a direct contractual relationship with the main contractor.

Design and build

Construction of the *Phase-1* (first two towers) of the Havelock City Project, Sri Lanka.

This approach has become more common in recent years and includes an entire completed package, including fixtures, fittings and equipment where necessary, to produce a completed fully functional building. In some cases, the Design and Build (D & B) package can also include finding the site, arranging funding and applying for all necessary statutory consents.

The owner produces a list of requirements for a project, giving an overall view of the project's goals. Several D&B contractors present different ideas about how to accomplish these goals. The owner selects the ideas he likes best and hires the appropriate contractor. Often, it is not just one contractor, but a consortium of several contractors working together. Once a contractor (or a consortium/consortia) has been hired, they begin building the first phase of the project. As they build phase 1, they design phase 2. This is in contrast to a design-bid-build contract, where the project is completely designed by the owner, then bid on, then completed.

Kent Hansen, director of engineering for the National Asphalt Pavement Association (NAPA), pointed out that state departments of transportation (DOTs) usually use design build contracts as a way of getting projects done when states don't have the resources. In DOTs, design build contracts are usually used for very large projects.

Management procurement systems

In this arrangement the client plays an active role in the procurement system by entering into separate contracts with the designer (architect or engineer), the construction manager, and individual trade contractors. The client takes on the contractual role, while the construction or project manager provides the active role of managing the separate trade contracts, and ensuring that they all work smoothly and effectively together.

Management procurement systems are often used to speed up the procurement processes, allow the client greater flexibility in design variation throughout the contract, the ability to appoint individual work contractors, separate contractual responsibility on each individual throughout the contract, and to provide greater client control.

Authority having jurisdiction

Construction on a building in Kansas City, Missouri

In construction, the **authority having jurisdiction** (AHJ) is the governmental agency or sub-agency which regulates the construction process. In most cases, this is the municipality in which the building is located. However, construction performed for supra-municipal authorities are usually regulated directly by the owning authority, which becomes the AHJ.

During the planning of a building, the zoning and planning boards of the AHJ will review the overall compliance of the proposed building with the municipal General Plan and zoning regulations. Once the proposed building has been approved, detailed civil, architectural, and structural plans must be submitted to the municipal **building department** (and sometimes the public works department) to determine compliance with the building code and sometimes for fit with existing infrastructure. Often, the municipal fire department will review the plans for compliance with fire-safety ordinances and regulations.

Before the foundation can be dug, contractors are typically required to notify utility companies, either directly or through a company such as Dig Safe to ensure that underground utility lines can be marked. This lessens the likelihood of damage to the existing electrical, water, sewage, phone, and cable facilities, which could cause outages and potentially hazardous situations. During the construction of a building, the municipal building inspector inspects the building periodically to ensure that the construction adheres to the approved plans and the local **building code**. Once construction is complete and a final inspection has been passed, an **occupancy permit** may be issued.

An operating building must remain in compliance with the **fire code**. The fire code is enforced by the local fire department.

Changes made to a building that affect safety, including its use, expansion, structural integrity, and fire protection items, usually require approval of the AHJ for review concerning the building code.

Construction careers

Ironworkers erecting the steel frame of a new building at Massachusetts General Hospital, Boston

There are many routes to the different careers within the construction industry which vary by country. However, there are three main tiers of careers based on educational background which are common internationally:

- Unskilled and Semi-Skilled - General site labour with little or no construction qualifications.

- Skilled - On-site managers whom possess extensive knowledge and experience in their craft or profession.
- Technical and Management - Personnel with the greatest educational qualifications, usually graduate degrees, trained to design, manage and instruct the construction process.

Skilled occupations in the UK require further education qualifications, often in vocational subject areas. These qualifications are either obtained directly after the completion of compulsory education or through "on the job" apprenticeship training. In the UK, 8500 construction-related apprenticeships were commenced in 2007. Skills in the United States and abroad differ very little: the very simple change that can be obviously perceived is language: some of the latest skills required in the United States can be interpreted by contacting Construction Citizen s in America and abroad.

Technical and specialised occupations require more training as a greater technical knowledge is required. These professions also hold more legal responsibility. A short list of the main careers with an outline of the educational requirements are given below:

- Architect - Typically holds at least a 5 to 6-year degree in architecture. To use the title "architect" the individual must hold chartered status with the Royal Institute of British Architects and be on the Architects Registration Board.
- Civil Engineer - Typically holds a degree in a related subject. The Chartered Engineer qualification is controlled by the Institution of Civil Engineers. A new university graduate must hold a master's degree to become chartered, persons with bachelor's degrees may become an Incorporated Engineer.
- Building Services Engineer - Often referred to as an "M&E Engineer" typically holds a degree in mechanical or electrical engineering. Chartered Engineer status is governed by the Chartered Institution of Building Services Engineers.
- Project Manager - Typically holds a 4-year or greater higher education qualification, but are often also qualified in another field such as quantity surveying or civil engineering.
- Quantity Surveyor - Typically holds a master's degree in quantity surveying. Chartered status is gained from the Royal Institution of Chartered Surveyors.
- Structural Engineer - Typically holds a bachelors or master's degree in structural engineering, new university graduates must hold a master's degree to gain chartered status from the Institution of Structural Engineers.

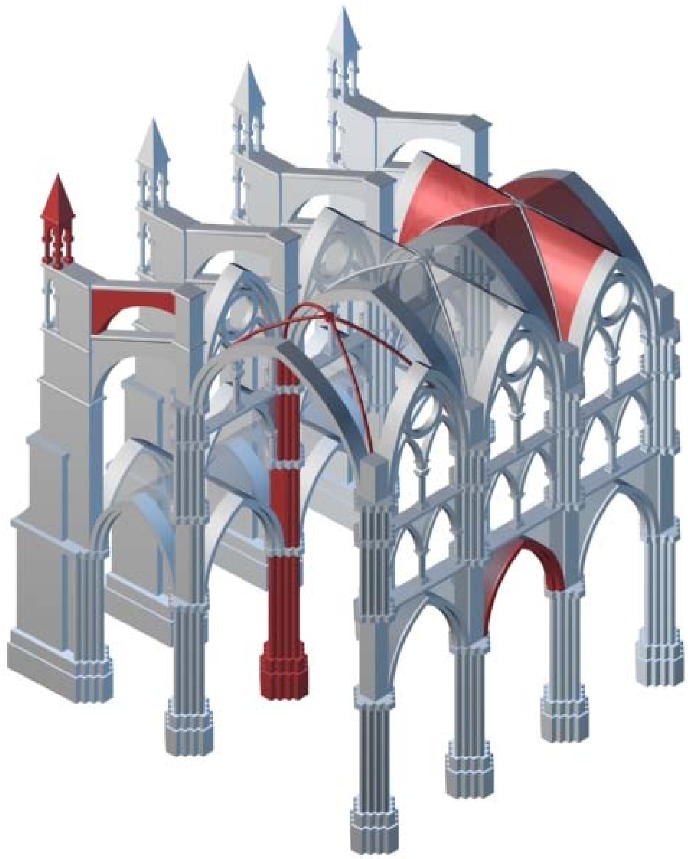
History

The first buildings were huts and shelters, constructed by hand or with simple tools. As cities grew during the Bronze Age, a class of professional craftsmen, like bricklayers and carpenters, appeared. Occasionally, slaves were used for construction work. In the Middle Ages, these were organized into guilds. In the 19th century, steam-powered machinery appeared, and later diesel- and electric powered vehicles such as cranes, excavators and bulldozers. Modern-day Construction involves creating awesome structures that can show the beauty and creativity of the human intellect. Some great examples of art in buildings or architecture include the London Shard, which can be viewed on Construction Citizen, a website updated daily for increasing construction labor.

Chapter- 2

History of Construction

Church in Kizhi, Russia is listed as UNESCO world heritage site as building constructed entirely out of wood, without a single nail



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Few things are more fascinating than how humans have changed the world around them. Mankind has **constructed** buildings and other structures since prehistory. The History of Construction is not limited to buildings but covers bridges, amphitheatres, dams, electricity pylons, road and canals to give just a few examples. Today we take the incredible feats of engineering very much for granted but virtually all of the building materials we use today have a long history and some of the structures built thousands of years ago without the aid of modern technology still have the ability to amaze. The history of construction is related to, but not identical with, the history of structural engineering. To understand why things were constructed the way they were, we also need to rely on archaeology to record the form of the parts that survive and the tools they used, economic history to inform us of how much they cost, social history to tell us about how the builders lived, and architectural history to tell us about the books and writings of the builders. It is a huge subject, but one that should interest anyone who wants to know more about how and why the built world around them is the way it is.

Chronological Development

The history of construction is a complex subject encompassing the history of building materials, the history of engineering, the history of building techniques, economic and social history of builders and workmen, the history of construction machinery and temporary works etc etc. Each of these has a complex literature devoted to it, but it perhaps worth providing the briefest of summaries here in the hope that others will start new more detailed pages.

Neolithic construction

Neolithic buildings in Skara Brae, Skara Brae is listed as a UNESCO world heritage site

The first bridges made by humans were probably wooden logs placed across a stream. The first buildings were simple huts, tents and shelters meant to suit the basic needs of protection from the elements, built by their inhabitants. The very simplest shelters, tents, leave no traces behind them. Because of this, what little we can say about very early construction is mostly conjecture and based on what we know about the way nomadic hunter-gatherers and herdsmen in remote areas build shelters today. The absence of metal tools placed limitations on the materials that could be worked, but it was still possible to build quite elaborate stone structures with ingenuity using dry stone walling techniques. The first mud bricks, formed with the hands rather than wooden moulds belong to the late neolithic period and were found in Jericho. One of the largest structures if this period was the Neolithic long house. In all cases of timber structures in these very early cultures, only the very lowest parts of the walls and post holes are unearthed in archaeological excavations, making reconstruction of the upper parts of these building purely conjectural.

Construction in Ancient Mesopotamia

Ziggurat of Ur

The earliest large scale buildings for which any real evidence survives have been found in ancient Mesopotamia. The smaller dwellings only survive in traces of foundations, but the later civilisations built very sizeable structures in the forms of palaces, temples and ziggurats and took particular care to build them out of materials that last. which has ensured that very considerable parts have remained intact.

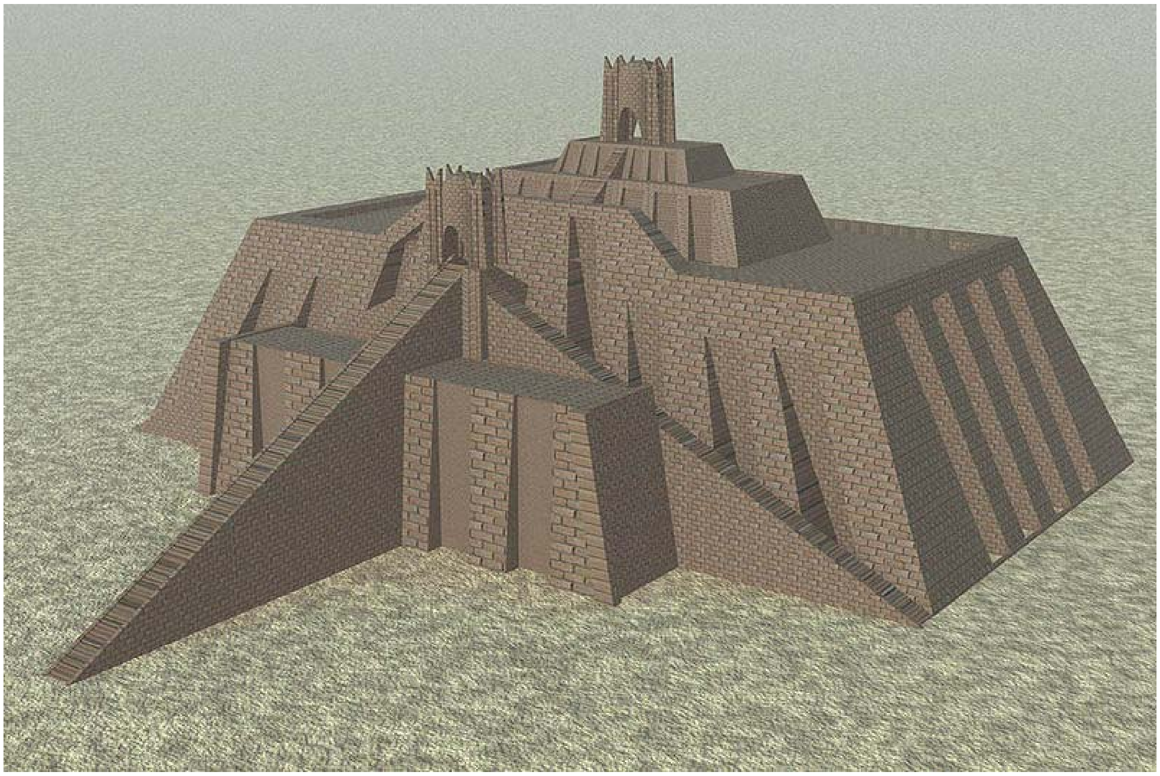
Materials

Detail of the Ishtar Gate showing the exceptionally fine glazed brickwork of the later period

The chief building material was the mud brick, formed in wooden moulds (adobe). Bricks varied widely in size and format from small bricks that could be lifted in one hand to ones as big as large paving slabs. Rectangular bricks are found but square format bricks were also common. They were laid in virtually every bonding pattern imaginable and used with considerable sophistication. Drawings survive on clay tablets from later periods showing that buildings were set out on brick modules. By 3500BC bricks were also being fired and records survives showing a very complex division of labour into separate tasks and trades. Life in general was governed by complex ritual and this extended to rituals for setting out buildings and moulding the first bricks. Contrary to popular belief the arch was not invented by the Romans, but was used in these civilisations. The later Mesopotamian civilisations, particularly Babylon and thence Susa, developed glazed brickwork to a very high degree, decorating the interiors and exteriors of their buildings with glazed brick reliefs, examples of which survive in the archaeological museum in Tehran, the Louvre Museum in Paris and the Pergamon Museum in Berlin.

Major technical achievements

The major technical achievements are in the construction of great cities such as Uruk and Ur. The Ziggurat of Ur remains one of the most outstanding surviving buildings of the period, despite major reconstruction work. Another fine example is the ziggurat at Chogha Zanbil in modern Iran.



Reconstruction of the Ziggurat of Ur

Babylon,the archaeological site in 1932, before major reconstruction work undertaken by Sadam Hussein

Construction in Ancient Egypt

Karnak, Hypostyle hall

Aerial view of the Ramasseum in Thebes with its associated adobe structures

As opposed to the cultures of Ancient Mesopotamia which built in brick, the pharohs of Egypt built huge structures in stone. The dry arid climate has preserved many of the ancient buildings largely intact.

Materials

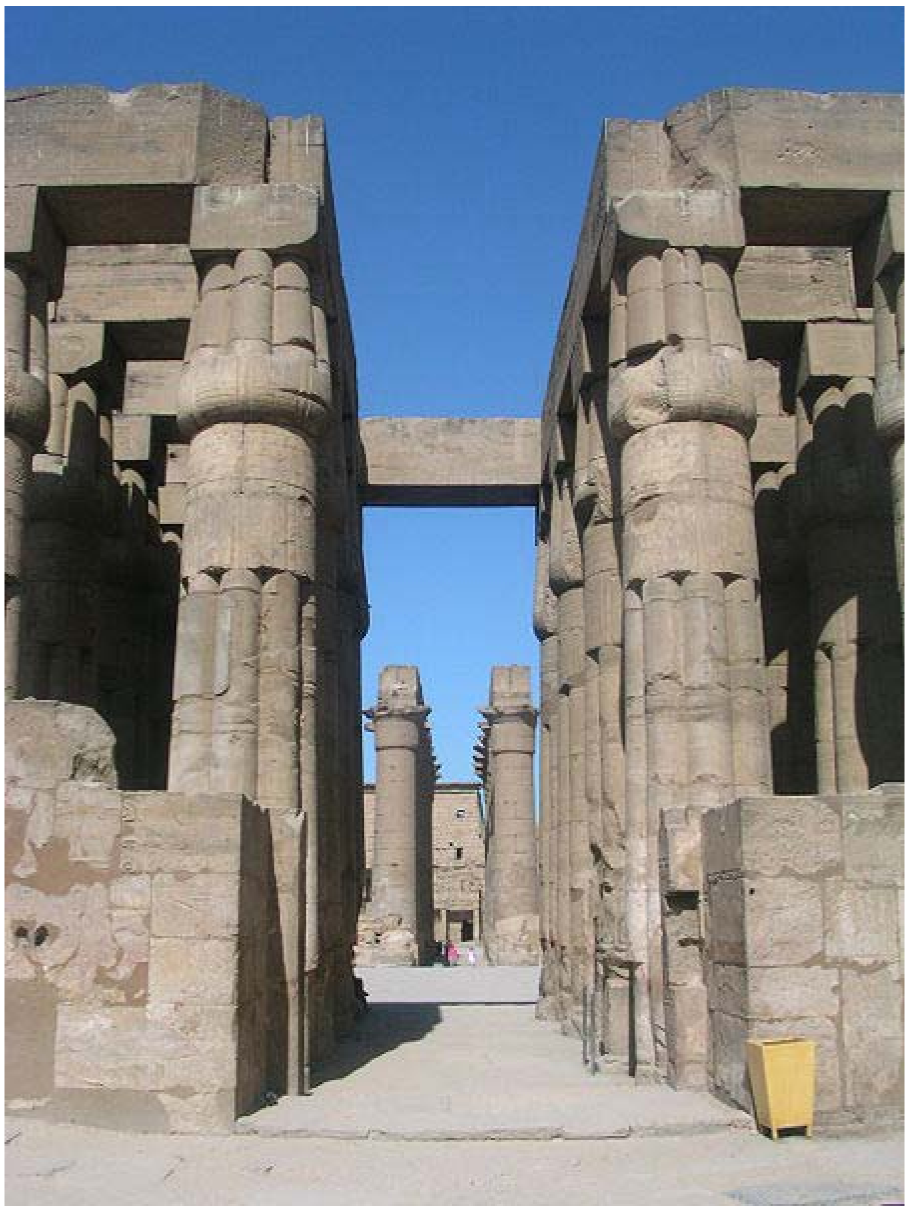
Adobe (sun-baked mud brick) construction was used for ancillary buildings and normal houses in ancient times and is still commonly used in rural Egypt today. The hot dry climate was ideal for mud-brick, which tends to wash away in the rain. The Ramesseum in Thebes, Egypt (Luxor) provides one of the finest examples of mud brick construction, with extensive storehouses with mud-brick vaults surviving, all constructed with sloping courses to avoid the need for formwork.

The grandest buildings were constructed in stone, often from massive masonry blocks. The techniques used to move the massive blocks often used in pyramids and temples have been subject to extensive debate. Some authors have even maintained that the larger blocks are not cut stone at all but actually artificial stone made using concrete. This theory is very controversial and not widely accepted.

Technology

Although the Egyptians achieved extraordinary feats of engineering, they appear to have done so with relatively primitive technology. As far as is known they did not use wheels or pulleys. They transported massive stones over great distances using rollers, ropes, and sledges, with large numbers of slaves hauling the loads. There are no surviving Egyptian manuals so there has been considerable speculation on how stones were lifted to great heights and obelisks erected. Most theories centre around the use of ramps.

Outstanding Achievements



Karnak, Hypostyle hall

The pyramids are chiefly impressive for their enormous size and the staggering manpower that must have been employed in their construction. Of these the largest is the Great Pyramid of Giza which remained the tallest structure in the world for 3800 years. The engineering problems involved were chiefly to do with the transport of blocks, sometimes over long distances, their movement into location and exact alignment. It is now generally agreed that the skilled building workers were respected and well treated, but undoubtedly very large numbers of laborers were necessary to provide much of the brute force.

The methods used in the construction of the pyramids have been the subject of considerable research and discussion.

Great Pyramid of Giza, the tallest building in the world for over 3800 years

Menkaures Pyramid, Giza

Construction in Ancient Greece

The ancient Greeks, like the Egyptians and the Mesopotamians,tended to build most of their common buildings out of mud brick, leaving no record behind them. However very many structures do survive, some of which are in a very good state of repair, although some have been party reconstructed or re-erected in the modern era. The most dramatic are the Greek Temples.

No timber structures survive (roofs, floors etc), so our knowledge of how these were put together is purely conjectural. The spans are in the main limited and suggest very simple beam and post structures spanning between stone walls.

Fire clay was mainly restricted to roofing tiles and associated decorations, but these were quite elaborate. Fired bricks were not commonly employed. Very prominent buildings were roofed in stone tiles, which mimicked the form of their terracotta counterparts. While later cultures tended to construct their stone buildings with thin skins of finished stones over rubble cores, the Greeks tended to build out of large cut blocks, joined with metal cramps. This was a slow expensive and laborious process which limited the number of buildings that could be constructed. The metal cramps have often led to later failure through corrosion.

Building structures used a simple beam and column system without vaults or arches, which based strict limits on the spans that could achieved. However the Greeks did construct Arch Bridges.

Greek mathematics was technically advanced and we know for certain that they employed and understood the principles of pulleys, which would have enabled them to build gibs and cranes to lift heavy stonework to the upper parts of buildings. Their surveying skills were exceptional, enabling them to set out the incredibly exact optical corrections of buildings like the Parthenon, although the methods used remain a mystery. Simpler decoration, such as fluting on columns was simply left until the drums of the columns were cut in place.

The Ancient Greeks never developed the strong mortars which were to become such an important feature of Roman construction.

Roman construction

The Baths of Caracalla, in 2009

Reconstructed Roman treadwheel crane at Bonn, Germany

The Pantheon in Rome looking up inside the concrete dome.

In striking contrast to previous cultures, an enormous amount is known about Roman building construction. A very large amount survives, including complete intact buildings like the Pantheon, Rome and very well preserved ruins at Pompeii and Herculaneum. We also have the first surviving treatise on architecture by Vitruvius which includes extensive passages on construction techniques.

Materials

The great Roman breakthrough was the development of hydraulic lime mortar. Previous cultures had used lime mortars but by adding volcanic ash the Romans managed to make a mortar that would harden underwater. This provided them with a cheap material for bulk walling. They used brick or stone to build the outer skins of the wall and then filled the space between with massive amounts of concrete, effectively using the brickwork as permanent shuttering. The concrete, being formed of nothing more than rubble and mortar was cheap and very easy to produce, requiring relatively unskilled labour, enabling the Romans to build huge on an unprecedented scale. They not only used it for walls but also to form arches, barrel vaults and domes, which they built over huge spans. The Romans developed systems of hollow pots for making their domes and sophisticated heating and ventilation systems for their thermal baths. Glass was commonly used in windows.

Organisation of Labour

The Romans had trade guilds. Most construction was done by slaves or freed men. The use of slave labour undoubtedly cut costs and was one of the reasons for the scale of some of the structures. The Romans placed a considerable emphasis in building their buildings extremely fast, usually within two years. For very large structures the only way this could be achieved was by the application of vast numbers of workers to the task.

Technology

Vitruvius gives details of many Roman machines. The Romans developed sophisticated timber cranes allowing them to lift considerable weights to great heights. The upper limit of lifting appears to have been 100 tonnes. Trajan's column in Rome contains some of the largest stones ever lifted in a Roman building and engineers are still uncertain exactly how it was achieved.

Outstanding technical Achievements

A list of the longest, highest and deepest Roman structures can be found at List of ancient architectural records. Roman building ingenuity extended over bridges, aqueducts, and covered amphitheatres. Their sewerage and water supply works were remarkable and some systems are still in operation today. The only aspect of Roman construction for which very little evidence survives is the form of timber roof structures, none of which are thought to have survives intact. Nevertheless its is generally agreed however that the Romans used triangulated roof trusses as this is the only way they could have covered the immense spans they achieved, the longest exceeding 30 metres.

Medieval construction

Notre Dame, Paris

Castle Bodiam, England

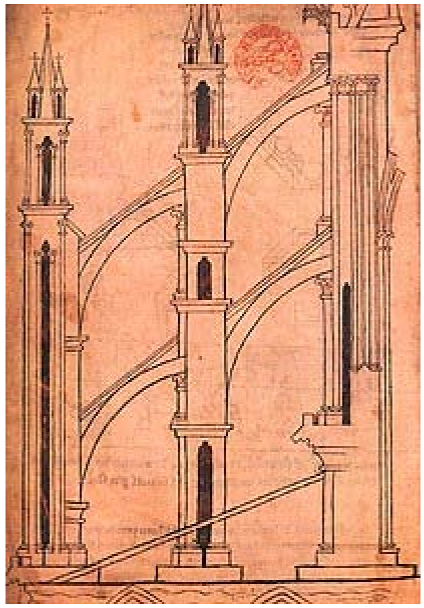
Milan Cathedral, Italy

In the Middle Ages of Europe fortifications, castles and cathedrals were the greatest construction projects. The Roman building techniques were lost.

Materials

Most buildings in Northern Europe were constructed of timber until c.1000 AD. In Southern Europe adobe remained predominant. Brick continued to be manufactured in Italy throughout the period 600-1000 AD but elsewhere the craft of brickmaking had largely disappeared and with it the methods for burning tiles. Roofs were largely thatched. Houses were small and gathered around a large communal hall. Monasticism spread more sophisticated building techniques. The Cistercians may have been responsible for reintroducing brickmaking to the area from Holland, through Denmark and Northern Germany to Poland leading to Backsteingotik. Brick remained the most popular prestige material in these areas throughout the period. Elsewhere buildings were typically in timber or where it could be afforded, stone. Medieval stone walls were constructed using cut blocks on the outside of the walls and rubble infill, with weak lime mortars. The poor hardening properties of these mortars were a continual problem, and the settlement of the rubble filling of Romanesque and Gothic walls and piers is still a major cause for concern.

Design



Villard de Honnecourt's drawing of a flying buttress at Reims, ca. AD 1320–1335 (Bibliothèque nationale)

There were no standard textbooks on building in the Middle Ages. Master craftsmen transferred their knowledge through apprenticeships and from father to son. Trade secrets were closely guarded, as they were the source of a craftsman's livelihood. Drawings only survive from the later period. Parchment was too expensive to be commonly used and paper did not appear until the end of the period. Models were used for designing structures and could be built in large scales. Details were mostly designed al full size on tracing floors, some of which survive.

Labour

In general medieval buildings were built by paid workers. Unskilled work was done by labourers paid by the day. Skilled craftsmen served apprenticeships or learned their trade from their parents. It is not clear how many women were invomembers of the guild holding a monopoly on a particular trade in a defined area (usually within the town walls). Towns were in general very small by modern standards and dominated by the dwellings of a small number of rich nobles or merchants and cathedrals and churches.

Techniques

Romanesque buildings of the period 600-1100 AD were entirely roofed in timber or had stone barrel vaults covered by timber roofs. The Gothic style of architecture with its vaults, flying buttresses and pointed gothic arches developed in the twelfth century and in the centuries that followed ever more incredible feats of constructional daring were achieved in stone. The resulting thin stone vaults and towering buildings were constructed entirely using rules derived by trial and error. Failure were frequent, particularly in difficult areas such as crossing towers. The resulting buildings remain astounding tributes to their builders.

The pile driver was invented around 1500.

Outstanding technical Achievements

While the scale of fortifications and castle building in the Middle Ages was impressive, no buildings in this period can match the daring of the gothic cathedrals with their thin masonry vaults, and walls of glass. Outstanding examples are: Beauvais Cathedral, Chartres Cathedral, King's College Chapel and Notre Dame, Paris.

Construction in the Renaissance

The Dome of Santa Maria del Fiore , designed by Filippo Brunelleschi.

The Renaissance in Italy, the invention of moveable type and the Reformation changed the character of building. The rediscovery of Vitruvius had a strong influence. During the Middle Ages buildings were designed by the people that built them. The master mason and master carpenters learnt their trades by word of mouth and relied on experience, models and rules of thumb to determine the sizes of building elements. Vitruvius however describes in detail the education of the perfect architect who he said must be skilled in all the arts and sciences.Filippo Brunelleschi was one of the first of the new style of architects. He started life as a goldsmith and educated himself in Roman architecture by studying ruins. He went on to engineer the dome of Santa Maria del Fiore in Florence.

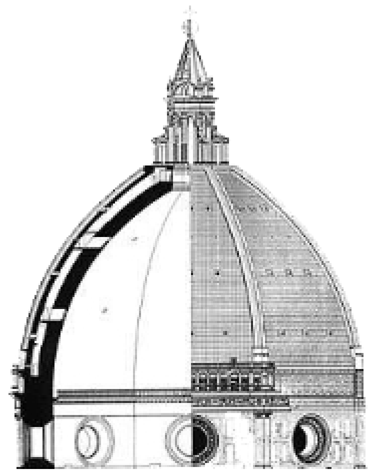
Materials

The major breakthroughs in this period were to do with the technology of conversion. Water mills in most of Western Europe were used to saw timber and convert trees into planks. Bricks were used in ever increasing quantities. In Italy the brickmakers were organised into guilds although the kilns were mostly in rural areas because of the risk of fire and easy availability of firewood and brickearth. Brickmakers typically paid by the brick which gave them an incentive to make them too small. As a result legislation was laid down regulating the minimum sizes and each town kept measures against which bricks had to be compared. An increasing amount of ironwork was used in roof carpentry for straps and tension members. The iron was fixed using forelock bolts. The screw-threaded bolt (and nut) could be made and are found in clockmaking in this period, but they were labour intensive and thus not used on large structures. Roofing was typically terracotta roof tiles. In Italy they followed Roman precedents. In Northern Europe plain tiles were used. Stone remained the material of choice where available for prestige buildings.

Design

The rebirth of the idea of an architect in the renaissance radically changed the nature of building design. Indeed Medieval buildings were conceived in totally different terms. The Renaissance reintroduced the classical style of architecture. Leon Battista Alberti's treatise on architecture raised the subject to a new level, defining architecture as something worthy of study by the aristocracy. Previously it was viewed merely as a technical art, suited only to the artisan. The resulting change in status of architecture and more importantly the architect is key to understanding the changes in the process of design. The Renaissance architect was often an artist (a painter or sculptor) who had little knowledge of building technology but a keen grasp of the rules of classical design. The architect thus had to provide detailed drawings for the craftsmen setting out the disposition of the various parts. This was what we call the process of design, from the Italian word for drawing. Occasionally the architect would get involved in particularly difficult technical problems but the technical side of architecture was mainly left up to the craftsmen. This change in the way buildings were designed had a fundamental difference on the way problems were approached. Where the Medieval craftsmen tended to approach a problem with a technical solution in mind, the Renaissance architect started with an idea of the what the end product need to look like and then searched around for a way of making it work. This led to extraordinary leaps forward in engineering.

Labour



The structure of the dome of Florence cathedral , showing the double skin structure.

Labour in the Renaissance was much he same as that in the Middle Ages: buildings were built by paid workers. Unskilled work was done by labourers paid by the day. Skilled craftsmen served apprenticeships or learned their trade from their parents. Craftsmen were organized in guilds which provided a limited form of building regulation in return for members of the guild holding a monopoly on a particular trade in a defined area (usually within the town walls). Towns were in general very small by modern standards and dominated by the dwellings of a small number of rich nobles or merchants and cathedrals and churches.

Technical advances

The wish to return to classical architecture created problems for the Renaissance buildings. The builders did not use concrete and thus comparable vaults and domes had to be replicated in brick or stone. The greatest technical feats were undoubtedly in these areas. The first major breakthrough was Brunelleschi's project for the dome of Santa Maria del Fiore. Brunelleschi managed to devise a way of building a huge dome without formwork, relying instead on the weight of the bricks and the way they were laid to keep them in position and the shape of the dome to keep it standing. The exact way the dome was built is still subject to heated debate today as it is not possible to take the dome apart to study its construction without destroying it. The dome is a double skin, linked by ribs, with a series of wooden and stone chains around it at intervals to attempt to deal with hoop stresses.

Brunelleschi's dome was completed (up to the base of the lantern) in 1446. It's size however was soon surpassed by the dome of St Peter's, built using flying scaffolding supported on the cornices and constructed using two stone shells.

Construction in the seventeenth century

The seventeenth century saw the birth of modern science which would have profound effects on building construction in the centuries to come. The major breakthroughs were towards the end of the century when architect-engineers began to use experimental science to inform the form of their buildings. However it was not until the 18th century that engineering theory developed sufficiently to allow sizes of members to be calculated. Seventeenth century structures this relied strongly on experience, rules of thumb and the use of scale models.

Materials

The major breakthrough in this period was in the manufacture of glass, with the first cast plate glass being developed in France. Iron was increasingly employed in structures. Christopher Wren used iron hangers to suspend floor beams at Hampton Court Palace, and iron rods to repair Salisbury Cathedral and strength the dome of St Paul's Cathedral. Most buildings had stone ashlar surfaces covering rubble cores, held together with lime mortar. Experiments were made mixing lime with tarrass to provide a hydraulic mortar, but there was still no equivalent of the Roman Concrete. In England, France and Holland cut and gauged brickwork was used to provide detailed and ornate facades. The triangulated roof truss was introduced to England and used by Inigo Jones and Christopher Wren.

There were many tools which have grown obsolete since the advent of modern technology, but which were previously used by all builders. Some major examples are the plumb-line, the slide-rule and the drafting compass.

Methods

Despite the birth of experimental science, the methods of construction in this period remained largely medieval. The same types of cranes that had been used in previous centuries were being still being employed. Flying scaffolds were employed at St Paul's Cathedral, England and in the dome of St Peters, Rome, but otherwise the same types of timber scaffolding that had been in use centuries before were retained. Cranes and scaffolding depended on timber. Complex systems of pulleys allowed comparatively large loads to be lifted, and long ramps were used to haul loads up to the upper parts of buildings.

Construction in the eighteenth century

The eighteenth century saw the development of many the ideas that had been born in the late seventeenth century. The architects and engineers became increasingly professionalised. Experimental science and mathematical methods began increasingly sophisticated and employed in buildings. At the same time the birth of the industrial revolution saw and increase in the size of cities and and increase in the pace and quantity of construction.

Materials

The major breakthroughs in this period were in the use of iron (both cast and wrought). Iron columns had been used in Wren's designs for the House of Commons and were used in several early 18th century churches in London, but these supported only galleries. In the second half of the eighteenth century the decreasing costs of iron production allowed the construction of major pieces of iron engineering. The Iron Bridge at Coalbrookdale (1779) is a particularly notable example. Large scale mill construction required fire-proof buildings and cast iron became increasingly used for columns and beams to carry brick vaults for floors. The Louvre in Paris boasted an early example of a wrought iron roof. Steel was used in the manufacture of tools but could not be made in sufficient quantities to be used for building.

Brick production increased markedly during this period. Many buildings throughout Europe were built of brick, but they were often coated in lime render, sometimes patterned to look like stone. Brick production itself changed little. Bricks were moulded by hand and fired in kilns no different to those used for centuries before. Terracotta in the form of Coade stone was used as an artificial stone in the UK.

Construction in the nineteenth century: Industrial Revolution

A structural worker building the Empire State Building. Workers such as this man were often referred to as "old timers" because in that time era, mostly only middle-aged men worked on building structures.

The industrial revolution was manifested in new kinds of transportation installations, such as railways, canals and macadam roads. These required large amounts of investment. New construction devices included steam engines, machine tools, explosives and optical surveying.

As steel was mass-produced from the mid-19th century, it was used, in form of I-beams and reinforced concrete. Glass panes also went into mass production, and changed from luxury to every man's property.

Plumbing appeared, and gave common access to drinking water and sewage collection.

Construction in the twentieth century

With the Second Industrial Revolution in the early 20th century, elevators and cranes made high rise buildings and skyscrapers possible, while Heavy equipments and power tools decreased the workforce needed. Other new technologies were prefabrication and computer-aided design.

Trade unions were formed to protect construction workers' interests. Personal protective equipment such as hard hats and earmuffs also came into use.

From the 20th century, governmental construction projects were used as a part of macroeconomic stimulation policies, especially during the Great depression.

In the end of the 20th century, ecology, energy conservation and sustainable development have become more important issues of construction.

Construction history as an academic discipline

The History of Construction is of interest to anyone who wants to know how and why things have been constructed the way they are. There is no established academic discipline of construction history but there are a growing number of researchers and academics working in this field who are structural engineers, archaeologists, architects, historians of technology and architectural historians. Although the subject has been studied since the Renaissance and there were a number of important studies in the nineteenth century, it largely went out of fashion in the mid-twentieth century. In the last thirty years there has been an enormous increase in interest in this field, which is vital to the growing practice of building conservation.

Early writers on construction history

The earliest surviving book detailing historical building techniques is the treatise of the Roman author, Vitruvius, but his appraoch was neither particularly scholarly nor particularly systematic. Much later, in the Renaissance, Vasari mentions Filippo Brunelleschi's interest in researching Roman building techniques, although if he wrote anything on the subject it does not survive. In the seventeenth century, Rusconi's illustrations for his version of Leon Battista Alberti's treatise explicitly show Roman wall construction but most of the interest in antiquity was in understanding its proportions and detail and the architects of the time were content to build using current techniques. While early archaeological studies and topographic works such as the engravings of Giovanni Battista Piranesi show Roman construction they were not explicitly analytical and much of what they do show is made up.

Nineteenth century studies on construction history

In the nineteenth century, lecturers increasingly illustrated their lectures with images of building techniques used in the past and these type of images increasingly appeared in construction text books, such as Rondelet's. The greatest advances however were made by English and French (and later German) architects attempting to understand, record and analyse Gothic buildings. Typical of this type of writing are the works of Robert Willis in England, Viollet-le-Duc in France and Ungewitter in Germany. None of these however were seeking to suggest that the history of construction represented a new approach to the subject of architectural history. August Choisy was perhaps the first author to seriously attempt to undertake such a study.

The early twentieth century studies of the construction history

Santiago Heurta has suggested that it was modernism, with its emphasis on the employment of new materials, that abruptly ended the interest in construction history that appeared to have been growing in the last few decades of the nineteenth century and the early years of the twentieth. With the advent of concrete and steel frame construction, architects, who had been the chief audience for such studies, were no longer as interested as they had been in understanding traditional construction, which suddenly appeared redundant. Very little was thus published between 1920 and 1950. The revival of interest started in archaeology with the studies of Roman construction in the 1950s, but it was not until the 1980s that construction history began to emerge as an independent field.

The late twentieth century

By the end of the twentieth century steel and concrete construction were themselves becoming the subject of historical investigation.The Construction History Society was formed in the UK in 1982. It produces the only academic international journal devoted to the subject annually. The First International Congress on Construction History was held in Madrid in 2003. This was followed by the Second International Congress in 2006 in Queens' College, Cambridge, England and the Third International Congress held in Cottbus in 2009. The Fourth International Congress is scheduled to be held in Paris in 2012

Chapter- 3

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 be able 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- 4

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.

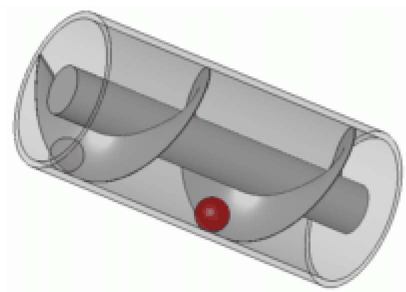
Civil engineering is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like bridges, roads, canals, dams and buildings. Civil engineering is the oldest engineering discipline after military 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

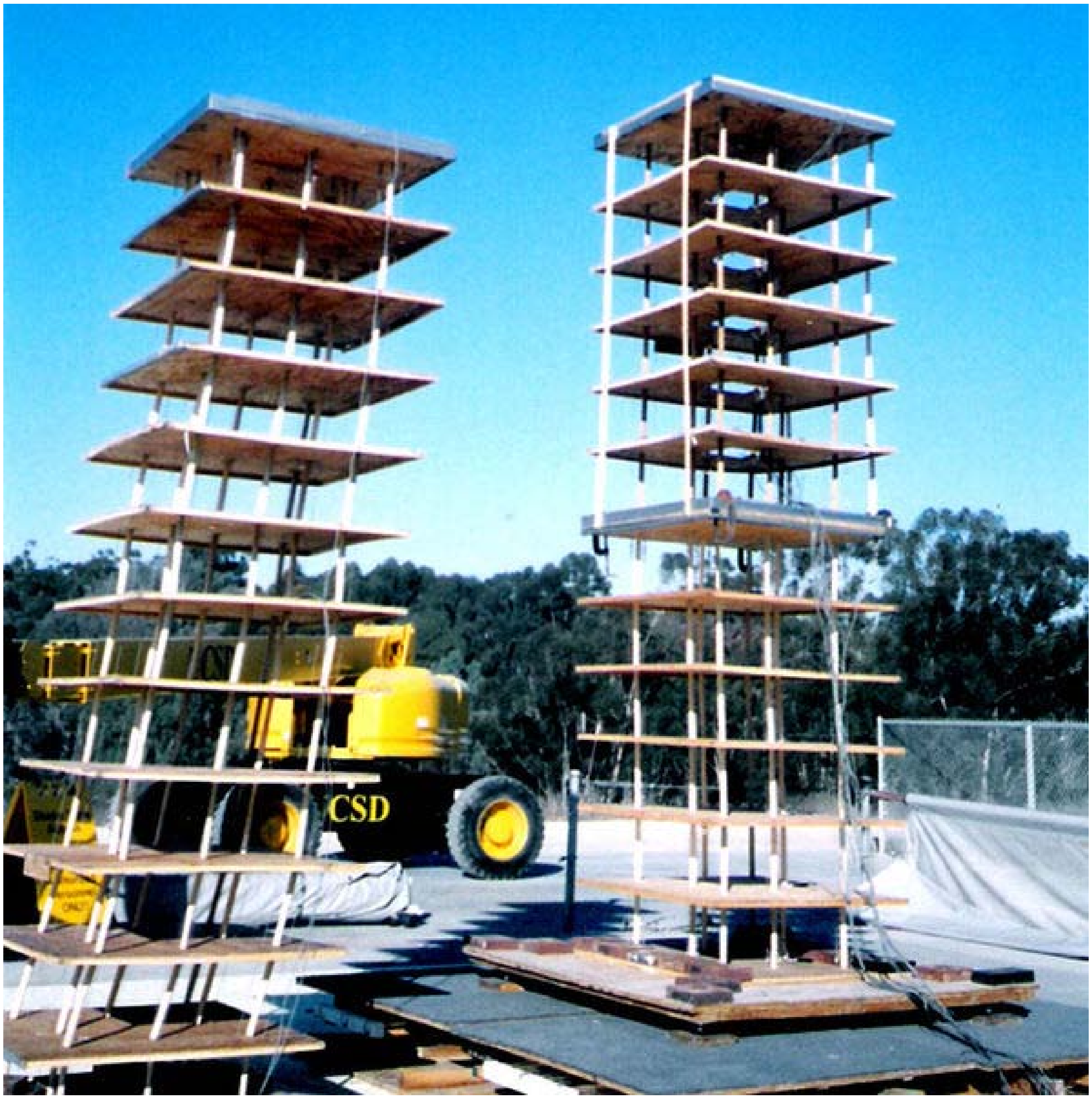
Construction engineering involves planning and execution of the designs from transportation, site development, hydraulic, environmental, structural and geotechnical engineers. As construction firms tend to have higher business risk than other types of civil engineering firms, many construction engineers 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.

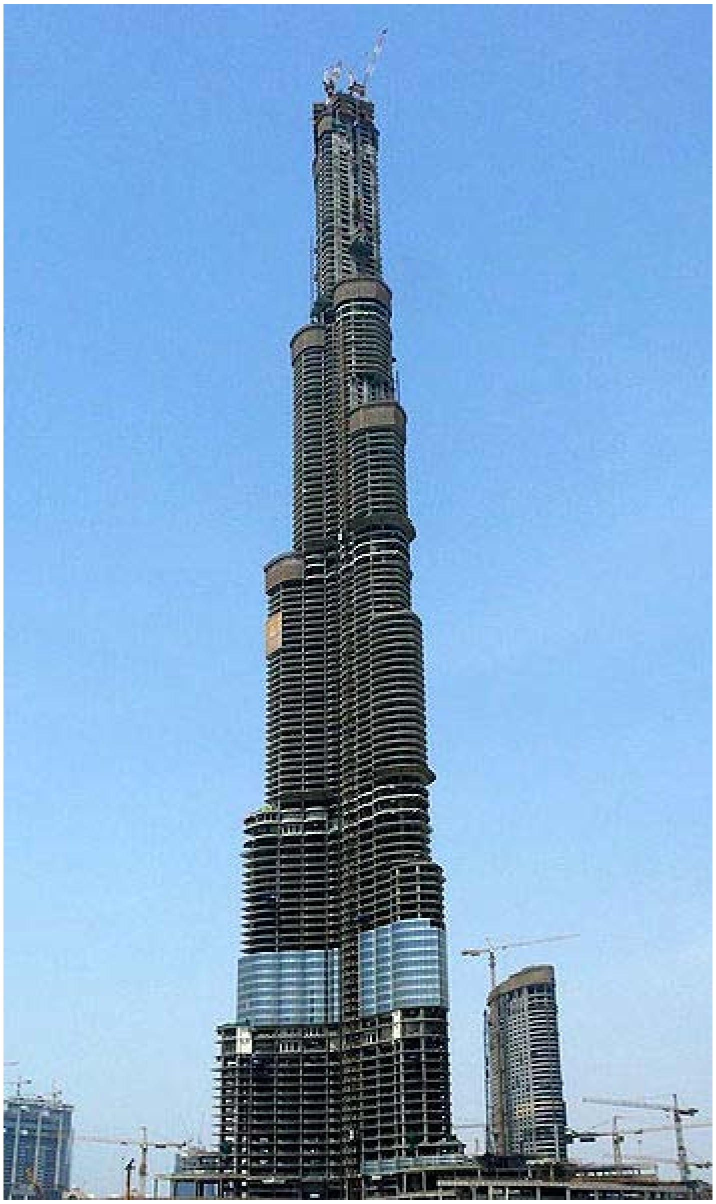
Hydraulic engineering is concerned with the flow and conveyance of fluids, principally water. This area of civil engineering is intimately related to the design of pipelines, water supply network, drainage facilities (including bridges, dams, channels, culverts, levees, storm sewers), and canals. Hydraulic 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- 5

Construction Law and Construction Management

Construction law

Construction law is a body of law that deals with matters relating to building construction and related fields. It covers a wide range of legal issues including contract law, bonds and bonding, guarantees and sureties, liens and other security interests, tendering, construction claims, and related consultancy contracts. Construction law affects many participants in the construction industry, including financial institutions, surveyors, architects, builders, engineers, construction workers, and planners.

Specific practice areas

Construction law builds upon general legal principles and methodologies and incorporates the regulatory framework (including security of payment, planning, environmental and building regulations); contract methodologies and selection (including traditional and alternative forms of contracting); subcontract issues; causes of action, and liability, arising in contract, negligence and on other grounds; insurance and performance security; dispute resolution and avoidance.

Construction law has evolved into a practice discipline in its own right, distinct from its traditional locations as a subpractice of project finance, real estate or corporate law. There are often strong links between construction law and energy law and oil and gas law.

Country specific practice

United Kingdom

In the United Kingdom, there has been an active Society of Construction Law since 1983, and there is now a European Society of Construction Law, and Societies of Construction Law in Australia, Hong Kong, Singapore and the UAE.

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 exist 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 though Construction Design Management regulations, which prevent incidents on construction sites and civil engineering structures once competent

Chapter- 6

Planning Permission

Planning permission or **planning consent** is the permission required in the United Kingdom in order to be allowed to build on land, or change the use of land or buildings. Within the UK the occupier of any land or building will need title to that land or building (i.e. "ownership"), but will also need "planning title" or planning permission. Planning title was granted for all pre-existing uses and buildings by the Town and Country Planning Act 1947. Since that date any new "development" has required planning permission. "Development" as defined by law consists of any building, engineering or mining operation, or the making of a material change of use in any land or building. Certain types of operation such as routine maintenance of an existing building are specifically excluded from the definition of development. Specified categories of minor or insignificant development are granted an automatic planning permission by law, and therefore do not require any application for planning permission. These categories are referred to as permitted development.

In the case of any proposal there is therefore a two stage test: *"is the proposal development at all?"* and, if the proposal is development, *"is it permitted development?"* Only if a development is not permitted development would an application for planning permission be required. An application for planning permission should be made to the Local Planning Authority (LPA).

Local Planning Authorities are generally the local Borough or District Council ('Local Authority' in Scotland), although an application for a mining operation, minerals extraction, or a waste management facility would be decided by the local County Council in non-metropolitan areas. Within a National Park planning applications are submitted to the National Park Authority.

All LPAs have their own website which will access relevant application forms, contact details and other relevant documents. Every local authority in England and Wales accepts online planning applications via the Planning Portal. They are generally receptive to pre-application discussion in order to clarify whether a proposal will require planning permission and, assuming that it does, the probability of such planning permission being granted.

Determination

The law requires that all applications for planning permission should be decided in accordance with the policies of the "development plan" – unless material planning considerations indicate otherwise. The decision on any planning application is therefore "policy-led" rather than "influence-led". Although the public and nearby residents will be consulted about almost any planning application, the decision will not be made on the grounds of popularity or unpopularity. The framing of the decision by reference to published planning policy prevents the decision on a planning application being made on grounds which are arbitrary, perverse, or subject to impropriety.

It is therefore most important that applicants for planning permission satisfy themselves about the relevant local development plan policies before making an application. These can also be viewed via the LPA's website, or the UK government's Planning Portal, which provides a nationwide clearing house on planning information and advice for both government and local planning policies. As a practical matter it is very advisable to discuss proposals with the LPA before incurring the fees and other costs that are involved in making a planning application, or the delays and abortive costs that would arise from the refusal of planning permission.

Some bodies, for example Network Rail have the power to grant their own planning permission. However, the Government stated when this was set up that where a development has "significant impact on amenity and environment" then the local planning authorities and the public should be consulted.

Types of application

A number of different types of planning permission can be applied for:

1. **Full** Planning Permission: A full planning permission would grant permission for all aspects of the proposed development, although it would generally be subject to various conditions.
2. **Outline** Planning Permission: Outline planning permission cannot be granted for a proposed change in the use of land or buildings. It might be appropriate when an applicant is seeking an agreement "in principle" to a proposed development, without being committed to a particular form of design or layout.
3. Approval of **"Reserved Matters"** Seeking permission for those aspects that were not dealt with in an outline planning permission, or seeking approval of aspects of a development which were reserved by a planning condition in an earlier grant of full planning permission.
4. **Renewal** of planning permission: This would arise when an earlier outline or full planning permission was subject to a time-limiting condition which has since expired. In essence this requires the entire planning application to be reviewed in light of current rather than previous planning policies. Applications for renewal of an earlier planning permission are usually granted anew, unless there has been a

significant change in the relevant material considerations which are to be weighed in the decision.

5. **Removal or alteration** of a planning condition: As a matter of law, conditions should only be imposed on a grant of planning permission when compliance with that condition is essential to make an unacceptable development acceptable – so it would be refused planning permission were it not for that condition. If the applicant or developer wished to proceed with a development without compliance with a condition, or perhaps with the condition in an alternative form, then an application can be made to "vary" the condition concerned – possibly by deleting it or offering an alternative form of words. Note that the LPA cannot alter any planning condition which imposes a time limit when the development is to be commenced. That would require a re-application for full or outline planning permission, but since October 2009 it has been possible to apply to extend an existing consent.

Conditions

Planning permissions are usually granted subject to a planning condition which requires the development to be commenced within 3 years. Typically they will also include a number of other conditions, for example the scheme to be built in accordance with the approved drawings, trees to be planted as per the landscape scheme and replaced if they die in the first few years, or the colour and finish of external materials to be approved by the Local Authority. Some of these will need to be complied with before any work starts on site; others will take effect once the development is commenced, or later.

Most conditions imposed on a granted planning permission will relate to implementation of works within the actual site of the application (the edges of which must be defined by a red line marked on an accurately scaled map of the site, usually an Ordnance Survey extract, accompanying the application). If there is a need to control aspects of the development which are required to occur outside the defined application site (such as related highway improvements) then the implementation of those aspects can be required by a Grampian condition. This would be worded to the effect that the development being permitted must not be commenced (or must not be occupied, as appropriate), until the required off-site works had been completed.

Planning conditions are imposed to require that something is done or not done by the developer in order to make the development acceptable. Sometimes, planning permission will only be granted subject to the applicant entering into a legal agreement under Section 106 of the Town and Country Planning Act requiring that certain things be done or money be paid to the Local Planning Authority e.g. to contribute towards the improvement of a highway junction serving the development before the development commences. Such contributions can only be required if they are necessary to make the development acceptable and relate directly to the development proposed.

Chapter- 7

Construction Equipments

Breaker (hydraulic)

A breaker is mounted on the excavator on the left side

A **breaker** is a powerful percussion hammer fitted to an excavator for demolishing concrete structures or rocks. It is powered by an auxiliary hydraulic system from the excavator, which is fitted with a foot-operated valve for this purpose. Additionally, demolition crews employ the hoe ram for jobs too large for jackhammering or areas where blasting is not possible due to safety or environmental issues.

Breakers are often referred to as "hoe ram" or "hoe rammer." This term is popular and commonly used amongst construction/demolition workers.

Concrete mixer

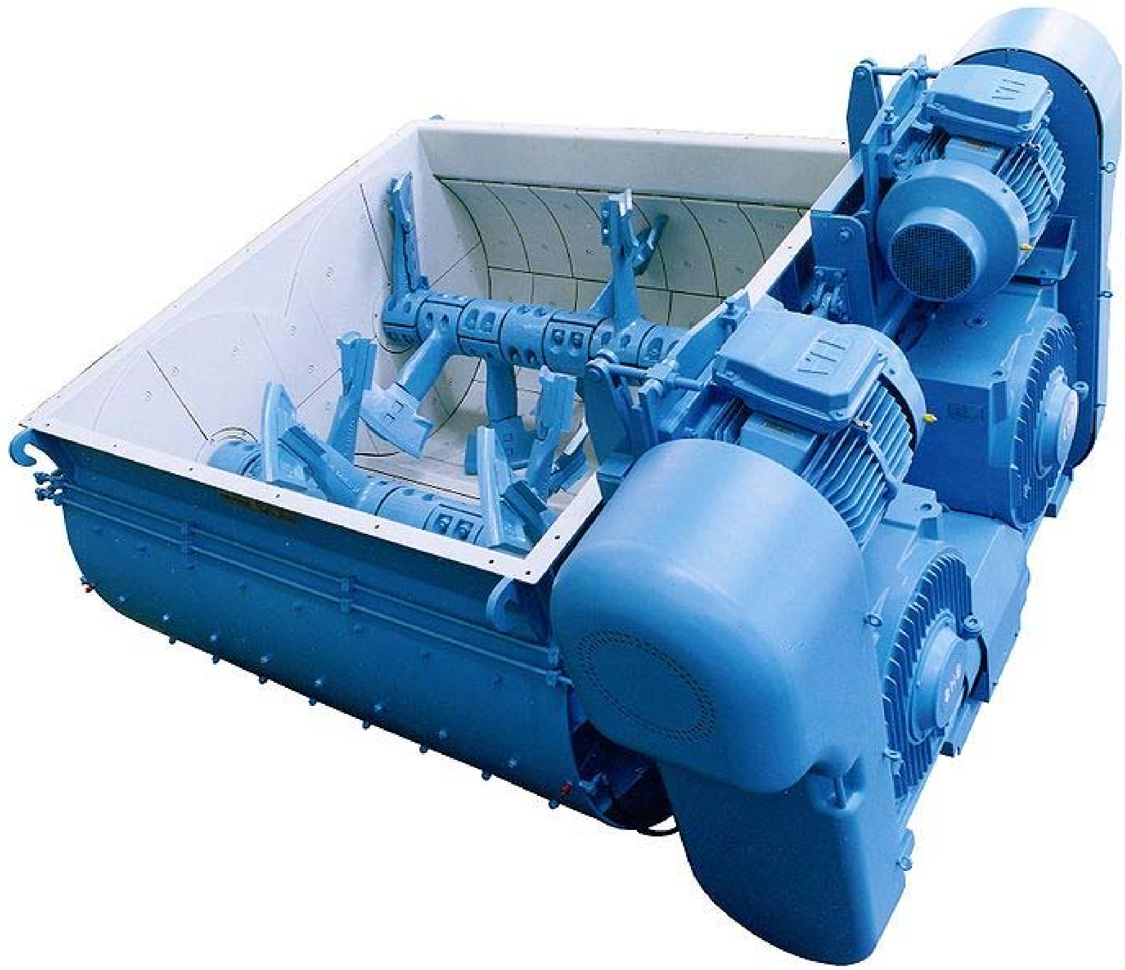
This portable concrete/mortar mixer has wheels and a towing tongue so that it can be towed by a motor vehicle and moved around the worksite by hand, and its rotation is powered by mains electricity. The lever allows the concrete/mortar to be tipped into a wheelbarrow.

An outdated model of a small-scale concrete mixer. These older mixers are heavy and can not be moved as easily. They are still however equipped with a electrical motor, so they do not pollute the surroundings

A **concrete mixer** (also commonly called a **cement mixer**) is a device that homogeneously combines cement, aggregate such as sand or gravel, and water to form concrete. A typical concrete mixer uses a revolving drum to mix the components. For smaller volume works portable concrete mixers are often used so that the concrete can be made at the construction site, giving the workers ample time to use the concrete before it hardens. An alternative to a machine is mixing concrete or cement by hand. This is usually done in a wheelbarrow; however, several companies have recently begun to sell modified tarps for this purpose.

The concrete mixer was invented by Columbus industrialist Gebhardt Jaeger.

Industrial mixers



Twin-shaft concrete mixer.

Today's market increasingly requires consistent homogeneity and short mixing times for the industrial production of ready-mix concrete, and more so for precast/prestressed concrete. This has resulted in refinement of mixing technologies for concrete production. Different styles of stationary mixers have been developed, each with its own inherent strengths targeting different parts of the concrete production market. The most common mixers used today fall into 3 categories: Twin-shaft mixers, Vertical axis mixers (Pan and Planetary mixers) and Drum mixers (Reversing Drum and Tilting Drum).

Twin-shaft mixers are known for their high intensity mixing, and short mixing times. These mixers are typically used for high strength concrete, RCC and SCC, typically in batches of 2–6 m^3. Vertical axis mixers are most commonly used for precast and prestressed concrete. This style of mixer cleans well between batches, and is favoured for coloured concrete, smaller batches (typically 0.75–3 m^3), and multiple discharge points. Within this category, the Pan mixers are losing popularity to the more efficient Planetary (or counter-current) mixers as the additional mixing action helps in production of more critical concrete mixes (colour consistency, SCC, etc.). Drum mixers (reversing drum mixer and tilting drum mixers) are used where large volumes of concrete are being produced (batch sizes of 3–9 m³). This type of mixer dominates the ready-mixed market as it is known to be capable of high production speeds, ideal for slump concrete, and where overall cost of production is important. Drum mixers are known to have the lowest maintenance and operating cost of the three styles of mixers. All the mixer styles have their own inherent strengths and weaknesses, and all three styles of mixers are used throughout the world to varying degrees of popularity.

Concrete mixing transport truck

Terex Advance front discharge truck with three lift axles including one tag axle

Front discharge truck cab detail

Volumetric Concrete Mixer

A rear–discharge concrete transport truck

Low-Profile Mining and Tunneling Concrete Mixer Truck

Special concrete transport trucks (**in–transit mixers**) are made to transport and mix concrete up to the construction site. They can be charged with dry materials and water, with the mixing occurring during transport.With this process, the material are already been mixing and also the concrete mixing transport truck maintains the material's liquid state, through agitation, or turning of the drum, until delivery. The interior of the drum on a concrete mixing truck is fitted with a spiral blade. In one rotational direction, the concrete is pushed deeper into the drum. This is the direction the drum is rotated while the concrete is being transported to the building site. This is known as "charging" the mixer. When the drum rotates in the other direction, the Archimedes' screw-type arrangement "discharges", or forces the concrete out of the drum. From there it may go onto chutes to guide the viscous concrete directly to the job site. If the truck cannot get close enough to the site to use the chutes, the concrete may be discharged into a concrete pump, connected to a flexible hose, or onto a conveyor belt which can be extended some distance (typically ten or more meters). A pump provides the means to move the material to precise locations, multi-floor buildings, and other distance prohibitive locations. The drum is traditionally made of steel but on some newer trucks as a weight reduction measure, fiberglass has been used.

"Rear discharge" trucks require both a driver and a "chuteman" to guide the truck and chute back and forth to place concrete in the manner suitable to the contractor. Newer "front discharge" trucks have controls inside the cab of the truck to allow the driver to move the chute in all directions. The first front discharge mixer was designed and built by Royal W. Sims of Holladay, Utah.

Concrete mixers are equipped with anywhere from two axles and up. Four, 5 and 6 axle trucks are the most common with the number being determined by the load and local legislation governing allowable loads on the road. These are necessary to distribute the load evenly and allow operation on weight restricted roads and to reduce wear and tear on normal roads. A two or three axle truck during the winter when road weight limits are reduced has no usable payload in many jurisdictions. Other areas may require expensive permits to operate. Additional axles other than those used for steering ("steers") or drivetrain ("drives") may be installed between the steers and drives or behind the drives. Mixers commonly will have multiple steering axles as well, which generally result in very large turning radii. To facilitate maneuvering the additional axles may be "lift axles" which allows them to be raised off the ground so that they do not scrub (get dragged sideways across the ground) on tight turns, or increase the vehicle's turning radius. Axles installed behind the drives are known as "tag axles" or "booster axles", and are often equipped to turn opposite to the steering axle to reduce scrubbing and automatically lift when the truck is put into a reverse gear.

Tractor trailer combination mixers where the mixer is installed on a trailer instead of a truck chassis are used in some jurisdictions, such as the province of Quebec where even 6 axle trucks would have trouble carrying a useful load.

Concrete mixers generally do not travel far from their plant, as the concrete begins to setup as soon as it is in the truck. Many contractors require that the concrete be in place within 90 minutes after loading. If the truck breaks down or for some other reason the concrete hardens in the truck, workers may need to enter the barrel with jackhammers; dynamite is still occasionally used to break up hardened concrete in the barrel under certain circumstances.

Stephen Stepanian filed a patent application for the first truck mixer in 1916. Trucks weigh 20,000 pounds (9,100 kg) to 30,000 pounds (14,000 kg), and can carry roughly 40,000 pounds (18,000 kg) of concrete although many varying sizes of Mixer Truck are currently in use. The most common truck capacity is 8 cubic yards (6 m^3).

Most concrete mixers in the UK are limited to a speed of 56 miles per hour (90 km/h).

Concrete mixer trailer

1 Yard Cart-Away Mixing Trailer

A variant of standard concrete transportation is the concrete or cement mixing trailer. These small versions of a transit-mix truck are used to supply short loads of concrete. These cart-away style trailers have a concrete mixing drum with a capacity of between 1-yard and 1.75 yards. Cart-aways are usually pulled behind a pick-up truck and batched from smaller batching systems. The mixing trailer system is popular with rental yards and building material locations, who use them to supply ready-mix to their regular customer base.

Concrete moisture meter

A **concrete moisture meter** is a type of moisture meter used by installers of flooring to measure the moisture levels of concrete. These meters have been used for decades to measure the moisture content in different materials and substances. Concrete meters have evolved from the successful wood moisture meter as flooring contractors tried to use their wood meters to measure the moisture in concrete.

Concrete moisture meters are designed to detect moisture to a depth of 1” of a concrete slab in order to avoid the rebar reinforcement below the surface. They are designed to be used as a relative test. The meters are used to “‘Spot check’ the top surface at one particular location on the slab.” The results can determine the best place to put a concrete relative humidity test.

Limitations

There is no ASTM standard for using a concrete moisture meter to determine a final moisture content reading.

Concrete moisture meters, either non-pin or pin meters are affected by what it sees in the concrete. This can be anything from the density of the concrete and aggregate size to the chemical properties of the slab.

Uncovered concrete dries from the top down. Concrete moisture meters measure only the top inch at most and this area is drier than the concrete further down. Once a floor covering has been installed the moisture in the slab equilibrates. In order to ensure the equilibrated moisture will be a safe level for a floor covering, a relative humidity sensor must be drilled and placed at 40% of the depth of the slab. This depth has been proven to be the relative humidity percentage that the slab will equilibrate once the top has been covered by a floor covering.

Concrete pump

Because it is a fluid, concrete can be pumped to where it is needed. Here, a concrete transport truck is feeding concrete to a concrete pumper, which is pumping it to where a slab is being poured.

A **concrete pump** is a tool used for transferring liquid concrete by pumping. There are two types of concrete pumps.

Construction site with concrete pump.

A Putzmeister concret pump in Germany in 1985.

Folded concrete pump for transport.

The first type of concrete pump is attached to a truck. It is known as a trailer-mounted boom concrete pump because it uses a remote-controlled articulating robotic arm (called a *boom*) to place concrete with pinpoint accuracy. Boom pumps are used on most of the larger construction projects as they are capable of pumping at very high volumes and because of the labour saving nature of the placing boom. They are a revolutionary alternative to truck-mounted concrete pumps.

Concrete pump

Putzmeister brand positive displacement mortar and plaster pump.

Boom concrete pump

The second main type of concrete pump is either mounted on a truck and known as a truck-mounted concrete pump or placed on a trailer, and it is commonly referred to as a *line pump* or trailer-mounted concrete pump. This pump requires steel or rubber concrete placing hoses to be manually attached to the outlet of the machine. Those hoses are linked together and lead to wherever the concrete needs to be placed. Line pumps normally pump concrete at lower volumes than boom pumps and are used for smaller volume concrete placing applications such as swimming pools, sidewalks, and single family home concrete slabs and most ground slabs.

There are also skid mounted and rail mounted concrete pumps, but these are uncommon and only used on specialized jobsites such as mines and tunnels.

World record

The world record was set at on 7 August 2009 during the construction of the Parbati Hydroelectric Project, near the village of Suind, Himachal Pradesh, India, when the concrete mix was pumped through a vertical height of 715 m (2,346 ft)using SCHWING STETTER concrete pump.

Dumper

Dumper in action

A **dumper** is a vehicle designed for carrying bulk material, often on building sites. Dumpers are distinguished from dump trucks by configuration: a dumper is usually an open 4-wheeled vehicle with the load skip in front of the driver, while a dump truck has its cab in front of the load. The skip can tip to dump the load; this is where the name "dumper" comes from. They are normally diesel powered. A towing eye is fitted for secondary use as a site tractor. Dumpers with rubber tracks are used in special circumstances and are popular in some countries.

Banford HDX 1000

Banford HDX 1000

Banford HDX 1000 3

Bridge Day 5 - Found...

Early dumpers had a payload of about a ton and were 2-wheel drive, driving on the front axle and steered at the back wheels. The single cylinder diesel engine (sometimes made by Lister) was started by hand cranking. The steering wheel turned the back wheels, not front. Having neither electrics nor hydraulics there was not much to go wrong. The skip was secured by a catch by the driver's feet. When the catch is released, the skip tips under the weight of its contents at pivot points below, and after being emptied is raised by hand.

Construction site

DUMPER34

Drivers seat.

Driving the dumper

Dumped! - geograph.o...

Modern dumpers have payloads of up to 10 tonnes and usually steer by articulating at the middle of the chassis (pivot steering). They have multi-cylinder diesel engines, some turbocharged, electric start and hydraulics for tipping and steering and are more expensive to make and operate. An A-frame known as a ROPS (Roll-Over Protection) frame, may be fitted over the seat to protect the driver if the dumper rolls over. Some dumpers have FOPS (Falling Object Protection) as well. Lifting skips are available for discharging above ground level. In the 1990s dumpers with swivel skips, which could be rotated to tip sideways, became popular, especially for working in narrow sites such as road works. Dumpers are the most common cause of accidents involving construction plant.

These vehicles are also called "dumper" in some mainland European languages.