6D-BUILDTECH

Preamble

From single family residential housing to very large commercial properties, building construction technology and methods have changed very little over the past 100 years. Most significant building structures are constructed on-site and are based upon a custom design that is the result of the work of a project team of design professionals. This antiquated model of ‘one off’ custom design and labor intensive on-site construction is under ever-increasing time, budget and liability pressures.

Thus, it is highly desirable to introduce a building system that offers design flexibility, dramatically reduces construction time and cost and provides for minimal impact to the environment. This can be accomplished using 6D-BuildTech by means of an expanding kit of manufactured compatible components (“blocks”) that are rapidly erected at the construction site.

Historical Perspective for Concrete and Precast Concrete Building Construction

3000 BC - Egyptian Pyramids

The Egyptians were using early forms of concrete over 5000 years ago to build pyramids. They mixed mud and straw to form bricks and used gypsum and lime to make mortars.

300 BC – Roman Architecture

The ancient Romans used a material that is remarkably close to modern cement to build many of their architectural marvels, such as the Colosseum, and the Pantheon. The Romans also used animal products in their cement as an early form of admixtures. Admixtures, additions to the mix used to achieve certain goals, are still used today,

1824 Portland Cement Invented

Joseph Aspdin of England is credited with the invention of modern Portland cement. He named his cement Portland, after a rock quary that produced very strong stone.

Types of Cement and What They Do

Portland Cement is a type of cement, not a brand name. Many cement manufacturers make Portland cement.

The Wide World of Cements

There are many different properties and applications of cements for use in concrete including portland, blended, and hydraulic cements.

Types of Portland Cement
Portland cements are hydraulic cements composed primarily of hydraulic calcium silicates. ASTM C150, Standard Specification for Portland Cement, recognizes eight types of portland cement.

Types of Blended Cements
Blended hydraulic cements are produced by intimately and uniformly intergrinding or blending two or more types of fine materials. The primary materials are portland cement, ground granulated blast furnace slag, fly ash, silica fume, calcined clay, other pozzolans, hydrated lime, and pre-blended combinations of these materials.

Types of Hydraulic Cements
All portland and blended cements are hydraulic cements. Hydraulic cement is merely a broader term. ASTM C1157, Performance Specification for Hydraulic Cements, is a performance specification that includes portland cement, modified portland cement, and blended cements. ASTM C1157 recognizes six types of hydraulic cements.

Cement Standards and Specifications

Product specifications and test methods are typically developed by national standards development organizations, such as ASTM in the U.S. and CSA in Canada. Full consensus standards are developed with the participation of all parties who have a stake in the standards' development and/or use.

Specifying Cement for Use in Concrete

When a cement is specified for a project, consideration should be given to the types of material available in that location. The specification should be flexible, allowing either portland or blended cements. Consideration should always be given to the use of locally available pozzolans and slag cements, provided the desired concrete properties can be achieved. Ideally, the specification should allow any cement that meets the performance requirements of the project. Cements with special or unique properties should not be required unless absolutely necessary.

Effect of Cement Characteristics on Concrete Properties

Cement, together with water, creates the paste that binds aggregate together to form concrete. Concrete quality depends upon the quantity and quality of the aggregate and the paste, as well as the bond between the two. Therefore, the properties of concrete are influenced by the properties of cement. Whether it is the clinker composition, the fineness of the individual cement grains, or the amount with which it is used in the concrete, the type and proportion of cement affect both the fresh and hardened properties of concrete. An understanding of cement characteristics can provide insight to many of the issues arising in concrete construction.

Impact of Hot Cement on the Concrete Mix

Hot cement describes clinker that has, through the process of grinding, gained additional energy stored in the form of heat. Once the clinker is ground, this hot cement is stockpiled in storage silos where the elevated temperature, especially in warm climates, is not readily abated.

Many attribute slump loss, strength reduction, or other concrete-related problems to the temperature of the cement upon batching. However, research has shown that cement's ultimate effect on the concrete mixture's temperature is quite minimal.

Are all Hydraulic Cements Created Equal?

In 2004 PCA conducted a survey to determine characteristics of commercially available cements. Included in the report released in 2008 (free download: PCA R&D Serial No. 2879), are results of that survey, which includes data on Portland, blended, and ASTM C1157 hydraulic cements, as well as masonry, plastic (stucco), and mortar cements. The report contains information on chemical and physical characteristics and compares current data with historically available data so that any trends can be observed.

An important characteristic used for comparing cements for general construction is ASTM C109 compressive strength. Survey results show that cements manufactured to meet ASTM C150, C595, and C1157, tend to have strengths that are relatively similar. This may not be too surprising since they compete in the same marketplaces.

These are very short descriptions of the basic types of cement. There are other types for various purposes such as architectural concrete and masonry cements, just to name two examples.

Your concrete supplier will know what the requirements are for your area and for your particular use. Simply ask them what their standard type of cement is and if that will work fine for your conditions.

Water to Cement Ratio: The #1 Issue Affecting Concrete Quality

A low water to cement ratio is the number one issue effecting concrete quality.

The ratio is calculated by dividing the water in one cubic yard of the mix (in pounds) by the cement in the in the mix (in pounds). So if one cubic yard of the mix has 235 pounds of water and 470 pounds of cement- the mix is a 0.50 water to cement ratio.

If the mix lists the water in gallons, multiply the gallons by 8.33 to find how many pounds there are in the mix.

Low water cement ratio impacts all the desired properties of hardened concrete listed in desired properties of concrete.

Use a maximum 0.50 water to cement ratio when concrete is exposed to freezing and thawing in a moist condition or to deicing chemicals per the 1997 Uniform Building Code. (Table 19-A-2)

Use a maximum .45 water to cement ratio for concrete with severe or very severe sulfate conditions per the 1997 Uniform Building Code (Table 19-A-4)

Water permeability increases exponentially when concrete has a water cement ratio greater than 0.50.

Durability increases the less permeable the concrete mix is.

Strength improves with lower water cement ratios. A 0.45 water cement ratio most likely will hit 4500 psi (pounds per square inch) or greater. A 0.50 water cement ratio will likely reach 4000 psi or greater.

For complete Uniform Building Code information regarding concrete construction, review with your architect, your concrete product supplier, or at your local library.

Portland cement, the basic ingredient of concrete, is a closely controlled chemical combination of calcium, silicon, aluminum, iron and small amounts of other ingredients to which gypsum is added in the final grinding process to regulate the setting time of the concrete. Lime and silica make up about 85% of the mass. Common among the materials used in its manufacture are limestone, shells, and chalk or marl combined with shale, clay, slate or blast furnace slag, silica sand, and iron ore.

Each step in manufacture of Portland cement is checked by frequent chemical and physical tests in plant laboratories. The finished product is also analyzed and tested to ensure that it complies with all specifications.

Two Manufacturing Processes

Two different processes, "dry" and "wet," are used in the manufacture of Portland cement.

When rock is the principal raw material, the first step after quarrying in both processes is the primary crushing. Mountains of rock are fed through crushers capable of handling pieces as large as an oil drum. The first crushing reduces the rock to a maximum size of about 6 inches. The rock then goes to secondary crushers or hammer mills for reduction to about 3 inches or smaller.

In the wet process, the raw materials, properly proportioned, are then ground with water, thoroughly mixed and fed into the kiln in the form of a "slurry" (containing enough water to make it fluid). In the dry process, raw materials are ground, mixed, and fed to the kiln in a dry state. In other respects, the two processes are essentially alike.

The raw material is heated to about 2,700 degrees F in huge cylindrical steel rotary kilns lined with special firebrick. Kilns are frequently as much as 12 feet in diameter - large enough to accommodate an automobile and longer in many instances than the height of a 40-story building. Kilns are mounted with the axis inclined slightly from the horizontal. The finely ground raw material or the slurry is fed into the higher end. At the lower end is a roaring blast of flame, produced by precisely controlled burning of powdered coal, oil or gas under forced draft.

As the material moves through the kiln, certain elements are driven off in the form of gases. The remaining elements unite to form a new substance with new physical and chemical characteristics. The new substance, called clinker, is formed in pieces about the size of marbles.

Clinker is discharged red-hot from the lower end of the kiln and generally is brought down to handling temperature in various types of coolers. The heated air from the coolers is returned to the kilns, a process that saves fuel and increases burning efficiency.

Aggregates

Cement and sand ready to be mixed.
Fine and coarse aggregates make up the bulk of a concrete mixture. Sand, natural gravel and crushed stone are used mainly for this purpose. Recycled aggregates (from construction, demolition and excavation waste) are increasingly used as partial replacements of natural aggregates, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are also permitted.

Decorative stones such as quartzite, small river stones or crushed glass are sometimes added to the surface of concrete for a decorative "exposed aggregate" finish, popular among landscape designers.

The presence of aggregate greatly increases the robustness of concrete above that of cement, which otherwise is a brittle material and thus concrete is a true composite material.

Redistribution of aggregates after compaction often creates inhomogeneity due to the influence of vibration. This can lead to strength gradients.

Reinforcement

Concrete is strong in compression, as the aggregate efficiently carries the compression load. However, it is weak in tension as the cement holding the aggregate in place can crack, allowing the structure to fail. Reinforced concrete solves these problems by adding either steel reinforcing bars, steel fibers, glass fiber, or plastic fiber to carry tensile loads. Thereafter the concrete is reinforced to withstand the tensile loads upon it.

1854 – Steel reinforcement of Concrete

William B. Wilkinson, an English plasterer, erected a small reinforced concrete two-story servant's cottage. He reinforced the concrete floor and roof with iron bars and wire rope. This is credited as the first reinforced concrete building.

Chemical admixtures

Chemical admixtures are materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes. In normal use, admixture dosages are less than 5% by mass of cement and are added to the concrete at the time of batching/mixing.[14] The common types of admixtures[15] are as follows.

Accelerators speed up the hydration (hardening) of the concrete. Typical materials used are $CaCl_2$, $Ca(NO_3)_2$ and $NaNO_3$. However, use of chlorides may cause corrosion in steel reinforcing and is prohibited in some countries, so that nitrates may be favored.

Retarders slow the hydration of concrete and are used in large or difficult pours where partial setting before the pour is complete is undesirable. Typical polyol retarders are sugar, sucrose, sodium gluconate, glucose, citric acid and tartaric acid.

Air entrainments add and entrain tiny air bubbles in the concrete, which will reduce damage during freeze-thaw cycles, thereby increasing the concrete's durability. However, entrained air entails a trade off with strength, as each 1% of air may result in 5% decrease in compressive strength.

Plasticizers increase the workability of plastic or "fresh" concrete, allowing it be placed more easily, with less consolidating effort. A typical plasticizer is lignosulfonate. Plasticizers can be used to reduce the water content of a concrete while maintaining workability and are sometimes called water-reducers due to this use. Such treatment improves its strength and durability characteristics. Superplasticizers (also called high-range water-reducers) are a class of plasticizers that have fewer deleterious effects and can be used to increase workability more than is practical with traditional plasticizers. Compounds used as superplasticizers include sulfonated naphthalene formaldehyde condensate, sulfonated melamine formaldehyde condensate, acetone formaldehyde condensate and polycarboxylate ethers.

Pigments can be used to change the color of concrete, for aesthetics.

Corrosion inhibitors are used to minimize the corrosion of steel and steel bars in concrete.

Bonding agents are used to create a bond between old and new concrete (typically a type of polymer) .

Pumping aids improve pump-ability, thicken the paste and reduce separation and bleeding.

Mineral admixtures and blended cements

There are inorganic materials that also have pozzolanic or latent hydraulic properties. These very fine-grained materials are added to the concrete mix to improve the properties of concrete (mineral admixtures), or as a replacement for Portland cement (blended cements).

Fly ash: A by-product of coal-fired electric generating plants, it is used to partially replace Portland cement (by up to 60% by mass). The properties of fly ash depend on the type of coal burnt. In general, siliceous fly ash is pozzolanic, while calcareous fly ash has latent hydraulic properties.

Ground granulated blast furnace slag (GGBFS or GGBS): A by-product of steel production is used to partially replace Portland cement (by up to 80% by mass). It has latent hydraulic properties.

Silica fume: A by-product of the production of silicon and ferrosilicon alloys. Silica fume is similar to fly ash, but has a particle size 100 times smaller. This results in a higher surface to volume ratio and a much faster pozzolanic reaction. Silica fume is used to increase strength and durability of concrete, but generally requires the use of superplasticizers for workability.

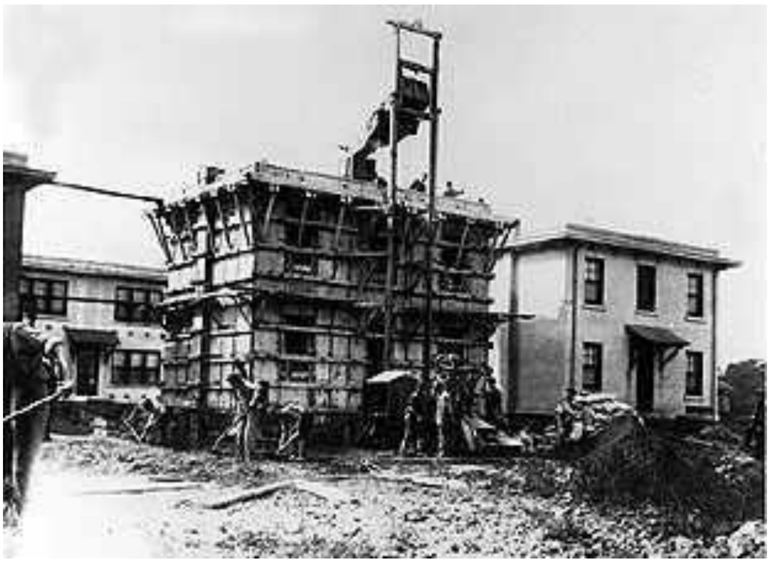
High reactivity Metakaolin (HRM): Metakaolin produces concrete with strength and durability similar to concrete made with silica fume. While silica fume is usually dark gray or black in color, high-reactivity metakaolin is usually bright white in color, making it the preferred choice for architectural concrete where appearance is important.

1903 Ingalis Building

The first concrete high rise was built in Cincinnati, Ohio (USA) in 1903. The Ingalls Building, as it is called, has sixteen stories, making it one of the great engineering feats of its time.

1904 – Two precast concrete projects in Sydney Harbor

In 1904, precast concrete was used in two projects in Sydney Harbor (Australia), Bradley's Head Lighthouse and Millers Point Wharves.



1908 – First Concrete Homes

In 1908, Thomas Edison designed and built the first concrete homes in Union, New Jersey (USA). These homes still exist today. Edison envisioned that his design would meet great success, and that before no time everyone in America would be living in a concrete home. However, his vision did not become a reality as soon as he expected; in fact, concrete homes are just starting to gain popularity now, one hundred years later.

1913 Ready Mix Concrete

The first load of ready mix was delivered in Baltimore, Maryland (USA) in 1913. The idea that concrete could be mixed at a central plant and delivered by truck to the job site for placement revolutionized the concrete industry.

1904 to 1932 - Precast concrete

Precast concrete is a construction product produced by casting concrete in a reusable mold or "form" which is then cured in a controlled environment, transported to the construction site and lifted into place. In contrast, standard concrete is poured into site-specific forms and cured on site. Precast stone is distinguished from precast concrete by using a fine aggregate in the mixture, so the final product approaches the appearance of naturally occurring rock or stone.

By producing precast concrete in a controlled environment (typically referred to as a precast plant), the precast concrete is afforded the opportunity to properly cure and be closely monitored by plant employees. Utilizing a Precast Concrete system offers many potential advantages over site casting of concrete. The production process for Precast Concrete is performed on ground level, which helps with safety throughout a project. There is a greater control of the quality of materials and workmanship in a precast plant rather than on a construction site. Financially, the forms used in a precast plant may be reused hundreds to thousands of times before they have to be replaced, which allows cost of formwork per unit to be lower than for site-cast production.

Many states across the United States require a precast plant to be certified by either the: Architectural Precast Association (APA), National Precast Concrete Association (NPCA) or Precast Prestressed Concrete Institute (PCI) for a precast producer to supply their product to a construction site sponsored by State and Federal DOTs.

There are many different types of precast concrete, forming systems for architectural applications, differing in size, function, and cost. Precast architectural panels are also used to clad all or part of a building façade, free-standing walls used for landscaping, soundproofing, and security walls, and some can be Prestressed concrete structural elements. Storm water drainage, water and sewage pipes, and tunnels make use of precast concrete units. The New South Wales Government Railways made extensive use of precast concrete construction for its stations and similar buildings. Between 1917 and 1932, they erected 145 such buildings.