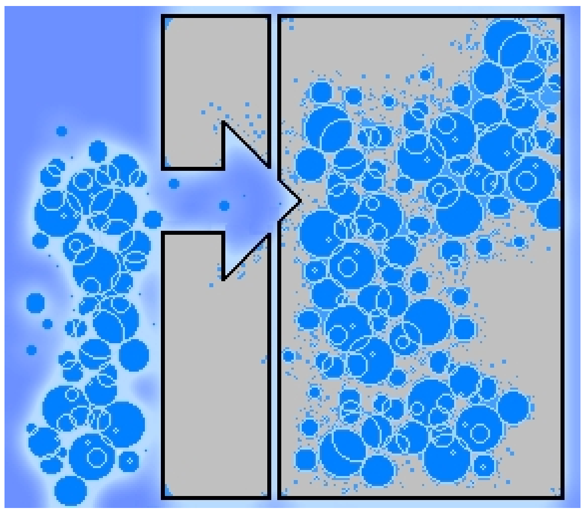
HIGH-STRENGTH STRUCTURAL LIGHTWEIGHT CONCRETE



A new direction towards advanced construction techniques
using High-Strength Lightweight Cellular Concrete
in the development of concrete in building and civil engineering construction

SPECIFIED DENSITY CONCRETE

INTRODUCTION

Rock, Stone, the Earth's perfect building material.

Cement, with different characteristics, is also a rock,. We crush, grind, then blend additional elements under intense heat to create this process. When properly proportioned with water, fine, medium and coarse aggregate and cured we then shape it back into a rock, but this time a shape that we want it to look like. We build highways, bridges, and structures.

However this new rock, or concrete is heavy and is limited because of it's composition to protect from heat and cold. It protects us somewhat from the elements: rain, wind, and fire. Rock, stone and concrete are to a degree good insulator but only as a thick or expanded volume.

What if we could find a lightweight building material that has the quality or durability and strength of rock contain freezing - thawing properties, and thermal conductivity as well.

How could we achieve this? We would have to change the composition: the weight or density.

One way is to incorporate a lightweight aggregate. Natural lightweight aggregates such as pumice [most widely used], scoria, volcanic cinders, tuff and diatomite. Or artificial aggregates or rotary kiln produced lightweight aggregates such as expanded clays, slates, slag, perlite or shale's. Cenospheres [hollow sphere comprised largely of silica and alumina with cavities filled of inert gases such as nitrogen and carbon dioxide] and recycled glass beads are additional multi-functional fillers. These low-density aggregates may function well; however they are economically available only in the vicinity of blast furnaces and are becoming increasingly expensive with increased material, fuel and labor costs.

What if we could find a way to lower the density with air? And add a relatively large amount that can be entrained in the concrete without substantially reducing the strength of the ultimate structure. Control the density, control the strengths.

This can be done by using a new, improved mechanical air-entraining admixture or concrete containing air cells or voids throughout its volume. A Specified Density Concrete [SDC] called High Strength Lightweight Structural Cellular Concrete or High-Performance Cellular Concrete [**HPCC**] / Air-Entrained Aggregate Concrete.

Cellular Concrete

Cellular Concrete is a cementitious paste of neat cement or cement and fine sand with a multitude of micro/macroscopic discrete air cells uniformly distributed throughout the mixture to create a lightweight concrete.

It is commonly manufactured by two different methods. Method A, consists of mixing a pre-formed foam [surfactant] or mix-foaming agents mixture into the cement and water slurry. As the concrete hardens, the bubbles disintegrate leaving air voids of similar sizes.
Method B, known as Autoclaved Aerated Concrete [AAC] consists of a mix of lime, sand, cement, water and an expansion agent. The bubble is made by adding expansion agents [aluminum powder or hydrogen peroxide] to the mix during the mixing process. This creates a chemical reaction that generates gas, either as hydrogen or as oxygen to form a gas-bubble structure within the concrete. The material is then formed into molds. Each mold is filled to one-half of its depth with the slurry. The gasification process begins and the mixture expands to fill the mold above the top. Similar to baking a cake. After the initial setting, it is then cured under high-pressured-steam [180° to 210°C / 356°to 410°F] “autoclaved” for a specific amount of time to produce the final micro/macro-structure.

Recently, a direction to concrete compositions prepared by using aqueous gels [aquagels] is being considered as all or part of the aggregate in a concrete mix. Aquagel spheres, particles, or pieces are formed from gelatinized starch and added to a matrix. Starch modified or unmodified such as wheat, corn, rice, potato or a combination of a modified or unmodified starches are examples of aqueous gels. A modified starch is a starch that has been modified by hydrolysis or dextrinizaton. Agar is another material that can create a pore or cell in concrete. During the curing process as an aquagel loses moisture, it shrinks and eventually dries up to form a dried bead or particle that is a fraction of the size of the original aquagel in the cell or pore in the concrete. This results in a cellular, lightweight concrete.

High carbon ash, recycled aluminum waste and zeolite powders are additional mechanical structures suitable in the production of cellular lightweight concrete.

These cells may account for up to 80% of the total volumne. Weight of the concrete mixtures range from 220 kilograms per cubic meter [l4 lbs. cubic foot] to 1922 kilograms per cubic meter [120 lbs. cubic foot] and compressive strengths vary from 0.34 megapascals [50 pounds per square inch] to 20.7 megapascals [3,000 pounds per square inch].

HIGH-PERFORMANCE CELLULAR CONCRETE

High-Performance Cellular Concrete [**HPCC**] has all the properties of cellular concrete and can achieve 55.37 MPa [8,000 psi]. Higher strengths can be produced with the addition of supplementary cementitious materials. Density and strengths can be controlled to meet specific structural and nonstructural design requirements. Where as in conventional cellular concrete these can not be achieved.

High-performance concrete is defined as "*concrete which meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials and normal mixing, placing and curing practices*." The requirements may involve enhancements of characteristics such as ease of placement and compaction without segregation, long term mechanical properties, density, volume, endurance, stability, or service life in severe or hostile environments.

Density is the best characteristic feature of cellular concrete. The lowest densities being used for fills and insulation; and the higher densities being used for structural applications, leading to a substantial reduction in the dead weight of a structure. 0.028 cubic meter [one cubic foot] of foam in a matrix replaces 28.30 kilograms [62.4 lbs.] of water, or 0.028 cubic meter [one solid cubic foot] of aggregate weighing 74.84 kilograms [165 lbs. per cubic foot].

HPCC has excellent insulation properties that significantly reduces the transfer of heat through the concrete member, This bubble is accountable for a superior freezing and thawing resistance and thermal reduce conductivity, low water absorption, high tensile strength, high fire resistance and sound retention, and corrects deficiencies in the sand that causes bleeding.

Forming, conveyance, placing and finishing systems for cellular concrete are no different than current methods in the construction industry.

HPCC also has the advantage of being conducive to mobile and remote projects where building materials are difficult to obtain or reach.

How does it work? It works in two ways.

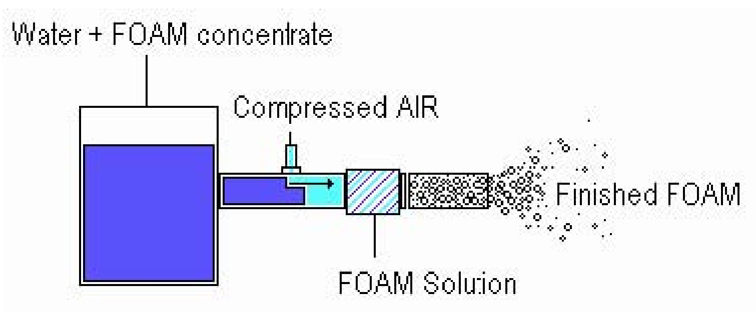
One it mechanically reduces the water/cement ratio [*w/cm*] similar to a high-range water-reducing admixture. This technique can generally reduce water requirements of a concrete mix by 20% to 54% providing a similar increase in concrete strength. 0. 69 MPa [100 psi] increase in strength for each 0.01 decrease in water/cement ratio *w/cm*]. The second technical feature is that it also performs as an aggregate. ***Air***

Conventional cellular concrete produced with a pre-formed foam mixture is produced by discharging a stream of preformed foam into a mixing unit on site or a transit mix load of sand-cement grout or cement-water slurry. This foam [surfactant] resembles shaving cream or the foam used for firefighting. Most of the foam concentrates are hydrolyzed proteins or synthetics and are available through proprietary sources. Amine and amine oxides, naphthalene sulphonate formaldehyde condensates are examples of these. Some of these products can contain a substance or substances classified as dangerous or hazardous to the environment, cautious attentiveness should be considered when using these products, especially towards the formaldehyde condensates, butyl carbitol, and glycol ethers.

Depending on an application using foam produced from a surfactant usually is not an environmental issue. However in some countries this can be a religious concern/significance. This would be the case when using hydrolyzed protein based surfactants that contain keratin or casein derivatives.

Surfactants are surface-active substance or agent [detergents, wetting agents, emulsifiers] that when added to water lowers surface tension and increases the “wetting” capabilities of the water, thus improving the process of wetting and penetrating that surface or material. When agitated forms a large mass of micro/macroscopic bubbles.

With this device or process [**HPCC**] a surfactant [wetting agent] or foam concentrate is diluted with water to form a foam solution. This solution is then injected with compressed air through a blending device or foam generator. The quantity of the foam injected into the mixture proportions is in the range of 0.07 to 0.40 per cubic meter [2 to 11 cubic foot per cubic yard] of concrete. The water/cement ratio [*w/cm*] is in the range from 0.23 to 0.32 and a foam of microscopic bubbles with at least a majority being in the range from 25 µm to 100 µm [0.025mm to 0.1 mm / 0.001 inches to 0.004 inches] in diameter. * Normal cellular concrete bubble range is
0.3 mm - 0.8 mm [0.012 in. - 0.032 in.] in diameter.



Concrete is formed by mixing the liquid cement paste with predetermined qualities of aggregate material. The aggregate is typically made up of medium and coarse aggregate or rock and fine aggregate or sand. Or the next generation of fillers that are artificial or recycled. These to include natural/artificial pozzolans, recycled glass, ceramic, expanded polystyrene beads, plastic, organic or inorganic materials.

In conventional concrete, the percentage of sand in the aggregate is 30% to 40%. However, the foamed cement of this process/invention is preferably mixed with an aggregate having a higher ratio of sand.

Preferably in the range of 40% to 50%. This reduces or eliminates voids in the concrete mixture, since gaps between larger rock particles may be filled with a combination of smaller rock, sand, and air bubbles. The smaller the spacing factor, the more durable the concrete will be. These microscopic

bubbles are smaller than the size of the sand particles increasing the plasticity or flowability of the mix.

As the concrete hardens, the bubbles disintegrate or transform, releasing the water which is absorbed into the cement matrix, thus aiding in the hydration process and leaving air voids of similar sizes. Thus, there is less need to wet the concrete during curing, as is normally necessary with conventional, unfoamed concrete.

An air-entraining admixture must produce stable air bubbles that won't coalesce to form larger bubbles during mixing. For a given air content or volume of air, if bubbles are too large, there won't be enough of them present to properly protect the paste. Large bubbles are also more likely to break while the concrete is being mixed, transported, placed and vibrated. If too much air is lost during these operations, the remaining air voids may not adequately protect the hardened concrete during cold weather or thermal conductivity. To prevent air loss, the bubble skin must be stable and tough enough to resist breaking and coalescing, and the size must be extremely small, minute or microscopic.

Grading and Segregation

Aggregate gradation significantly affects concrete mixture proportioning and workability. The particle size distribution, particle shape and surface texture are all important elements in the assurance of concrete quality and durability.

Variations in grading materials, either by blending selected size aggregates or an adjustment of concrete mix proportions involves constant attention to meet a performance specification.

When particles are poorly distributed within the mixture or if there is a deficiency of intermediate [medium] aggregates, mechanical properties of the mix, as well as placing and finishing will result in an inferior product. Eventually, the mechanical and physical properties of the concrete will continue to deteriorate creating additional problems.

AC I 116R-00 "Cement and Concrete Terminology" defines grading as *"the distribution of particles of granular material among various sizes; usually expressed in terms of cumulative percentages larger or smaller than each of a series of sizes (sieve openings) or the percentages between certain ranges of sizes (sieve openings) "*. Proportioning should be made in accordance with ASTM C33-99ae1 [Standard Specification for Concrete Aggregate] and ASTM C136-96a [Standard Test Method for Sieve Analysis of Fine and Coarse Aggregate].

The quantity of the fine aggregate and coarse aggregates in a mixture must be in balance with one another so as to create a particle size distribution to produce a specified accumulated density. However selection of the aggregates is or sometimes not always consistent. Accessibility, environmental mandates and the cost to import supplementary natural or artificial intermediate aggregates are issues that must be addressed so that a maximum optimized concrete can be produced economically for performance, durabilty, and structural construction methodology.

High-Performance Cellular Concrete is an excellent choice to use as an intermediate aggregate when these material sizes are substantially absent, creating an improved concrete uniformity or an optimal particle size distribution.

Segregation is greatly decreased, especially in concrete where sand gradation is poor. [Segregation is when coarse aggregate separates from the water, settles to the bottom and the water rises to the top producing poor workability and excessive bleeding.]

How is segregation controlled? These microscopic strong super bubbles puts the matrix in suspension.

Extended-set:

This air-entraining admixture is also advantageous for special applications where extended set or where delivery over long distances is necessary. One way to extend or prolong this is the use of hydration stabilizers. With this process [**HPCC**] a mix can be transported/placed exceeding ASTM C94-96el, without the addition of a stabilizer, water or admixtures.

In paragraph 11.7 of ASTM C94-96el, "Standard Specification for Ready-Mixed Concrete" states "discharge of the concrete shall be completed within 1½ hours, or before the drum has revolved 300 revolutions, whichever comes first, after the introduction of the mixing water to the cement and aggregates or the introduction of the cement to the aggregates."

Vibration:

This process can be vibrated and will not cause segregation of the mortar and coarse aggregate. In most applications no vibration is necessary.

APPLICATION

Brief History

Cellular Concrete was first developed in Stockholm, Sweden in the early 1900's. The original material was known as "gas concrete" to be used in producing heat-insulated building materials. This led to the development of related lightweight concrete which are now known as cellular concrete, foamed concrete, aerated concrete and autoclaved cellular concrete.

After the Second World War, this technology quickly spread to different parts of the world, mostly Europe and the Soviet Union. The applications were for economical large-size structural panel units. These were used in site reconstruction and low-rise structures.

It wasn't till the late 1950's when this was introduced to the US as foamed or cellular concrete. The applications were for floor, roof and wall units. Having low compression strengths, it limited this product to fills and insulation only.

Currently

The major use in recent years in the United States has been over plywood on wood floor systems or over hollow-core precast slabs. The material is also used in light density for roof fills 481 kilograms per cubic meter [30 pounds per cubic foot] providing good insulating properties.

Even today this material still generate low compressive strengths limiting it to these two applications. Range options are 3.45 MPa [500 psi] to 6.89 MPa [1,000 psi] for midrange nonstructural densities and 10.3 MPa [1,500 psi] to 24.1 MPa [3,500 psi] for higher densities 1762 kg/m^3 [110 lb/ft^3].

New Direction

Concrete design has evolved rapidly in the last 30 years. Construction technology has seen the introduction of a variety of concrete products to the market as well as an increased use of supplementary cementitious materials and recently blended cements. Emphasis has been placed on creating more durable concrete through changes to the mix constituents and proportions, including the aggregates, admixtures and the water-cement ratio. These changes have been reflected in national and hopefully will lead to global/International design, standards, performance specifications and codes which address such factors as performance, durability, permeability, cement constituent ratios, and limitations on impurities. This evolution, along with improved reinforcing steel strength, has lead to modifications in design philosophy - most notably the use of thinner structural members.

As for a lower weight of these structural members, there are many applications for which a 1602 kg/m^3 [100 lb/ft^3] or lower structural concrete would be beneficial. With normal lightweight concrete in the 1,442 - 1,681 kilograms per cubic meter [90 - 105 pounds per cubic foot] range requires lightweight fine aggregate as well as coarse. When natural sand is used with lightweight coarse aggregates, strengths of 34.5 - 48.3 megapascals [5,000 - 7,000 pounds per square inch] can be obtained but the weight runs from 1,842 - 2,002 kilograms per cubic meter [115 to 125 pounds per cubic foot] adding to the weight. With High Performance Cellular Concrete [**HPCC**] the weight is significantly reduced to a 1041 - 1522 kilograms per cubic meter [65 to 95 pounds per cubic foot] with a 34.5 to 48.3 megapascals [5,000 - 7,000 pounds per square inch] resulting in improved structural efficiency in terms of strength/weight ratios, with fewer structural components, and a consequent reduction in the number and size of reinforcements. Panel width can be manufactured as thin as 63.5 millimeters [2.5 inches].

What are the applications and benefits.

Architectural:

Improved structural efficiency in terms of strength/weight ratios resulting load reduction on the structure and substructure, fewer structural components resulting in more usable space in the structure, a reduction in the number and size of reinforcements, increased flexibility in absorbing strains and improved thermal properties minimizing the effects of differential temperatures resulting in building energy conservation as well as improved fire/spalling mitigation.

It is ideally suited for precast concrete products as larger units can be handled with the same handling equipment or manually for same size units, resulting in speed and economy in construction. These units in addition to smaller ones can be lifted or managed by down-sizing machinery resulting in reducing site cranage requirements and maximizing the number of concrete elements on trucks without exceeding highway load limits reducing transportation delivery cost.

Architectural Applications:

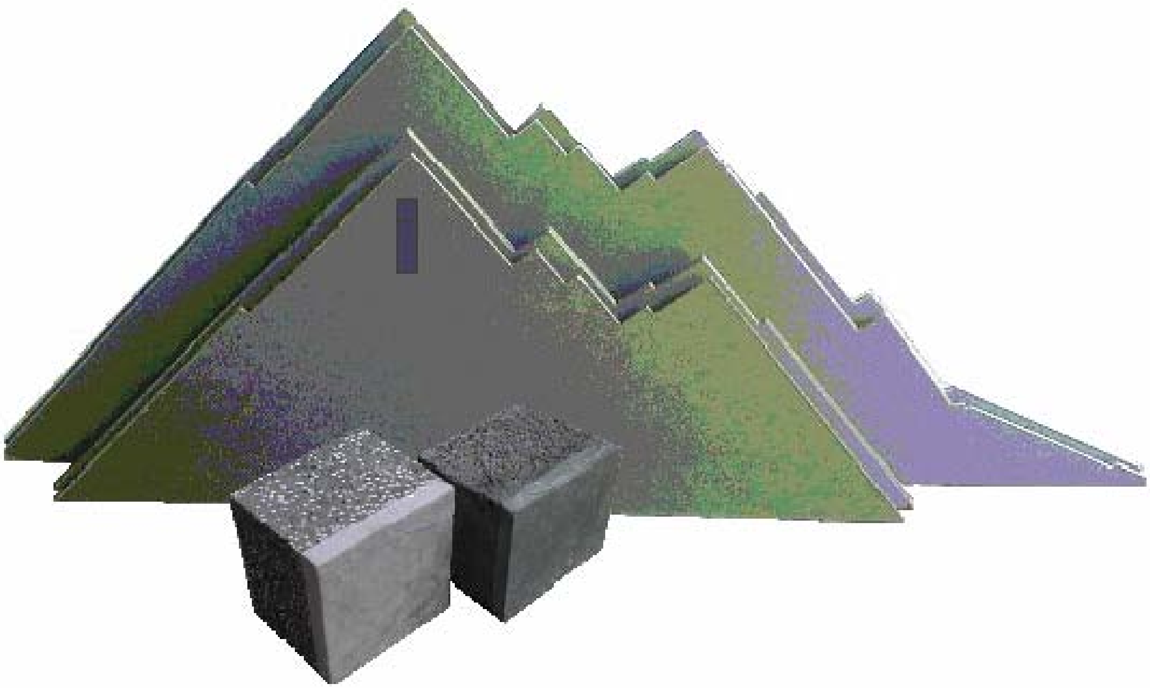
Precast Architectural Panels Cladding Load Bearing Wall Units Shear Walls	**Reinforced Load Bearing Wall Units** Hollow Core Ribbed Plank Beam-block Massive Composite	**Blast and Shock Mitigation** **Sound Attenuation**
Cast-in-Place Columns and Beams	**Partition Walls** **Fire Walls**	**Seismic Energy Absorption.**
Non Load Bering Facade/Wall	**Modular Segmental Systems**	**Foundation Renovation.**
Precast/Prestressed Columns and Beams	**Transportation Structures** Bridge Decking Composites Noise Abatement	**Precast Pressure Pipe**
Single/Double TEE's	**Tilt Up**	**Lightweight Masonry Blocks**
Precast Riser/Rake Beams	**High-Performance Composites** Specialized Single Skin Double Skin	**Lightweight Plaster Aggregate** **Sprayed Fire-Resistive Materials [SFRP]** **Cellular Grout**

Sandwich Panels	**Spandrel Units**	**Decorative Concrete**

Advanced Construction Techniques for Precast Panel System

Implementation of advanced construction techniques using cellular concrete technology.

One example of areas to which High Performance Cellular Concrete can be applied is in the development of a lightweight binary density insulating concrete panel system. This product could be a consideration for future applications in a new generation of buildings. These elements can be used for the construction in all types of building or structures worldwide. For instance affordable housing, schools, senior citizen's centers, industrial, military and municipal facilities, and structures requiring service life in severe or hostile environments. Another precast application would be for new or replacing metal sheeting on the exterior skins on metal buildings.



[A] EPS beads + foam [B] foam only
50.80 mm [2 in. X 2 in.] cube specimens

These two illustrated samples represent this binary process. The thinner 7.62mm [3/8"] coloured finish would contain a density in the range of 1522 kg/m³ to 1762 kg/m³ [95 lb/ft³ to 110 lb/ft³]. And the second density following the first would be a 1041 kg/m³ [65lb/ft³] thermal density. Two main advantages with system is [1] Savings on colouring, since it only is encapsulated in this thin area, and not throughout the entire mix. [2] Thermal conductivity through both members lowering costs to heat or cool inside the structure. The binary system reduces the weight of the material in addition decreasing structural weight yet maintaining medium or high Mpa [psi].

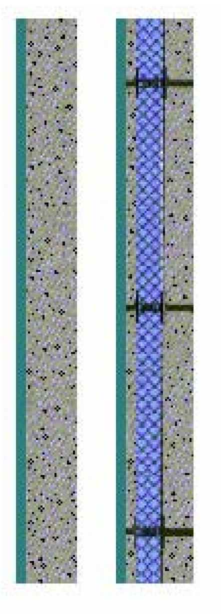
Precast Panel mix/material variation:

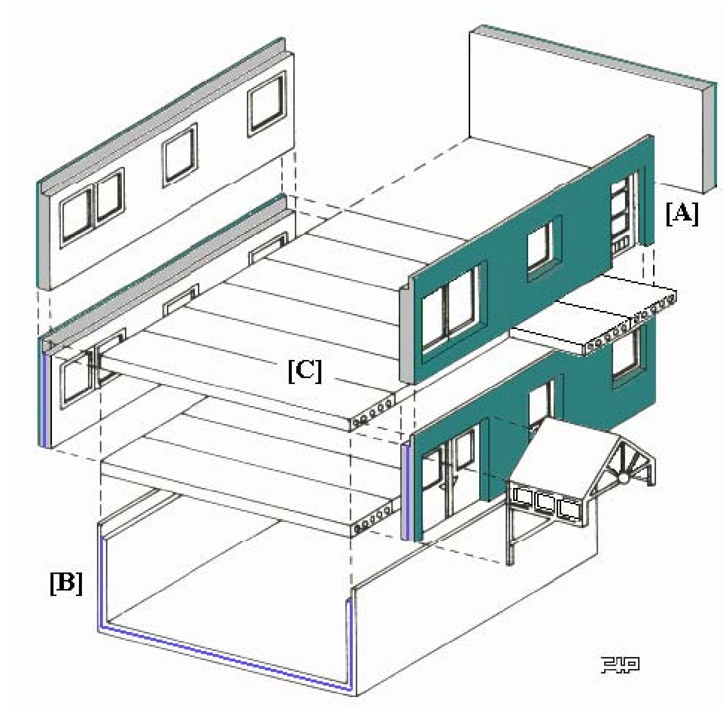
[A] Single Skin Bi-Density Panel with EPS Beads
Facing skin: Clay, Ceramic, Brick Face, Terra Cotta ,Stone, Marble, Metal]

[B] Sandwich Panel with internal rigid insulation board with EPS beads

[C] Hollow Core Planks produced with HPCC

[A]   *[B]*



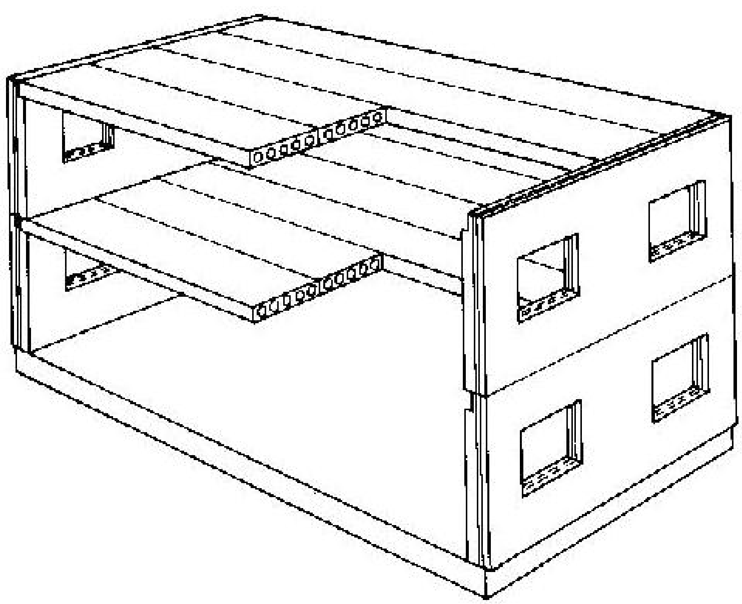


Hollow Core

Application that can benefit from this process. Hollow core concrete planks and wall panels products are one of the most advanced building materials being used in the construction industry today. The advantage of these extruded wall panels is in durability. They offer outstanding reductions in sound transmission and can obtain fire ratings of up to 4 hours. The problem with this product it has very little or if any insulation properties.

High-Performance Cellular Concrete [**HPCC**] can provide excellent insulation and reduce the weight to half of the normal weight for this product to 32 kilograms per cubic foot [70 pounds].

Principle of load-bearing facades



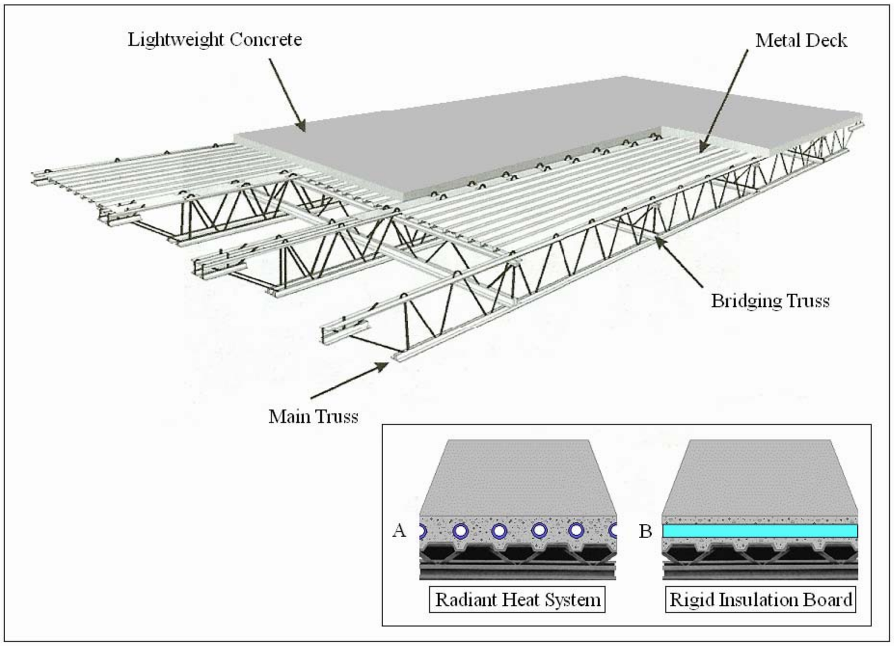



Photos: LightConcrete LLC   Nov. 2000

Housing project: Relocation/resettlement project near New Zigui township, Hubei Province, China in conjunction with the Three Gorges Project [**TGP**] also known as **China Yangtze Three Gorges Dam** [**TGD**], a massive public works program currently underway. Typical exterior finishing surface to these Hollow Core panels will include ceramic tiles or mortar/plaster mix. Roof : ceramic tiles

TGP is a multi purpose hydro development project producing comprehensive benefits mainly in flood control, power generation and navigation improvement to the Yangtze [Chang-Jiang] River.

Composite Roof and Floor Steel Decking



Application for insulated properties as well as a sound barrier for lightweight composite roof or floor deck in commercial, industrial, residential buildings/structures. This would especially true for power utility problems currently being experienced in hot and cold regions where electricity, gas or oil consumption is an issue. Heating and cooling costs are reduced.

Architects have been specifying lightweight concrete steel decking for years. Cost has always been a issue from rising and falling prices associated with lightweight aggregates, this is especially true with expanded shale, clay and slate. The cost to produce these in the immediate future will rise significantly.

Pre-Cast or Poured-in-Place Sound Barriers

Lightweight Fire-Resistance
+
Insulating Facade Panels

Architectural Precast-Panels or High-Performace Plaster applied to exterior metal framing providing high-guality material performance and upgrading design appearance to obsolete or dated structures

High-Performance Lightweight Plaster Application on Cold Steel Framing

Precast Composite Binary Insulated panel + cold metal system

Geotechnical

Primary application of CLSM [Controlled Low Strength Material] is as a structural fill or backfill in lieu of compacted soil. Compaction is not required and is ideal for use in tight or restricted-access areas where placing and compacting fill is difficult.

Low density CLSM is especially advantageous where weak soil conditions are encountered and the weight of the fill must be minimized. Provides superior thermal insulation and shock mitigation properties.

Geotechnical Engineered Fill

Flowable Fill or Controlled Low Strength Material [**CLSM**], Low Density Controlled Low

Strength Material [**LD-CLSM**] and Controlled Low Strength Material-Controlled Density Fill [**CLSM-CDF**] are all Engineered Geotechnical Fills. Common names for this material are flowable fill, controlled density fill, unshrinkable fill and soil-cement slurry.

Flowable fill is an engineered backfill material used as an alternative to compacted fill that can make backfill faster, is self leveling, and can obtain total compaction within a few hours of placement. Compressive strengths can be adjusted according to the project requirements. Placing as a permanent material or permitting re-excavation at a later date.

There are two types: [1] normal with a density or weight in the range of 1842-2323 kg/m^3 [115-145 lb/ft^3], which is greater than most compacted materials. [2] As a controlled low density/medium density fill using lightweight aggregates and/or with a pre-formed foam.

CLSM is defined by the ACI Committee 229 as a cementitious material that is in a flowable state at the time of placement and having a specified compressive strength of 8.3 MPa [1,200 psi] or less at the age of 28 days. Flowabilty can be varied from very stiff to very fluid depending upon requirements.

Mixture proportions consists primarily of a filler, a binding agent of some type, such as ash cement or Class C or Class F fly ash and water that is usually twice of normal concrete. Some mixes contain a fine aggregate, fly ash (optional) , cement (small amount) and hydration. When a controlled density is required, foam or lightweight aggregates are added to lower the density or weight. Cement based mixes generate highest long-term strengths. Superior resistance to freezing and thawing and thermal cycles. Foam also eliminates segregation and settlement. Recycled and non-standard materials are excellent fillers for the use of/for the aggregate.

These to include or a combination of fly ash, slag, cinders, light expanded clay. Non-standard materials consist of material not meeting ASTM C33-99ael [Standard Specifications for Concrete Aggregates] that drastically reduce the cost of CLSM mixtures can be expanded polystyrene beads [extremely light material, about 100 times lighter than ordinary filling material], plastic waste, shredded tires, wood fiber, glass, sludge waste.

Before allowing the use of recycled waste materials, the producer of the Geotechnical fill must first evaluate the potential environmental effects of using these candidate materials to ensure compliance with federal and state environmental laws. Even if the use of recycled waste materials complies with environmental laws, materials that are determined to be non-hazardous wastes can still be toxic in the environment. Use of recycled materials that result in measurable environmental toxicity could result in the producer becoming liable for future clean up and/or damages to nearby third party landowners. To manage these potential environmental risks, you should develop a risk bioassay method that evaluates the relative toxicity of current used transportation materials compared to their proposed replacements. Currently there are methods to encapsulate or treat these materials but this will bring an additional cost to the engineered fill depending on the application. This would be particularly true if the fill is to be placed near water containment areas: wells, streams, ponds or lakes.

Using foam produced from a surfactant is not an environmental issue. However in some countries this can be a religious concern/significance. This would be the case when using hydrolyzed protein based surfactants.

CLSM is also being used as a foundation material where soft soil and weak organic deposits are to the extent of being very poor quality, greatly reducing stability or settlement problems. This system can reduce or balance loads, or transfers them to more resistant layers, improve or replace problem soils. Variations and combinations of the basic methods mentioned here may be applicable.

Typical mix proportions for CLSM are: fine aggregate known as the filler aggregate which makes up the major portion, 72% of a typical CLSM mixture and water 17% and portland cement providing cohesion at 3% - 7%.

Moderate strength in the 3.54 MPa [500 psi] to 10.3 MPa [1,500 psi] range is similar to that of many naturally occurring bedrock formations. 0.35 [50 psi] to 0.7 MPa [100 psi] compressive strengths designs is suggested for removability or re-excavation.

Lightweight foamed concrete fill has been used successfully to prevent increased loads on embankment foundations. By removing a quantity of existing fill or natural material and replacing it with an equal weight of lighter fill to the required grade lines, no additional load is transferred to the foundation soil. For example, if 0.3 meter of existing material, with a density of 1920 kg/m^3 [120 lb/ft^3], is excavated, 0.9 meters of lightweight fill with a density of 641 kg/m^3 [40 lb/ft^3] can be placed without introducing any additional loading on the foundation soils. It also used as a backfill to prevent increased lateral loading on existing abutments and retaining walls. In some placements a dense layer of lightweight foamed concrete is used as a footing base. Some placements also involve a dense top lift upon which a reinforced concrete pavement is placed directly.

Density/compressive strength, permeability, absorption, buoyancy and durability are all physical and chemical properties of foamed concrete which are of concern when it is used as an engineered construction material.

Water absorption is a great concern for a lightweight foamed concrete that has a density under 320 kg/m³ [20 lb/ft³]. Since 80 % of the mix is air, this can make it very porous. This high degree of absorption can lead to a 50-percent loss of compressive strength after saturation and additional significant deterioration in freeze and thaw cycle.

Design for these variables can be controlled by additional specifications by eliminating the water from the surface, encapsulation, or additional filler aggregates resistant to surface/subsurface hydrology. Expanded polystyrene [EPS] beads, which is an extremely light material, about 100 times lighter than ordinary filling material are a excellent choice. Not only does it have sufficient strength to sustain the loads in a given structure, it also is a good insulator. Another solution is placing a thin denser lightweight concrete on top of the less dense lightweight foamed concrete fill.

Another consideration on ground water is since the behavior of lightweight foamed concrete is particularly sensitive to inundation, the groundwater level, as well as any seeps or springs, should be identified in the subsurface investigation. Where seeps and springs are present which may introduce water into the bottom or sides of the foamed concrete fill, drains or a drainage blanket of sized and graded granular material should be provided to carry the water away from the fill. Geotechnical mats are a good choice.

Recently airports in the United States as well as other countries world wide are placing a Low Density Controlled Low strength Material [LD-CLSM] as a Soft Ground Arresting System or Engineered Materials Arresting Systems [EMAS]. This system is constructed of high-energy-absorbing materials of selected strength located in the safety area, or overrun, of the runway. They are designed to crush under the weight of commercial airplanes to provide controlled deceleration force on the landing gear in case of an overrun. More information concerning EMAS is in Federal Aviation Administration Advisory Circular AC 150/5220-22, *Engineered Materials Arresting Systems [EMAS] for Aircraft Overruns.*

Mix Proportion per Cubic Yard with a 2083 kg/m³ [130 lb/ft³] Density with no foam [Geotechnical Fill]

Component	Weight [lb]	Volume	Volume %
Cement	100	0.51	2%
Water	584	9.36	34%
Fly Ash [Class F]	300	1.96	7%
Fine Aggregate	2600	15.55	57%
Air [1.5%]	-----	0.41	
Total	3584	27.79	100%

Cement/Fly Ash Mix with a 1466 kg/m³ [91.5 lb/ft³] Density
Compressive Strength - 0.41 MPa [60 psi] @ 28 day

Component	Weight [lb]	Volume [ft³]	
Cement	158	0.81	
Water	1052	16.86	
Fly Ash [Class F]	1262	9.03	
Air	___	0.30	
Total	2472	27.00	

Mix Proportions per Cubic Yard with a 1121 kg/m³ [70 lb/ft³] Density with foam [Thermal Fill [CLSM-CTF]]

Component	Weight [lb]	Volume [ft³]	Volume %
Cement	200	1.01	4%
Water [.40]	80	1.28	5%
Fine Aggregate	1630	9.85	36%
Add Aggregate*			
Foam [Air]	56	15.00	55%
Total	1966	27.14	100%

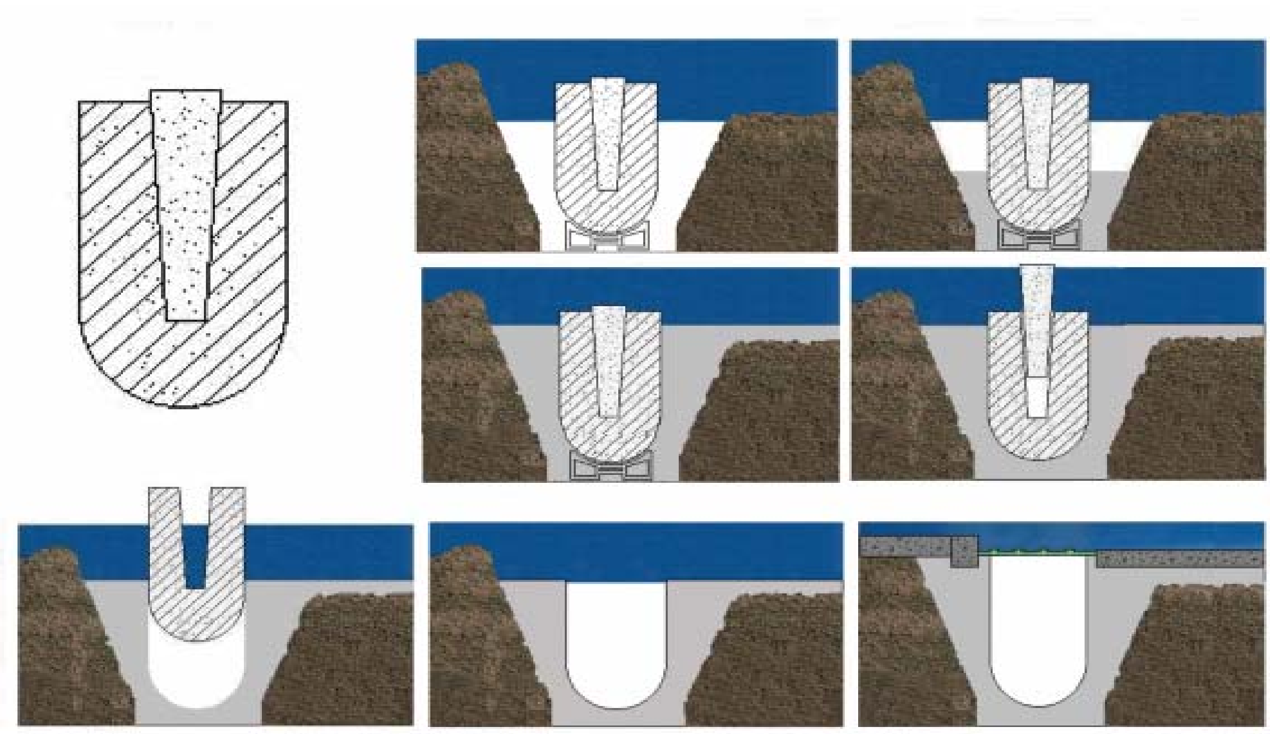
Geotechnical Applications

Thermal Fills [CLSM-CTF]
Pavement Base [CLSM-CPB]
Controlled Structural Fill [CLSM-CSF]
Anti-corrosion Fill [CLSM-ACF]
Self-Compacting Concrete [SCC]
Sub-base
Erosion Control / Soil Stabilization
Conduit / Pipe Bedding
Bridge Approach / Abutment
Insulating / Isolation Fills
Site Reconstruction
Shock and Blast Mitigation
Shock Absorbing Concrete [SACON]
Seismic Energy Absorption
Soft Ground Arresting Systems [EMAS]
Load reducing Engineered Fill over underground structures.
Void filling for abandoned underground and mining facilities, wells, tunnel shafts, or additional cavity fill.
Culvert Fill for Substandard Bridge Conversions
Backfill in or around engineering structures when this is more practical than using soils.
Fill to reduce hydrostatic pressure on retaining walls
Canal Distribution Systems [CDS] Flood Control Reconstruction and Land Reclamation
Slurry Walls

Drainage trench

Common drainage trench construction with stone and mortar. Slow and labour intense. A simpler, accelerated and economical approach would be to use the technique below.

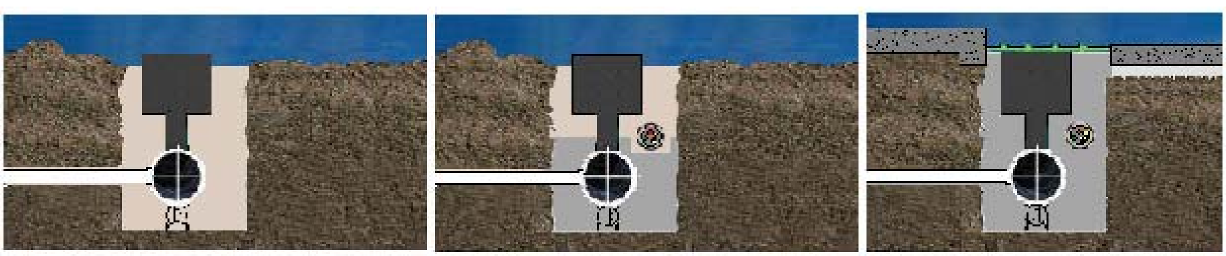
Rigid pre-sloped expanded polystyrene forms 3 meters in length are placed in excavated channel. An engineered Geotechnical fill with a specified strength and density is poured around the forms and allowed to harden. Form is removed and additional site completion either as an open or closed system.



Utility Trench Fill

The flowable backfill [soil cement pipe bedding] is designed to completely surround the pipe and extend a minimum of 152.40 mm [6 inches] above the top of the pipe as shown in the following illustrations for a common street and sidewalk application.

In the placement area of the foamed concrete fill is easily accommodated by setting the drainage [concrete, clay or polyethylene plastic pipe] on supports [Figure A]. These can be plastic chairs or to economize, used/broken concrete, bricks, stones, or recycled material. Once the fill has been placed to just below the utility elevation, temporary blocking or bracing could be used to hold the utility pipe in place as the lightweight foamed concrete fill is placed around it. Additional utility [electric or gas] can then be placed at this time [Figure B]. The last rise/lift fill is poured to the level that will receive the top surface. Additional various density concrete can be specified for sidewalk, sub-base, road surface, pavers or precast panels. [Figure C].

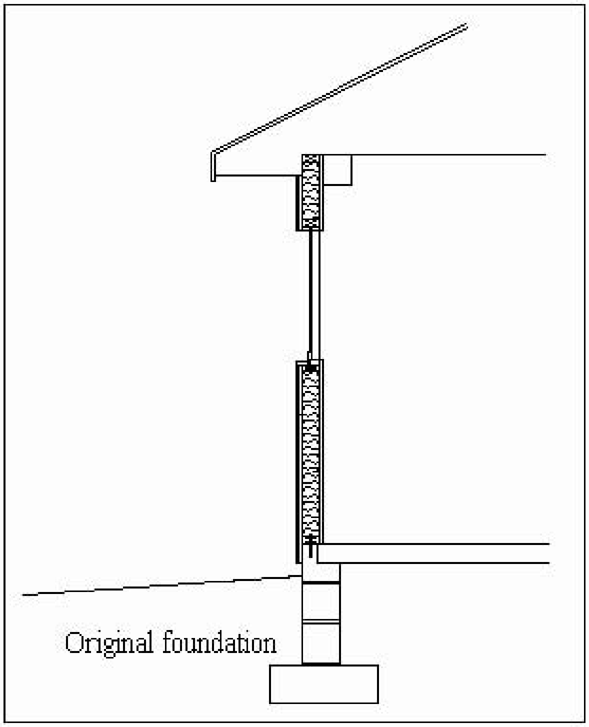


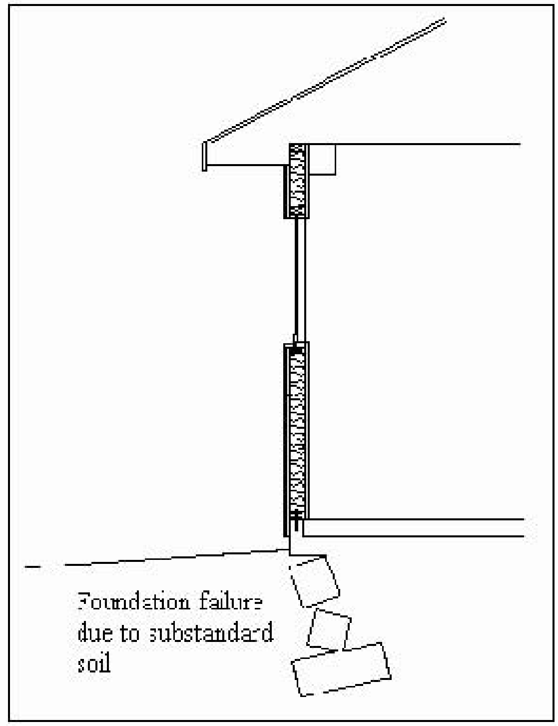
[A] [B] [C]

This allows the use of a flowable fill to minimize the excavation required for the pipeline. And the use of elaborate sheeting and shoring [top inset photo] is not necessary because workmen do not have to enter the trench to compact the bedding material in lifts. Polyethylene plastic pipe has the economic advantage over conventional clay, concrete or metal pipe placement.

Post-construction utility installation can be accomplished effortlessly/efficiently by re-excavating the lightweight foamed concrete fill at a later date with a backhoe, jackhammer, or hand tools. Pipe jacking or boring operations are also options. The corresponding specified strengths are based upon the initial mix design: backhoe less than 8.27 MPa [1,200 psi], mechanical: less than 1.38 MPa [200 psi], and hand tools being less than 0.69 MPa [100 psi].

If the backfill is for a hostile or severe environment for gas or oil, a thermal fill would be designed/specified [CLSM-CTF]

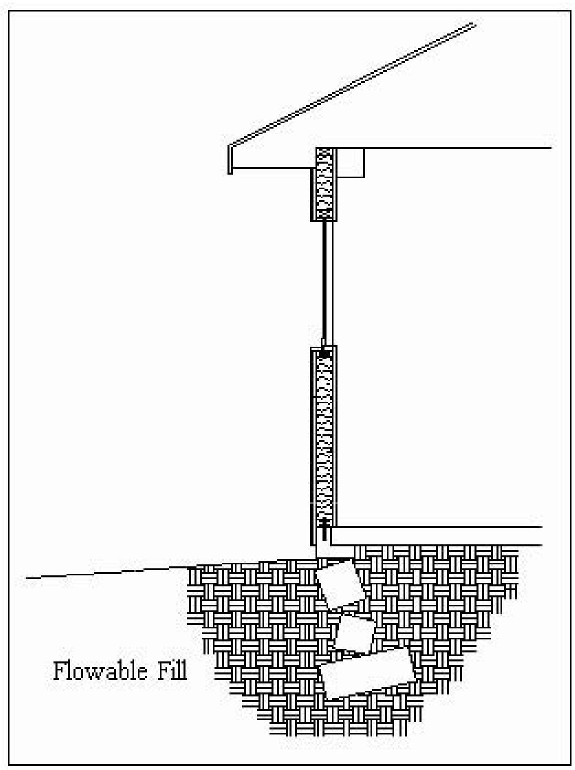




Structural Fill

Application where substandard soil under a structure has failed and is now replaced with a fill.

Structure is supported by a density and compressive strength specified by a structural engineer.



STANDARD & REFERENCE DOCUMENTS

American Concrete Institute [ACI]

116R-90 Cement and Concrete Terminology
117-90 Standard Specifications for Tolerances for Concrete and Materials
201.2R [Reapproved 1997] Guide to Durable Concrete
209-92 [Reapproved 1997] Prediction of Creep, Shrinkage, and Temperature Effects in Concrete Structures
211.1-91 [Reapproved 1997] Selecting Proportions for Normal, Heavyweight and Mass Concrete
211.2-98/221.2-98 Standard Practice for Selecting Proportions for Structural Lightweight Concrete
211.3R-97 Guide for Selecting Proportions for No-Slump Concrete
211.4R-93 [Reap. 1998] Guide for Selecting Proportions for High-Strength Concrete with Portland Cement and Fly Ash
211.5R-96 Guide for Submittal of Concrete Proportions
212.3R-91 Chemical Admixtures for Concrete
212.4R-93 [Reap. 1998] Guide for the Use of High-Range Water-Reducing Admixtures [Superplasticizers] in Concrete
213R-87 [Reapproved 1999] Guide for Structural Lightweight Aggregate Concrete
214.3R-88 [Re 1997] Simplified Version of the Recommended Practice for Evaluation of Strength Test Results of Concrete
216-97 Guide for Determining the Fire Endurance of Concrete Elements
216.1-97 Standard Method for Determining Fire Resistance of Concrete and Masonry Construction Assemblies
221R-96 [Reapproved 2001] State-of-the-Art Report on Alkali-Aggregate Reactivity [ACI 221.1R-98]
222R-96 Corrosion of Metals in Concrete
223-98 Standard Practice for the Use of Shrinkage-Compensating Concrete
225R-99 Guide to the Selection and Use of Hydraulic Cements
229R-99 Controlled Low Strength Materials [CLSM]
230.1R-90 [Reapproved 1997] State-of-the-Art Report on Soil Cement
332.1R-00 Use of Raw or Natural Pozzolans in Concrete
232.2R-96 Use of Fly Ash in Concrete
233R-95 Ground Granulated Blast-Furnace Slag as a Cementitious Constituent in Concrete
234R-96 Guide for Use of Silica Fume in Concrete
301-99/301M-99 Standard Specification for Structural Concrete [Metric]
302.1R-96 Guide for Concrete Floor and Slab Construction
303R-91 Guide to Cast-in-Place Architectural Concrete Practice
304R-89 Guide for Measuring, Mixing, Transporting and Placing Concrete
304.2R-96 Placing Concrete by Pumping Methods
304.5R-91 Batching, Mixing and Job Control of Lightweight Concrete
304.6R-91 Guide for the Use of Volumetric Measuring and Continuous-Mixing Concrete Equipment
305R-99 Hot Weather Concreting
306-1-90 Standard Specification for Cold Weather Concreting
308.92 Standard Practice for Curing Concrete
308.1-98 Standard Specification for Curing Concrete
309R.96 Guide for Consolidation of Concrete
311.4R-00 Guide for Concrete Inspection
311.5R-97 Batch Plant Inspection and Field Testing of Ready Mix Concrete
318-02 Building Code Requirements for Structural Concrete
325.3R-87 Guide for Design of Foundations and Shoulders for Concrete Pavements
325.9R-91 Guide for Construction of Concrete Pavements and Bases
347R-94 Guide for Formwork for Concrete
357R-84 Guide for the Design and Construction of Fixed Offshore Concrete Structures
357.2R-88 State-of-the-Art Report on Barge-like Concrete Structures
360R-92 Design of Slabs on Grade
363R-92 [Reapproved 1997] State-of-the-Art Report on High-Strength Concrete
363.2R-98 Guide to Quality Control & Testing of High Strength Concrete
523.1R-92 Guide for Cast-in-Place Low Density Concrete
523.2R-96 Guide for Precast Cellular Concrete Floor, Roof and Wall Units
523.3R-93 Guide for Cellular Concrete above 50 pcf and for Aggregate Concrete Above 50 pcf with Compressive Strengths less than 2,500 psi
533R-93 Guide for Precast Concrete Wall Panels
544.1R-96 State-of-the-Art on Fiber Reinforced Concrete
544.2R-89 Measurement of Properties of Fiber Reinforced Concrete
544.3R-93 [Reapproved 1998] Guide for Specifying, Proportioning, Mixing, Placing of Finishing Steel Fiber Reinforced Concrete
544.4R-88 [Re. 1999] Design Considerations for Steel Fiber Reinforced Concrete

547R-79 Refractory Concrete State-of –the-Art Report
548.1R Guide for the Use of Polymers in Concrete
550R-96 Design Recommendations for Precast Concrete Structures
551R-92 Tilt-Up Concrete Structures
SP-2 Manual of Concrete Inspection
SP-4[95] Formwork for Concrete
SP-150 Controlled Low-Strength Materials
SP-71[91] ASTM Standards in ACI 301 & 318
SP-136 Structural Lightweight Aggregate Concrete Performance

ACI Technical Committee

211 Proportioning Concrete Mixtures
213 Lightweight Aggregate
216 Fire Resistance & Fire Protection of Structures
221 Aggregates
229 Controlled Low Strength Material
230 Soil Cement
308 Curing Concrete
523 Cellular Concrete

Precast / Prestressed Concrete Institute

Architectural Precast Concrete
PCI Design Handbook: Precast and Prestressed Concrete
State-of -the Art of Precast/Prestressed Sandwich Wall Panels [PCI Committee Report]

Portland Cement Association

PCA Design and Control of Concrete Mixtures

American Society for Testing and Materials [ASTM]

A185-01 Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete
A674-00 Standard Practice for Polyethylene Encasement for Ductile Iron Pipe for Water or Other Liquids
C29/C29M-97 Standard Test Method for Bulk Density [Unit Weight] and Voids in Aggregate
C31/C31M-00 Standard Proportions for Making and Curing Concrete Test Specimens in the Field
C33-01 Standard Specifications for Concrete Aggregates
C34-96 Standard Specification for Structural Clay Load-Bearing Wall Tile
C39/C39M-99 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
C40-99 Standard Test Method for Organic Impurities in Fine Aggregates for Concrete
C42/C42M-99 Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C55-01 Standard Specification for Concrete Brick
C56-96 Standard Specification for Structural Clay Non-Load-Bearing Tile
C67-01 Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile
C70-00 Standard Test Method for Surface Moisture in Fine Aggregates
C78-00 Standard Test Method for Flexural Strength of Concrete [Using Beam with Third-Point Loading]
C87-83[1995]e1 Standard Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
C90-01 Standard Specifications for Load-Bearing Concrete Masonry Units
C94/C94M-00e2 Standard Specifications for Ready-Mixed Concrete
C108-46[1998] Standard Symbols for Heat Transmission
C109/C109M-99 Standard Test Method for Compressive Strength of Hydraulic Cement Mortars [Using 2-in. or [50-mm] Cube Specimens]
C113-93[1998] Standard Test Method for Reheat Change of Refractory Brick
C114-00 Standard Test Methods for Chemical Analysis of Hydraulic Cement
C117-95 Standard Test Method for Materials Finer than 75-:m [#200] Sieve in Mineral Aggregates by WashingC118M-99 Standard Specification for Concrete Pipe for Irrigation or Drainage [Metric]
C123-98 Standard Test Method for Lightweight Particles in Aggregate
C125-00a Standard Terminology Relating to Concrete and Concrete Aggregate
C126-99 Standard Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick, and Solid Masonry Units
C127-88[1993]e1 Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate
C128-97 Standard Test Method for Specific Gravity and Absorption of Fine Aggregate

C129-00a Standard Test Method for Non-Load-Bearing Concrete Masonry Units
C133-97 Standard Test Methods for Cold Crushing Strength and Modulus of Rupture of Refractories
C136-96a Standard Test Method for Sieve Analysis of Fine and Coarse Aggregate
C138-92[2000] Standard Test Method for Unit Weight, Yield, and Air Content [Gravimetric] of Concrete
C140-01ae1 Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
C142-97 Standard Test Method for Clay Lumps and Friable Particles in Aggregates
C143/143M-00 Standard Test Method for Slump of Hydraulic Cement Concrete
C150-99a Standard Specification for Portland Concrete
C163-88[1997] Standard Practice for Mixing Thermal Insulating Cement Samples
C165-00 Standard Test Method for Measuring Compressive Properties of Thermal Insulations
C168-01 Terminology Relating to Thermal Insulating Materials
C172-99 Standard Practice for Sampling Freshly Mixed Concrete
C173-94ae1 Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C177-97 Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot Plate Apparatus
C187-98 Test Method for Normal Consistency of Hydraulic Cement
C192/C192M-00 Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory
C201-93[1998] Standard Test Method for Thermal Conductivity of Refractories
C212-00 Standard Specification for Structural Clay Facing Tile
C231-97e1 Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C232-99 Standard Test Methods for Bleeding of Concrete
C233-00 Standard Test Methods for Air-Entraining Admixtures for Concrete
C236-89[1993]e1 Standard Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box
C260[2000] Standard Specification for Air-Entrained Admixtures for Concrete
C270-01 Standard Specification for Mortar for Unit Masonry
C271-99 Standard Test Method for Density of Sandwich Core Materials
C272-01 Standard Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions
C273-00e1 Standard Test Method for Shear Properties of Structural Core Materials
C274-99 Standard Terminology of Structural Sandwich Construction
C289-01 Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates [Chemical Method]
C295-98 Standard Guide for Petrographic Examination of Aggregates for Concrete
C297-94[1999] Standard Test Method for Flatwise Tensile Strength of Sandwich Construction
C309-98a Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
C311-00 Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Admixture in Portland Cement Concrete
C317/C317M-00 Standard Specification for Gypsum Concrete
C330-00 Standard Specification for Lightweight Aggregates for Structural Concrete
C331-00 Standard Specifications for Lightweight Aggregates for Concrete Masonry Units
C332-99 Standard Specification for Lightweight Aggregates for Insulating Concrete
C349-97 Standard Test Method for Compressive Strength of Hydraulic Mortars
C354-97 Standard Test Method for Compressive Strength of Thermal Insulating or Finishing Concrete
C363-00 Standard Test Method for Delamination Strength of Honeycomb Core Materials
C364-01 Standard Test Method for Edgewise Compressive Strength of Sandwich Constructions
C365-00 Standard Test Method for Flatwise Compressive Strength Properties of Sandwich Cores
C366-99 Standard Test Method for Measurements of Thickness of Sandwich Cores
C373-88[1999] Standard Test Method for Water Absorption, Bulk Density, Apparent Porosity, and Apparent Specific Gravity of Fired Whiteware Products
C393-00 Standard Test Method for Flexural Properties of Sandwich Constructions
C394-00 Standard Test Method for Shear Fatigue of Sandwich Core Materials
C403/C403M_99 Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
C404-97 Standard Specification for Aggregate for Masonry Grout
C417-93[1998] Standard Test Method for Thermal Conductivity of Unfired Monolithic Refractories
C457-98 Standard Test Method for Microscopical Determinations of Parameter of the Air-Void System in Hardened Concrete
C469-94 Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression
C480-99 Standard Test Method for Flexure Creep of Sandwich Constructions
C481-99 Standard Test Method for Laboratory Aging of Sandwich Constructions
C494/C494M-99a Standard Specifications for Chemical Admixtures for Concrete
C495-99a Standard Test Method for Compressive Strength of Lightweight Insulating Concrete
C496-96 Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens
C506-00/C506M_00 Standard Specification for Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe
C507-00/C507M_00 Standard Specification for Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe
C512-87[1994] Standard Test Method for Creep of Concrete in Compression

C513-89[1995] Standard Test Method for Obtaining and Testing Specimens of Hardened Lightweight Insulating Concrete for Compressive Strength
C518-98 Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
C566-97 Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying
C567-00 Standard Test Method for Density Structural Lightweight Concrete
C578-95 Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation
C595-00ae1 Standard Specification for Blended Hydraulic Cements
C595M-97 Standard Specification for Blended Hydraulic Cements [Metric]
C611-98 Standard Test Method for Electrical Resistivity of Manufactured Carbon and Graphite Articles at Room Temperature
C617-98 Standard Practice for Capping Cylindrical Concrete Specimens
C618-00 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete
C634-00 Terminology Related to Environmental Acoustics
C641-98e1 Standard Test Method for Staining Materials in Lightweight Concrete Aggregates
C642-97 Standard Test Method for Density, Absorption, and Voids in Hardened Concrete
C666-97 Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing
C671-94 Standard Test Method for Critical Dilation of Concrete Specimens Subjected to Freezing
C684-99 Standard Test Method for Making, Accelerated Curing, and Testing Concrete Compression Test Specimens
C685/C685M-00a Standard Specification for Concrete made by Volumetric Batching and Continuous
C709-98 Standard Terminology Relating to Composite Materials
C728-97e1 Specification for Perlite Thermal Insulation Board
C773-88[1999] Standard Test Method for Compressive [Crushing] Strength of Fired Whiteware Materials
C778-00 Standard Specification for Standard Sand
C780-00 Standard Test Method for Preconstruction and Construction in Evaluation of Mortars for Plain and Reinforced Unit Masonry
C796-97 Standard Test Method of Testing Foaming Agents for Use in Producing Cellular Concrete Using Preformed Foam
C803/C803M-97e1 Standard Test Method on Penetration Resistance of Hardened Concrete
C805-97 Standard Test Method for Rebound Number of Hardened Concrete
C823-00 Standard Practice for Examination of Samples of Hardened Concrete in Construction
C825-97 Standard Specifications for Precast Concrete Barriers
C845-96 Standard Specification for Expansive Hydraulic Cement
C862-01 Standard Practice for Firing Refractory Concrete Specimens
C856-95e1 Standard Practice for Petrographic Examination of Hardened Concrete
C858-83[1997] Standard Specification for Underground Precast Concrete Utility Structures
C869-91[1999] Standard Specification for Foaming Agents Used in Making Preformed Foam for Cellular Concrete
C873-99 Standard Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds
C882-99 Standard Test Method for Bond Strength of Epoxy - Resin Systems Used with Concrete by Slant Shear
C900-99 Standard Test Method for Pullout Strength of Hardened Concrete
C918-97e1Standard Test Method for Measuring Early-age Compressive Strength and Projecting Later-Age Strength
C926-98e Standard Specification for Application of Portland Cement-Based Plaster
C936-96 Standard Specification for Solid Concrete Interlocking Paving Units
C939-97 Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete [Flow Cone Method]
C976-90[1996]e1 Standard Test Method for Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box
C979-99 Standard Specification for Pigments for Integrally Colored Concrete
C985-00/C985M-00 Standard Specification for Nonreinforced Concrete Specified Strength Culvert, Storm Drain, and Sewer Pipe
C989-99 Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
C1017/C1017M-98 Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete
C1019-00b Standard Test Method for Sampling and Testing Grout
C1026-87[1996] Standard Test Method for Measuring the Resistance of Ceramic Tile to Freeze-Thaw Cycling
C1058-97 Practice for Selecting Temperatures for Evaluating and Reporting Thermal Properties of Thermal Insulation
C1064/C1064M-99 Standard Test Method for Temperature of Freshly Mixed Portland Cement Concrete
C1077-00 Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
C1114-00 Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Thin-Heater Apparatus
C1116-00 Standard Specification for Fiber-Reinforced Concrete and Shotcrete
C1145-02 Terminology of Advanced Ceramics
C1155-95[2001] Standard Practice for Determining Thermal Resistance of Building Envelope Components from the In-Situ Data
C1157-00a Standard Performance Specification for Hydraulic Cement
C1158-97 Standard Practice for Use and Installation of Radiant Barrier Systems [RBS} in Building Construction
C1213-98 Standard Terminology Relating to Precast Concrete Products
C1222-99 Standard Practice for Evaluation of Laboratories Testing Hydraulic Cement
C1227-00b Standard Specification for Precast Concrete Septic Tanks

C1231/C1231MM-00el Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders
C1240-00e1 Standard Specification for Silica Fume for Use as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar & Grout
C1260-94 Standard Test Method for Potential Alkali Reactivity of Aggregates [Mortar-Bar Method]
C1262-98 Standard Test Method for Evaluating the Freeze-Thaw Durability of Manufactured Concrete Masonry Units and Related Concrete Units
C1286-94 Standard Classification for Advanced Ceramics
C1289-01 Standard Specification for Faced Rigid Cellular Polyisocyanurate Thermal Insulation Board
C1292-00 Standard Test Method for Shear Strength of Continuous Fiber-Reinforced Advanced Ceramics at Ambient Temperatures
C1319-99 Standard Specification for Concrete Grid Paving Units
C1323-96[2001] Standard Test Method for Ultimate Strength of Advanced Ceramics with Diametrally Compressed C-Ring Specimens at Ambient Temperatures
C1338-00 Standard Test Method for Determining Fungi Resistance of Insulation Materials and Facings
C1362-97 Standard Test Method for Flow of Freshly Mixed Hydraulic Cement Concrete
C1417-00/C1417M_00 Standard Specification for Manufacture for Reinforced Concrete Sewer, Storm Drain, and Culvert Pipe for Direct Design
C1425-99 Standard Test Method for Interlaminar Shear Strength of 1-D and 2-D Continuous Fiber-Reinforced Advanced Ceramics at Elevated Temperatures
C1436-99 Standard Specification for Materials for Shotcrete
C1450-00 Standard Specification for Performance of Non-Asbestos Fiber-Reinforced Cement Shake, Shingle, and Slate Roofing Systems
C1470-00 Standard Guide for Testing the Thermal Properties of Advanced Ceramics
C1483-00 Standard Specification for Exterior Solar Radiation Control Coatings on Buildings
C1491-01 Standard Specification for Concrete Roof Pavers
C1492-01 Standard Specification for Concrete Roof Tile
C1974-98 Standard Practice for Estimating Concrete Strength by the Maturity Method

D75-97 Standard Practice for Sampling Aggregates
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D422-63[1998] Standard Test Method for Particle-Size of Soils
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D558-96 Standard Test Methods for Moisture-Density Relations of Soil-Cement Mixtures
D559-96 Standard Test Methods for Wetting and Drying Compacted Soil-Cement Mixtures
D560-96 Standard Test Methods for Freezing and Thawing Compacted Soil-Cement Mixtures
D570-98 Standard Test Method for Water Absorption of Plastics
D638-01 Standard Test Methods for Tensile Properties of Plastics
D648-01 Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
D653-97[2000] Terminology Relating to Soil, Rock, and Contained Fluids
D695-02 Standard Test Methods for Compressive Properties of Rigid Plastics
D698-00a Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort [12,400 ft-lbf/ft^3 [600 kN-m/m^3]]
D790-02 Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D792-00 Standard Test Methods for Density and Specific Gravity [Relative Density] of Plastics by Displacement
D854-00 Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer
D1140-00 Standard Test Methods for Amount of Material in Soils Finer than No. 200 [0.075mm] Sieve
D 1173 -53[2001] Standard Test Method for Foaming Properties of Surface-Active Agents Used in Making Cellular Concrete
D1196-93[1997] Standard Test Methods for Nonrepetitive Static Plate Load Tests of Soils and Flexible Pavement Components for Use in Evaluation and Design of Airport and Highway Pavements
D1505-98e1 Standard Test Method for Density of Plastics by the Density-Gradient Technique
D1556-00 Standard Test Method for Density and Unit Weight of Soil in Place by the Sand Cone Method
D1558-99 Standard Test Method for Moisture Content Penetration Resistance Relationships of Fine-Grained Soils.
D1633-00 Standard Test Method for Compressive Strength of Molded Soil-Cement Cylinders
D1634-00 Standard Test Method for Compressive Strength of Soil-Cement Using Portions of Beams Broken in Flexure [Modified Cube Method]
D2216-98 Standard Test Method for Laboratory Determination of Water [Moisture] Content of Soil and Rock by Mass
D248700 Standard Classification of Soils for Engineering Purposes [Unified Soil Classification System]
D2488-00 Standard Practice for Description & Identification of Soils [Visual-Manual Procedure]
D2844-94 Standard Test Method for Resistance R-Value & Expansion Pressure of Compacted Soils
D2922-00 Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods [Shallow Depth]
D2937-00 Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method
D3017-96e1 Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Method [Shallow Depth]
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D3740-99c Standard Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D3846-02 Standard Test Method for In-Plane Shear Strength of Reinforced Plastics
D3878-01 Standard Terminology of Composite Materials
D4102-82[1999] Standard Test Method of Thermal Oxidative Resistance of Carbon Fibers
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D4258-83[1999] Standard Practice for Surface Cleaning Concrete for Coating
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D4496-87[1998]e1 Standard Test Method for D-C Resistance or Conductance of Moderately Conductive Materials
D4609-94e1 Standard Guide for Evaluating Effectiveness of Chemicals for Soil Stabilization
D4832-95e1 Standard Test Method for Preparation and Testing of Controlled Low Strength Material [CLSM] Test Cylinders
D4914-99 Test Methods for Density of Soil and Rock in Place by the Sand Replacement Method in a Test Pit
D5030-89[1994]e1 Standard Test Method for Density of Soil and Rock in Place by the Water Replacement Method in a Test Pit
D5048-97 Standard Test Method for Measuring the Comparative Burning Characteristics and Resistance to Burn-Through of Solid Plastic Using 125-mm Flame
D5057-90[2001] Standard Test Method for Screening Apparent Specific Gravity and Bulk Density of Waste
D5239-98 Standard Practice for Characterizing Fly Ash for Use in Soil Stabilization
D5312-92[1997] Standard Test Method for Evaluation of Durability of Rock for Erosion Control Under Freezing and Thawing Conditions
D5379/5379M-98 Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method
D5778-95[2000] Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils
D5860-95 Standard Test Method for Evaluation of the Effect of Water Repellent Treatments on Freeze-Thaw Resistance of Hydraulic Cement Mortar Specimens
D5971-96 Standard Practice for Sampling Freshly Mixed Controlled Low Strength Material
D6023-96 Standard Test Method for Unit Weight, Yield, Cement Content, and Air Content [Gravimetric] of Controlled Low Strength Material [CLSM]

D6024-96 Standard Test Method for Ball Drop on Controlled Low Strength Material [CLSM] to Determine Suitability for Load Applications
D6103-97 Standard Test Method for Flow Consistency of Controlled Low Strength Material [CLSM]
D6489-99 Standard Test Method for Determining the Water Absorption of Hardened Concrete Treated with a Repellent Coating

E72-98 Standard Test Methods for Conducting Strength Tests of Panels for Building Construction
E84-01 Test Method for Surface Burning Characteristics of Building Materials
E90-99 Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements
E96-00 Test Method for Water Vapor Transmission of Material
E119-00a Standard Test Methods for Fire Tests of Building Construction and Materials
E154-99 Standard Test Methods for Water Vapor Retarders Used in Contact with Earth Under Concrete Slabs, on Walls, or as Ground Cover
E176-01 Standard Terminology of Fire Standards
E288-94[1998] Standard Specifications for Laboratory Glass Volumetric Flasks
E330-97e1 Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls , and Doors by Uniform Static Air Pressure Difference
E336-97 Standard Test Method for Measurement of Airborne Sound Insulation in Buildings
E413-87[1999] Standard Classification for Rating Sound Insulation
E488-96 Standard Test Methods for Strength of Anchors in Concrete and Masonry Elements
E575-99 Standard Practice for Reporting Data from Structural Tests of Building Constructions, Elements, Connections, and Assemblies
E605-93[2000] Standard Test Methods for Thickness and Density of Sprayed Fire-Resistive Material [SFRM] Applied to Structural Members
E621-94[1999]e1 Standard Practice for the Use of Metric [SI] Units in Building Design and Construction
E631-93a[1998]e1 Standard Terminology of Building Constructions
E695-79[1997]e1 Standard Method for Measuring Relative Resistance of Wall, Floor, and Roof Construction to Impact Loading
E729-96 Standard Guide for Conducting Acute Toxicity Tests on Test Materials with Fishes, Macroinvertebrates, and Amphibians
E760-92[2000] Standard Test Method for Effect of Impact on Bonding of Sprayed Fire-Resistive Materials Applied to Structural Members
E761-92[2000] Standard Test Method for Compressive Strength of Sprayed Fire-Resistive Material Applied to Structural Members
E800-99 Guide for Measuring of Gases Present or Generated During Fires
E833-01a Standard Terminology of Building Economics

E937-93[2000] Standard Test Method for Corrosion of Steel by Sprayed Fire-Resistive Material [SFRM] Applied to Structural Members
E1050-98 Standard Test Method for Impedance and Absorption of Acoustical Materials Using a Tube, Two Microphones, and a Digital Frequency Analysis System
E1225-99 Standard Test Method for Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique
E1266-88[1999] Standard Practice for Processing Mixtures of Lime, Flyash, and Heavy Metal Wastes in Structural Fills and other Construction Applications
E1321-97a Standard Test Method for Determining Material Ignition and Flame Spread
E1725-95[2001] Standard Test Methods for Fire Tests of Fire-Resistive Battier Systems for Electrical System Components
E1730-99 Standard Specification for Rigid Foam for Use in Structural Sandwich Panel Cores
E1907-97 Standard Guide for Determining Moisture-Related Acceptability of Concrete Floors to Receive Moisture-Sensitive Finishes
E2122-01 Standard Guide for Conducting In-situ Field Bioassays with Marine, Estuarine, and Freshwater Bivales
E2127-01a Standard Methods of Static Load Test for Combined ensile and Transverse Load Resistance of Paneled Wall Systems in Building Construction
E2151-01 Standard Terminology of Guides for Specifying and Evaluating Performance of Single Family Attached and Detached Dwellings
E2156-01 Standard Guide for Evaluating Economic Performance of Alternative Designs, Systems, and Materials in Compliance with Performance Standard Guides for Single-Family Attached and Detached Dwellings

F1166-95a [2000] Standard Practice for Human Engineering Design for Marine Systems, Equipment and Facilities

IEEE/ASTM SI-10 Standard Practice for Use of the International System of Units [SI]: The Modern Metric System

R0030 Manual of Aggregate and Concrete Testing

STP 169C Significance of Tests and Properties of Concrete and Concrete-Making Materials

ASTM Technical Committee

C01 Cement
C09 Concrete and Concrete Aggregates
C27 Precast Concrete Products
C16 Thermal Insulation
D04 Road and Paving Materials
D18 Soil and Rock
E05 Fire Standards
E06 Performance of Buildings
E07 Testing [nondestructive]

National Institute of Standards and Technology [NIST]

Building and Fire Research Laboratory [BFRL]
Construction Materials Reference Laboratory [CMRL]

International Federation for Structural Concrete [fib - fédération internationale du béton]

CEB European Committee for Concrete [CEB Comité Euro-International du Béton]
FIP International Federation for Precast/Pretressing [FIP Fédération de la Précontrainte]

International Organization for Standardization [ISO]

ISO 64-97 Guide for inclusion of environmental aspects in product standards
ISO 140-5:1998 Acoustics - Measurement of sound insulation in buildings and of building elements
ISO 304:1985 Surface active agents - Determination of surface tension by drawing up liquid films
ISO 679:1989 Methods of testing cements- determination of strength
ISO 696 Surface active agents - Measurement of foaming power - Modified Ross-Miles method
ISO 834-1:1999 Fire-resistance tests - Elements of building construction - Part 1 : General requirements
ISO 834-3 Fire resistance tests - Elements of building construction - Part 3: Commentary on test method and teat data application
ISO 862 Surface active agents- Vocabulary
ISO 896 Surface active agents - Scientific classification

ISO 1000:1992 SI units & recommendations for the use of their multiples and of certain other units
ISO 1063 Surface active agents - Determination of stability in hard water
ISO 1064 Surface active agents; determination of apparent density of pastes on filling
ISO 1182 Fire tests; Building materials; Non-combustibility test
ISO 1716 :2002 Reaction to fire tests for building products - Determination of the heat of combustion
ISO 1920:1976 Concrete tests - Dimensions, tolerances and applicability of test specimens
ISO 2076:1999 Textiles-man made fibers-Generic names
ISO 2131 Surface active agents - Simplified classification
ISO 2227 Formaldehyde solutions for industrial use _ Determination of formaldehyde content
ISO 2268 Surface active agents [non-ionic] - Determination of polyethylene glycols and non-ionic matter [adducts]
ISO 2736-1:1986 Concrete tests - Test specimens - Part 1 - Sampling of fresh concrete
ISO 2736-2:1986 Concrete Tests – Test specimens - Part 2 : Making and curing of test specimens for strength tests
ISO/TR 3814 Tests for measuring "reaction-to-fire" of building materials; Their development and application
ISO 3893:1977 Concrete - Classification by compressive strength
ISO/TR 3956 Principles of structural fire-engineering design with special regard to the connection between real fire exposure and the heating conditions of the standard fire-resistance test [ISO 834]
ISO 4012 Concrete - Determination of compressive strength of test specimen
ISO 4013 Concrete - Determination of flexural strength of test specimens
ISO 4103 Concrete - Classification of consistency
ISO 4108 Concrete - Determination of tensile spitting strength of test specimens
ISO 4109:1980 Fresh concrete - Determination of the consistency - slump test
ISO 4318 Surface active agents - Determination of water content - Azeotropic distillation method
ISO 4365 Liquid flow in open channels; Sediment in stream and canals; Determination of concentration, particle size distribution and relative density
ISO 4898 Cellular plastics; Specifications for rigid cellular materials used in the thermal insulation of buildings
ISO 5018 Refractory materials, Determination of true density
ISO 5657 Reaction to fire tests - Ignitability of building products using a radiant heat source
ISO/TR 5658-1 Reaction to fire tests - Spread of flame - Part 1: Guidance on flame spread
ISO/TR 5658-2 Reaction to fire tests - Spread of flame - Part 2: Lateral spread on building products in vertical configuration
ISO 5660-1 Fire tests; Reaction to fire; Part 1: Rate of heat release from building products
ISO 6060:1989 Water quality - Determination of the chemical oxygen demand
ISO 6240:1980 Performance standards in building - Contents and presentation
ISO 6241:1984 Performance standards in building - Principles for their preparation and factors to be considered
ISO 6274 Concrete - Sieve analysis of aggregates
ISO 6275:1982 Concrete hardened - Determination of density
ISO 6276 Concrete; compacted fresh; Determination of density
ISO 6388 Surface active agents - Determination of flow properties using a rotational viscometer
ISO 6512:1982 Building construction - Modular coordination - Story heights and room heights
ISO 6782:1982 Aggregates for concrete - Determination of bulk density
ISO 6783 Coarse aggregates for concrete; Determination of particle density and water absorption, Hydrostatic balance method
ISO 6784 Concrete - Determination of static modulus of elasticity in compression
ISO 6946:1996 Building components and building elements - Thermal resistance and thermal transmittance - Calculation method
ISO 7033:1987 Fine and coarse aggregates for concrete - Determination of the particle mass - per - volume and water absorption: Pycnometer method
ISO 7203-1 Fire extinguishing media - Foam concentrates - Part 1: Specification for low expansion foam concentrates for top application to water-immiscible liquids
ISO 7203-2 Fire extinguishing media - Foam concentrates - Part 2: Specification for medium and high expansion foam concentrates for top application to water-immiscible liquids
ISO 7203-3 Fire extinguishing media - Foam concentrates - Part 3: Specification for low expansion foam concentrates for top application to water-miscible liquids
ISO 7345 Thermal insulation; physical quantities and definitions
ISO 7361:1986 Performance standards in building - Presentation of performance levels of facades made of same - source components
ISO 7892:1998 Vertical building elements - Impact resistance tests -Impact bodies and general test procedures
ISO 8840 Refractory materials; determination of bulk density of granular materials [grain density]
ISO 9000-2000 Quality Management: Fundamentals on vocabulary
ISO 9001-2000 Quality Management Systems - Requirements
ISO 9002:1994 Quality System - Model for Quality Assurance in Production, in Installation and Serving
ISO/TR 9122-5 Toxicity testing of fire effluents; Part 5: Prediction of toxic effects of fire effluents
ISO 9194 Bases for design of structures; actions due to the self-weight of structures, non-structural elements and stored materials; density
ISO 9705 Fire tests; Full-scale room test for surface products
ISO 9924-2 Rubber and rubber products - Determination of the composition of vulcanizates and compounds by thermogravimetry -

Part 2: Acrylonitrile-butadiene and halobutyl rubbers
ISO/TR 10158 Principals and rationale underlying calculation methods in relation to fire resistance of structural elements
ISO 10211:1995 Thermal bridges in building construction – Heat flows and surface temperature - Part 1 General calculation methods
ISO 10456-1997 [E] Building materials and products - Procedures for determining declared and design thermal values
ISO/TR 11696-2:1999 Uses of reaction to fire test results - Part 2: Fire hazard assessment of construction products
ISO/TR 12470:1998 Fire resistance tests - Guidance on the application and extension of results
ISO 13786:1999 Thermal performance of building components - Dynamic thermal characteristics - calculation methods
ISO 13793:2001 Thermal performance of buildings - Thermal design of foundations to avoid frost heave
ISO 14000-00 Environmental Management Systems
ISO/TR 14697 Fire tests - Guidance of the choice on substrates for building products

ISO/DIS 14832-1 Fire resistance tests – Load-bearing elements of building construction - Part 1: Requirements for vertical separating load-bearing elements
ISO/DIS 14832-2 Fire resistance tests - Load bearing elements of building construction - Part 2: Requirements for horizontal separating load-bearing elements
ISO/DIS 14832-3 Fire resistance tests – Load-bearing elements of building construction- Part 3: Requirements for beams
ISO/DIS 14832-4 Fire resistance tests – Load-bearing elements of building construction - Part 4: Requirements for columns

National Standards System Network / National Resource for Global Standards [NSSN] [ANSI]

ANSI A37.19 Compressive Strength of Thermal Insulation
ANSI A164.1 Structural Lightweight Concrete
ANSI/ASAE S289.2-98 Concrete Slip Form Canal Linings

American Society of Civil Engineers [ASCE]

ASCE 7-95 Minimum Design Loads for Buildings and Other Structures

European Committee for Standardization [CEN-Comité Européen de Normalisation]

SIA 162.107 Determination of the dry density of lightweight aggregate concrete with open structure
SIA V 162.005 Eurocode 2: Design of concrete structures - Part 1-4: General rules; lightweight aggregate concrete with closed structures
SIA 162.109 Determination of static modulus of elasticity under compression of autoclaved aerated concrete or lightweight aggregate concrete with open structure
SIA 162.105 Test methods for verification of corrosion protection of reinforcement in autoclaved aerated concrete and lightweight aggregate concrete with open structure
SIA 162.113 Performance test for prefabricated reinforced components of autoclaved aerated concrete or lightweight aggregate concrete with open structure under transverse load
SIA 279.066 Thermal insulating products for building applications - Determination of compressive behaviour
SIA 162.111 Determination of compressive strength of lightweight aggregate concrete with open structure
SIA 215.011Methods of testing cement - Part 1: Determination of compressive strength
SIA V 160.004 Eurocode 1: Basis of design and actions on structures - Part 2-2: Actions on structures - Actions on structures exposed to fire
SIA V 161.002 Eurocode 3 - Design of steel structures - Part 1-2 General rules; Structural fire design

VDI 3490 Measurements of gases; calibration gas mixture; determination of the composition by gas density measuring techniques, gas density balance

German Institute for Standardization [DIN-Deutsches Institut für Normung e.V]

DIN EN 990 Test methods for verification of corrosion protection of reinforcement in autoclaved aerated concrete and lightweight aggregate concrete with open structure
Din EN 991 Determination of the dimension of prefabricated reinforced components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure
DIN EN 992 Determination of the dry density of lightweight aggregate concrete with open structure
DIN 1045-2 Concrete, reinforced and prestressed Concrete Structures - Part 2: Concrete, Specification, Properties, Production and Conformity
DIN 1045-4 Concrete, reinforced and prestressed Concrete Structures Part 4: Additional rules for the Production and Conformity Control of Prefabricated Elements
DIN 1048-2 Testing Concrete; testing of hardened concrete [specimens taken in situ]

DIN 1048-4 Test methods for concrete; determination of the compressive strength in hardened concrete in structures and components; application of reference lines and evaluation with special methods
DIN 1048-5 Testing concrete; testing of hardened concrete [specimens prepared in mould]
DIN 1055-2 Design Loads for Buildings; Soil Characteristics, Specific weight, Angle of Fiction, Cohesion, Angle of Wall Friction
DIN EN 1094-5 Insulating refractory products - Part 5: Determination of cold crushing strength of shaped products
DIN EN 1352 Determination of static modulus of elasticity under compression of autoclaved aerated concrete or lightweight aggregate concrete with open structure
DIN EN 1354 Determination of compressive strength of lightweight aggregate concrete with open structure
DIN EN 1355 Determination of creep strains under compression of autoclaved aerated concrete or lightweight aggregate concrete with open structure
DIN EN 1356 Performance test for prefabricated reinforced components of autoclaved aerated concrete or lightweight aggregate concrete with open structure under transverse load
DIN EN 1364-4 Fire resistance tests on non-load bearing elements - Part 4: Curtain Walling
DIN EN 1367-4 Tests for thermal and weathering properties of aggregates - Part 4: Determination of drying shrinkage
DIN EN 1520 Prefabricated components of lightweight aggregate concrete with open structure
DIN EN 1521 Determination of flexural strength of lightweight aggregate concrete with open structure
DIN EN 1737 Determination of shear strength of welded joints of reinforcement mats or cages for prefabricated components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure
DIN EN 1739 Determination of sheer strength for in-plane forces of joints between prefabricated components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure
DIN EN 1740 Performance Test for Prefabricated Reinforced Components Made of Autoclaved Aerated Concrete or Lightweight Aggregate Concrete with Open Structure Under Predominantly Longitudinal Load [Vertical Components]
DIN EN 1741 Determination of shear strength for out-of-plane forces of joints between prefabricated components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure
DIN EN 1742 Determination of shear strength between different layers or multilayer components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure
DIN EN 1926 Natural stones test methods - Determination of compressive strength
DIN ENV 1992-1-4 Eurocode 2: Design of concrete structures. Part1-4: General rules. Lightweight aggregate concrete with closed structure
DIN 4028 Reinforced Concrete Slabs Made of Lightweight Concrete with Internally Porous Texture; Requirements, Testing, Design, Construction, Installation
DIN 4102-1 Fire behavior of building materials and building components - Part 1: Building materials; concepts, requirements and tests
DIN 4102-2 Fire Behavior of Building Materials and Building Components; Building Components; Definitions, Requirements and Tests
DIN 4101-3 Fire Behavior of Building Materials and Building Components; Fire Walls and Non-load-bearing External Walls; Definitions, Requirements and Tests
DIN 4102-4 Fire behavior of building materials and building components; synopsis and application of classified building materials, components and special components
DIN 4102-5 Fire Behavior of Building Materials and Building Components; Fire Barriers, Barriers in Lift Wells and Glazings Resistant against Fire; Definitions, Requirements and Tests
DIN 4102-7 Fire behavior of building materials and building components - Part 7: Roofing; definitions, requirements and testing
DIN 4102-8 Fire behavior of building materials and components; small scale test furnace
DIN 4102-17 Fire behavior of building materials and elements; determination of melting point of mineral fiber insulating materials; concepts, requirements and testing
DIN 4108-3 Thermal protection and energy economy in buildings - Part 3 : Protection against moisture subject to climate conditions; Requirements and directions for design and construction
DIN V 4108-4 Thermal insulation and energy economy in buildings - Part 4: Hydrothermal design values
DIN 4132 No Fines Lightweight Concrete Walls; Design & Construction
DIN 4164 Aerated and foamed concrete; production, utilization and testing ; guidelines
DIN 4219 P1 Lightweight concrete and reinforced lightweight concrete of dense structure; properties, manufacture and inspection
DIN 4219 P2 Lightweight Concrete and reinforced lightweight concrete of dense structure; design and construction
DIN 4226-2 Aggregates for concrete and motor - Part 2 Lightweight aggregates
DIN 4227 P4 Prestressed concrete, prestressed lightweight concrete structural components
DIN 4232 No fines lightweight concrete walls, design and construction
DIN EN 12390-7 Testing hardened concrete - Part 7; Density of hardened concrete
DIN EN 12394 Testing concrete - Determination of compressive strength of test specimens
DIN EN 12843 Precast concrete masts and poles
DIN EN 13009 Hygrothermal performance of building materials and products - Determination of hygric expansion coefficient
DIN EN 13198 Precast concrete products - Street furniture and garden products
DIN EN 13279-2 Gypsum and gypsum based building plaster - Part 2: Test methods
DIN EN 13693 Special precast prestressed concrete roof elements
DIN 18122-2 Soil-investigation and testing - Part 2: Determination of the shrinkage limit

DIN 18136 Soil - Investigation and testing - unconfined compression test
DIN 18148 Lightweight concrete hollow-boards
DIN 18162 Lightweight concrete wallboards, unreinforced
DIN 18218 Pressure of fresh concrete on vertical formwork
DIN 51043 Testing of ceramic materials; unshaped refractory materials; Test of the characteristics of test pieces during or after firing
DIN 52170-1 Determination of composition of hardened concrete; general terms, sampling dry-bulk density
DIN 52251-5 Indirect methods of determining the frost resistance of roofing tiles; Determination of drying shrinkage and firing shrinkage
DIN 52450 Testing of inorganic non-metallic building materials: Determination of shrinkage and expansion on small specimens

Austrian Standards Institute [ON-Österreichisches Normungsinstitut]

OENORM B 3358-3 Non-load bearing interior wall systems-Part 3: Systems made of concrete blocks of normal-or lightconcrete
OENORM B 4200-11 Lightweight concrete - Production and quality control
OENORM EN 990 Test methods for verification of corrosion protection of reinforcement in autoclaved aerated concrete and lightweight aggregate concrete with open structure
OENORM EN 991 Determination of the dimensions of prefabricated reinforced components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure
OENORM EN 992 Determination of the dry density of lightweight aggregate concrete with open structure
OENORM EN 1352 Determination of static modulus of elasticity under compression of autoclaved aerated concrete or lightweight aggregate concrete with open structure
OENORM EN 1354 Determination of compressive strength of lightweight aggregate concrete with open structure
OENORM EN 1355 Determination of creep strains under compression of autoclaved aerated concrete or lightweight aggregate concrete with open structure
OENORM EN 1356 Performance test for prefabricated reinforced components of autoclaved concrete or lightweight aggregate concrete with open structure under transverse load
OENORM EN 1520 Prefabricated components of lightweight aggregate concrete with open structure
OENORM EN 1521 Determination of flexural strength of lightweight aggregate concrete with open structure
OENORM EN 1739 Determination of shear strength for in-plane forces of joints between prefabricated components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure
OENORM EN 1740 Performance test for prefabricated components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure under predominantly longitudinal load [vertical components]
OENORM EN 1741 Determination of shear strength for out-of-plane forces of joints between prefabricated components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure
OENORM EN 1742 Determination of sheer strength between different layers of multilayer components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure
OENORM EN 1992-1-4 Eurocode 2: Design of concrete structures - Part 1-4: General rules - Lightweight aggregate concrete with closed structure
OENORM 4414-1 Earthwork and foundation engineering; Analysis of soil specimen bulk density [Lab method]
OENORM 4414-2 Geotechnical engineering [foundation engineering] analysis of soil specimens, determination of bulk density

Japanese International Standards [JIS] [JSA]

JSI A 1161: Testing methods for bulk specific gravity, water content, absorption and compressive strength of cellular concrete
JSI A 1162: 1973 Testing methods for volumne change of cellular concrete

International Bureau for the Standardization of Man-Made Fibers [BISFA]

Terminology of Fibers

LightConcrete LLC

LightConcrete LLC offers a full range of services including the design, production, installation and technical support for High-Performance Cellular Concrete - a Specified Density High-Strength Lightweight Concrete.

Principals to include all construction specifications in residential, industrial, commercial, municipal, specialized facilities, military, marine and structures requiring service life in severe or hostile environments. Also in the design and installation of Engineered Geotechnical Fill applications.

LightConcrete LLC is also offering a full range of technical and consulting services in connection with the planning, design and implementation of advanced construction techniques using **HPCC** technology.

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