Smart Foam Liquid Concentrate Solutions Series

WHITE PAPER

What is Cellular Concrete ... and If It is So Great, Why Doesn't Everyone Use It?

ABSTRACT

Cellular concrete has an established and long record of success in construction, manufacturing, and mining applications. This white paper introduces project owners, permit-granting agency staff, specifiers and other construction professionals, governmental officials and regulators, students, educators, media professionals, and the general public to the basics of cellular concretes.

Included in this informative white paper is a brief history of cellular concrete, methods of cellular concrete production, cellular concrete properties, typical cellular concrete applications, cellular concrete installation, innovations in cellular concrete technology, and the roles cellular concrete plays in enhancing the environment, meeting green building objectives, and supporting sustainable development. The paper also raises and answers a key question: "If cellular concrete is so great, why doesn't everyone use it?"

KEYWORDS

Cellular concrete; aerated concrete; air-cured lightweight concrete; autoclaved aerated concrete (AAC); autoclaved cellular concrete (ACC); cellular light weight concrete; cellular light-weight concrete; cellular lightweight concrete; foam concrete; foamed concrete; gas concrete; gassed concrete; insulated cellular lightweight concrete; insulating concrete; lightweight concrete; lightweight aggregate cellular concrete; low-density concrete; moderate-strength light-weight concrete; neat-cement cellular concrete; pervious cellular lightweight concrete; sanded cellular concrete; foam; bubbles; foaming agents; preformed foam; foam liquid concentrate; smart foam liquid concentrates; cellular concrete properties; thermal insulation; sound absorption; fire resistance; thermal mass; cellular concrete applications; foundation fills; geotechnical fills; density-controlled load relief; highway fills; insulating floor screeds; non-structural floor fills; insulating roof screeds; void fills; designer dirt; annular grouting; permeable fills; unstable soil replacement; controlled, low-strength materials (CLSM); stormwater runoff detention; low-density precast slabs; low-density precast panels; low-density block; sound insulation wall fills; cast-in-place walls, floors, and roofs; cast-in-suti affordable housing; on-site block production; partition walls; low-rise, load-bearing construction; multi-story block construction; cultured stone; architectural elements; cellular concrete production methods; the environment; green building; and sustainable development.

cellularconcrete SOLUTIONS

engineers integrated, smart foam liquid concentrate solutions for construction, mining, and manufacturing applications. Learn more at www.cellular-concrete.com.

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A BRIEF HISTORY OF CELLULAR CONCRETE

Cellular concrete is engineered, low-density concrete with special properties germane to solving a sweeping assortment of construction, mining, and manufacturing challenges.

Produced by the substitution of a uniform cellular structure of air voids for some or all of the aggregate particles found in traditional concretes (air voids of up to 80 percent of total volume are common), cellular concrete is known by many names, depending on production methods employed, ingredients used, engineered properties of the finished material, project applications, or regional and proprietary preferences. In a quick search of online literature, other non-proprietary nomenclature for cellular concrete included: Aerated concrete, air-cured lightweight concrete, autoclaved aerated concrete, autoclaved cellular concrete, cellular light weight concrete, cellular light-weight concrete, cellular lightweight concrete, foam concrete, foamed concrete, gas concrete, gassed concrete, insulated cellular lightweight concrete, insulating concrete, lightweight concrete, lightweight aggregate cellular concrete, low-density concrete, moderate-strength lightweight concrete, neat-cement cellular concrete, pervious cellular lightweight concrete, and sanded cellular concrete.

Invented in Sweden in the second decade of the twentieth century, cellular concrete was used commercially across Scandinavia and in Germany and the United Kingdom in the 1920s and gained traction throughout Europe and much of the rest of the globe after the Second World War. In these early years, cellular concrete was produced on site with portland cement, water, and a foaming agent, and used mostly in insulating roof and floor screed applications and in underground pipe installations.

Today, cellular concretes have an established and long record of worldwide success in construction, manufacturing, and mining applications and, depending on the application, are produced either on site or at manufacturing plants.

Foam liquid concentrates for enabling the production of cellular concrete were introduced in the 1920s. Hydrolyzed, protein-based foam liquid concentrates were introduced in the years following World War II, resulting in relatively stable air cells (bubbles) and acceptable density control for a broad range of construction and manufacturing applications. These days, protein-based preformed foaming agents enable the production of tightly-controlled, low-density cellular concretes with excellent placement and durability characteristics, and high compressive strengths in sanded mixes.

Synthetic-based foam liquid concentrates were introduced in the 1990s and came to the fore in the early years of this century. Synthetic-based foam liquid concentrates feature highly-stable bubbles with extended maximum life in the plastic state (vs. protein-based foams) and enable the production of cellular concretes with excellent longevity and durability, which can be pumped longer distances and placed in higher lifts, and at higher pump pressures, compared to protein-based-produced cellular concretes.

Blended foam liquid concentrates (blends of protein and synthetic ingredients) were introduced to the market early in this century, providing mix design technicians additional tools for proportioning cellular concrete mixtures to meet demanding project or product performance requirements.

METHODS OF CELLULAR CONCRETE PRODUCTION

Though there are many proprietary production methods and agents used in cellular concrete production, the methods can be summarized in three broad categories:

- Methods dependent on the chemical reaction of a rising agent
- Methods dependent on mechanical beating
- A hybrid method, dependent on both mechanical beating of a preformed foam produced from smart foam liquid concentrate and a chemical reaction.

Methods dependent on the chemical reaction of a rising agent are best used for cellular concrete production in manufacturing and pre-casting plants. Methods dependent on mechanical beating are best used for cellular concrete production for job site applications. The hybrid method can be used for cellular concrete production for job site applications and in manufacturing and pre-casting plants.

Autoclaved cellular concrete (ACC) is an example of a cellular concrete production dependent on the chemical reaction of a rising agent in the concrete mixture. Typical ACC mixes contain quartz sand, portland cement and supplemental cementitious material (fly ash and/or ground granulated blast furnace slag), lime, water, and a small amount (5 to 8 percent by volume) of aluminum powder. When the ingredients are batched, mixed, and cast in forms, a chemical reaction take place. The aluminum powder reacts with calcium hydroxide in the cement and supplemental cementitious materials and with the water to form hydrogen. The hydrogen gas foams the raw mix to double its volume (with gas bubbles up to 1/8-inch in diameter). At the end of the foaming process, the hydrogen escapes to the atmosphere and is replaced by air. After a set period, forms are removed from the foamed material, which is solid but soft. The material is then cut into blocks or panels and cured in an airtight, high-pressure, autoclave steam chamber for 12-hours or longer. Following curing, the pre-cast material is either stocked in a supply warehouse or transported to the construction site for immediate use.

Two processes can be used in methods dependent on mechanical beating for cellular concrete production. In the first process, a predetermined amount of either protein- or synthetic-based liquid concentrate is added directly to a portland cement-based slurry mixture (containing no aggregate) or grout mixture (a slurry mixture containing aggregates) and air is entrained by the use of high-speed mixing equipment with high shear action. Varying the amount of foam liquid concentrate, or the mixing time, or both the amount of foam liquid concentrate and the mixing time, varies the range of densities in cellular concretes produced by this process.

In the second mechanical beating process, foam liquid concentrate is preformed in a foam-generating device, blending the foam liquid concentrate, water, and compressed air in predetermined amounts. The blended liquid expands, creating preformed foam that is blended into a cementitious slurry or grout through injection from a calibrated nozzle or inline mixer.

The preformed foam method of mechanical beating generally provides better control of final density of the installed or molded cellular concrete material than entraining air by mechanical beating with the use of high-speed mixing equipment.

A new generation of foam liquid concentrates designed specifically for cellular concrete production and described as “smart foam” by one of the innovators, is used in the hybrid method of cellular concrete production. These “smart foam liquid concentrates” are designed to create their unique physical properties only when mixed with cementitious materials and a chemical reaction occurs. For the hybrid method, smart foam liquid concentrate is preformed in a foam-generating device, as described above. After the preformed foam is blended into a cementitious mixture (slurry or grout), the chemical reaction process takes place. The preformed foams produced by the hybrid method create and maintain stable, exceptionally resilient air cells, which stay intact during mixing, high-pressure pumping, installation (or molding), and curing.

The hybrid method of cellular concrete production provides the best control of final density and other desired properties of the installed or molded material.

Because there is an abundance of information available on ACC, and because precise control of the final density of installed or molded cellular concrete material is difficult when entraining air by means of mechanical beating with the use of high-speed mixing equipment method, the remainder of this white paper will focus on cellular concretes produced with preformed foams.

CELLULAR CONCRETE PROPERTIES

Cellular concretes are used to problem-solve a wide variety of challenges in construction, mining, and manufacturing applications. The breadth of applications results from the ability to precisely control the density of cellular concrete materials and the numerous useful properties inherent in cellular concretes or related to density control.

Beneficial properties associated with cellular concretes include:

- Workability
- Stability
- Durability
- Flow-ability
- Self-leveling
- Self-compaction
- Thermal insulating
- Fire resistance
- Mold resistance
- Sound absorption
- Seismic resistance
- Permeability
- Energy absorption
- Density
- Strength
- Walk-ability (in roof deck and flooring applications)
- Nail-ability and saw-ability (pre-cast and manufacturing applications).

The physical properties of cellular concrete are closely related to the type, quantity, and quality of the foam liquid concentrate used; the constitution and proper proportioning of the other mix ingredients (including portland cement and/or supplementary cementitious materials, water, and, if used, sand and/or other aggregates, chemical admixtures, polymers, and fiber reinforcement); the production method employed; and the execution of proper batching, mixing, installation (or molding), and curing protocols.

Mix design, and batching, mixing, and detailed installation/molding practices, are beyond the scope of this introductory white paper.

TYPICAL CELLULAR CONCRETE APPLICATIONS

Multiple production methods and diverse engineered material properties create a diverse menu of practical cellular concrete applications.

For example, the outstanding flow characteristics of the material in its plastic state, its self-leveling and self-compacting properties, and the ability to precisely control material density makes cellular concretes excellent solutions for many geotechnical fill challenges. Engineered cellular concrete fills – sometimes called designer dirts – have a long and established track record of success (see history section above), providing value-engineered solutions when granular fill or lightweight aggregate material solutions are too heavy, site access is limited, or project schedules must be contracted. Cellular concrete geotechnical fills maintain their shape following placement, do not require pre-loading for project-area settlement mitigation, and provide a 2-to-1 point-load-distribution edge, compared with competing geotechnical fill materials.

Another application example: The thermal insulating, sound absorption, flow-ability, walk-ability, and fire, moisture, mold, and seismic resistance properties of cellular concrete make the material a natural for roof and floor fill applications.

Listings of typical cellular concrete applications follow.

Construction, Renovation, and Rehabilitation:

- Insulating cellular concrete roof decks with 2-hour fire ratings (UL-listed)
- Insulating roof deck fills
- Composite insulated roof decks
- Floor/ceiling fill systems
- Cast-in-situ affordable housing
- Cast-in-place walls, floors, and roofs
- Pre-cast, reinforced-concrete wall, floor, and roof panels
- Air-cured, cast-in-situ lightweight concrete blocks and pre-fabricated elements
- Permeable pavement underlayment and recharge beds
- Firewalls
- Slab-on-grade insulation and subbase fill
- Underground thermal conduit linings
- Pipeline and culvert installation (bedding and backfill)
- Roadway rehabilitation
- Retaining wall backfill

Geotechnical and Mining:

- Replacement of unstable soils
- Annular grouting
- Density-controlled load relief
- Load-reducing fill over structures
- Void fills
- Structural fills

LINKS TO APPLICATION CASE STUDIES

Use the links below or visit the "Case Study" section under the "Links" tab at: **www.cellular-concrete.com**

CITI FIELD
Pervious cellular lightweight concrete (PCLWC) supports new stadium construction for the New York Mets.

OREGON TRANSIT TUNNEL
Annular grouting with cellular concrete saves $600,000 for transit tunnel project.

CONEY ISLAND FACILITY
Mini-pile system stops 60 years of subsidence, with an assist from cellular concrete.

ON THE WATERFRONT
Load-reducing benefits of cellular concrete enables 850,000 square foot building conversion project on Boston waterfront.

Geotechnical and Mining, continued:

- Permeable fills/Stormwater runoff retention
- Controlled, low-strength material (CLSM)

Manufacturing:

- Thermal insulation for doors, safes, storage tanks, coolers, etc.
- Sound absorption for partition walls
- Fireproofing panels
- Architectural elements
- Cultured stone

Specialty Applications:

- Protective structures for military weaponry
- Fragmentation shields
- Tunnel linings
- Blast walls
- Crash and target-range-bullet barriers
- Void fill for ships, planes, and vehicles.

CELLULAR CONCRETE INSTALLATION

In construction and mining applications, cellular concrete is typically purchased from and placed by specialty contractors with extensive training (provided by foam liquid concentrate manufacturers and distributors) and experience in cellular concrete installation. These contractors use foam generators made specifically for job site cellular concrete production and work with project engineers to ensure the wet density of the material produced at the job site is within a specified range of the designed wet-density project mix and meets project strength requirements.

Cellular concrete is most typically placed by pumping. The cell structure of smart foam liquid concentrate-produced cellular concretes are not affected by long pump runs and have been successfully pumped beyond 500 feet vertically and 5,000 feet horizontally. Installation rates of more than 100 yards per hour are common. Other placement methods can include bucket cranes, ready-mix truck chute placement, wheelbarrow placement, and even hand placement from carried buckets.

Installation and finishing methods differ for each type of cellular concrete application. As most cellular concrete is covered by another material, it is not surface-finished like a typical concrete slab.

Foam liquid concentrate manufacturers and distributors also provide training and technical support for cellular concrete used in pre-casting and other manufacturing applications.

BENEFITS OF SELECTING CELLULAR CONCRETE SOLUTIONS

With so many engineered properties and applications, it is difficult to provide a generic listing of cellular concrete benefits. Generally, cellular concretes provide superior performance, more efficient construction, and reduced costs when compared to alternative construction and manufacturing technologies. Cellular concretes:

- Balance effectively and efficiently load reduction and strength requirements
- Provide consistent, predictable performance
- Supply insulating, sound and energy absorption, and fire-resistance properties
- Increase project/manufacturing quality and productivity
- Improve job site safety
- Support sustainable/green building objectives (see below)
- Can contribute to LEED points and Green Building accreditation.

INNOVATIONS IN CELLULAR CONCRETE TECHNOLOGY

Recent innovations in cellular concrete technologies include the smart foam liquid concentrates discussed above, advances in foam generation equipment, and the development of pervious versions of geotechnical cellular concrete fills, permeable, open-cell, lightweight concrete, able to stabilize soil without disturbing or redirecting natural water flow.

In instances where projects are sited on marginal lands with areas of soft or loose soils incapable of supporting typical aggregate loads, the use of pervious cellular lightweight concrete (PCLWC) technology permits designers and geotechnical engineers to control both site bearing capacity and drainage characteristics.

When used in post-construction, stormwater-management practices, PCLWC provides improved runoff detention over granular pervious fill or lightweight aggregate materials. PCLWC technology improves stormwater runoff detention, providing high-detention capacity while imparting minimal impact on native soils, eliminating compaction testing and pre-loading for project area settlement mitigation, and significantly reducing project carbon dioxide emissions. PCLWC has a detention capacity of 4.8 gallons per cubic foot, is self-leveling, and will naturally achieve 100% compaction, eliminating settlement with no reduction in runoff-detention capacity. These properties

What are Smart Foam Liquid Concentrates?

Smart foam liquid concentrates:

1. are designed specifically for cellular concrete production.
2. are designed to create their unique physical properties only when mixed with cementitious materials and a chemical reaction occurs.

make PCLWC ideal for used as a pavement underlayment and recharge bed, enhancing the performance of permeable pavement applications, especially on project sites where native soils provide slow drainage characteristics.

A link to a white paper describing the benefits of using pervious cellular lightweight concrete in post construction stormwater management practices is included in the Resource Section of this white paper.

CELLULAR CONCRETE, THE ENVIRONMENT, GREEN BUILDING, AND SUSTAINABLE DEVELOPMENT

Sustainable development is a holistic endeavor, making it difficult to define the independent role any of the thousands of materials, products, or technologies used on a given construction site bring to supporting project-specific green-building objectives. But cellular concretes do play constructive roles in enhancing the environment, meeting green-building objectives, and attaining sustainable development.

Cellular concretes help achieve sustainable building solutions in many areas, including:

- Building reuse – Cellular concrete is an excellent material for re-roofing applications and for floor restoration applications.
- Disaster resistance – When used in roof deck, flooring, in-situ affordable housing, cast-in-place walls, floors, or roofs, or block or pre-fabricated element applications, cellular concrete provides proven deformation resistance properties and an ability to absorb loads and crush in a controlled manner. Cellular concrete is also fire resistant.
- Durability – Cellular concrete provides excellent durability, compared to other low-density materials.
- Indoor air quality – Negligible VOC emissions from cellular concrete support indoor air quality in structure applications.
- Locally produced – The raw materials used to make the cement slurry or grout for cellular concrete production are abundant in most areas of the world and are usually obtained or extracted from sources within 300 miles of the project site or pre-cast or manufacturing facility. Cellular concrete is produced on-site in most construction and manufacturing applications or at a pre-cast facility within 200 miles of the construction site. Local production reduces shipping distances for building materials, minimizing fuel requirements for transportation and handling, and associated energy and carbon dioxide emissions.

On-site production of cellular concrete in geotechnical applications reduces a project's carbon footprint significantly. Projects with volumes exceeding 10,000 cubic yards of geotechnical fill use an on-site batch plant that produces and pumps cementitious slurry, with trucking needed only for the delivery of cement. Such was the case in Queens, New York, during construction of Citi Field, the new home of the New York Mets. More than 17,000 cubic yards of pervious cellular lightweight concrete were batched on-site, eliminating the need for a fill-truck staging area outside the stadium and removing more than 1,000 trucks from the Van Wyck Expressway, Grand Central Parkway, and other borough streets. For projects with volumes of 10,000 cubic yards or less, cellular concrete production also happens on site, by treating slurry or grout manufactured at a local ready-mix plant and delivered and discharged by transit mixer to the hopper of a job site concrete pump. Preformed foam is injected into the delivered mix in the pump hose — not the transit mixer. This method expands the volume of the delivered mix about 3.8 times (i.e., one seven cubic-yard slurry load produces 27-cubic yards of cellular concrete), eliminating up to 55% of the trucks (and the accompanying road-traffic congestion) that would be required if a granular fill option were used.

- Minimal site disruption – When used as pavement underlayment and recharge bed in permeable pavement applications, pervious cellular lightweight concrete can reduce the amount of excavation required by as much as 50%, minimizing site disruption, saving time and money, and reducing the project's carbon footprint.
- Recyclable – Cellular concrete is inert and can be safely removed and reused. One green use of recycled cellular concrete is as aggregate in vegetated roof construction (green rooftops).
- Recycled content – Cellular concrete can incorporate ground granulated blast-furnace slag or fly ash in the slurry or grout mix design without adversely affecting cellular concrete performance. The use of these post-industrial byproducts eliminates the need to landfill the materials and reduces the need for virgin materials in cellular concrete production – and the environmental impacts from the extraction and processing of these virgin materials.
- Reduced sound transmission – When used in roof deck, flooring, in-situ affordable housing, cast-in-place walls, floors, or roofs, block or pre-fabricated elements, fire or partition wall applications, or as cavity fill for vehicles, the void structure of cellular concrete reduces the passage of sound.

- Stormwater runoff detention management – See above … a link to additional information is included in the Resource Section of this white paper.
- Thermal performance – Cellular concrete supports thermal performance optimization in many construction and manufacturing applications.

IF CELLULAR CONCRETE IS SO GREAT, WHY DOESN'T EVERYONE USE IT?

When designed, manufactured, and installed correctly, cellular concrete performs as advertised, providing engineered solutions for construction, mining, and manufacturing challenges. But a number of factors have influenced the slow rate of adoption for cellular concrete solutions.

As the sections on "A Brief History" and "Typical Applications" above demonstrate, the versatility of cellular concrete is substantial. This utility presents difficulties when promoting the material. The breadth of applications requires a corresponding breadth of marketing and customer education tools, which the cellular concrete industry has yet to fully develop and effectively deploy.

Lack of customer education and fully-developed marketing tools has led to a general lack of awareness of cellular concrete benefits on the part of project owners, construction professionals, manufacturing and mining principals, and the general public. Self-directed research can be difficult: A recent Google search for "cellular concrete" produced less than 55,000 search-engine-result links, most to proprietary sites or to difficult-to-understand technical papers and publications. (In contrast, a recent Google search for "colored stamped concrete" produced over a million search-engine-result links.)

Although embraced by construction professionals in most parts of the world, code and design bias in North America toward "traditional" materials (granular fills, manufactured lightweight aggregates, insulation board, etc.) has slowed adoption of cellular concrete applications. A learning curve can be required for implementing cellular concrete solutions, while design specifications and installation protocols are in place for "traditional" material solutions.

Past problems with foam liquid concentrates (the quality of concentrates vary, from poor to exceptional … many of the foam liquid concentrates promoted in the marketplace are not designed specifically for cellular concrete production); mix designs; technical support (the quality of technical support also varies greatly, from zero support to true partnering); production equipment; and installation methods have slowed acceptance of cellular concrete solutions in North America.

Finally, embracing change is never easy. Nineteenth century British businessman and essayist Walter Bagehot once asserted: *One of the greatest pains to human nature is the pain of a new idea. It makes you think your favorite notions may be wrong, your firmest beliefs ill founded."* Though cellular concrete performs as advertised, cellular concrete solutions challenge construction, mining, and manufacturing industry norms and the favorite notions of many project owners and specifiers. Thus, when advancing the benefits of cellular concrete applications, North American cellular concrete promoters essentially advance the pain of new ideas.

CONCLUSION

Cellular concrete supplies engineered, low-density solutions, germane to solving a sweeping assortment of construction, mining, and manufacturing challenges. Its specialized material-performance properties support safe, sustainable construction and manufacturing practices. When a lightweight, cost-effective material is required, cellular concrete often provides the best option.

NEXT STEPS

Interested specifiers and other construction professionals, agency staff, project owners, mine and manufacturing principals, and public officials can learn more about cellular concrete by:

- Contacting John Sedenquist, COO of Cellular Concrete Solutions 888.235.5015 | **jsedenquist@cellular-concrete.com**
- Visiting **www.cellular-concrete.com**

RESOURCE SECTION

Book | Chapter 47 – "Fouad H. Fouad on Cellular Concrete" in **Significance of Tests and Properties of Concrete and Concrete-making Materials**, by Joseph F. Lamond, and J. H. Pielert; edition: 5, published by **ASTM International**, in 2006; ISBN 0803133677, 9780803133679; pp 561 to 569 of 664 pages.

Online | Visit **www.cellular-concrete.com**. Be sure to check out the "Links", "Support", and "White Paper" sections, and sign up for the free, quarterly eNewsletter, "Smart Foam Liquid Concentrate Solutions for Construction, Mining, and Manufacturing Applications."

White paper link | *"Improving Stormwater Runoff Management."*

ABOUT CELLULAR CONCRETE SOLUTIONS

Cellular Concrete Solutions engineers integrated, smart foam liquid concentrate solutions for construction, mining, and manufacturing applications, applying research, innovation, and technical expertise and support to help specifiers, contractors, mining professionals, and manufacturers expand markets, improve quality and job site safety, and reduce project/environmental costs.

The innovative Cellular Concrete Solutions product line includes protein, synthetic, and protein/synthetic blend liquid foam concentrate formulations for use in insulated concrete roof deck and floor construction, low slump and lightweight concrete applications, and mining and geotechnical applications, including pervious cellular lightweight concretes.

The engineered foams are designed to release their unique physical properties only when mixed with the cementitious materials and a chemical reaction occurs. Construction professionals find Cellular Concrete Solutions' smart foam liquid concentrates to be the most stable pre-formed products in the cellular concrete industry, durable cell structures not affected by long pump runs, extended mixing, or most fly ashes or ground granulated blast-furnace slags.

Smart foam liquid concentrate products include:

- Mearl 40™ - for low-density, insulated concrete roof deck and floor applications
- Mearl Geofoam 40 Non Pervious™ - for low-density geotechnical construction applications
- Mearlcell 3532-40™ - for pre-cast construction applications
- Mearl Transport™ - for surface tailings disposal and backfilling
- Mearl Geofoam Non Pervious™ - for geotechnical, grouting and tremie applications
- Mearl Geofoam Pervious™ - for pervious geotechnical applications
- CellFlow™ - for the production of CLSM materials (flowable fill)

Cellular Concrete Solutions also sells foam generation systems designed specifically for producing consistent foam for cellular concrete production, including jobsite-tough tank generators, tankless auto generators, and portable, lab-foam generators for producing accurate results in the laboratory.

More information about smart foam liquid concentrates and Cellular Concrete Solutions is available online at **www.cellular-concrete.com**.