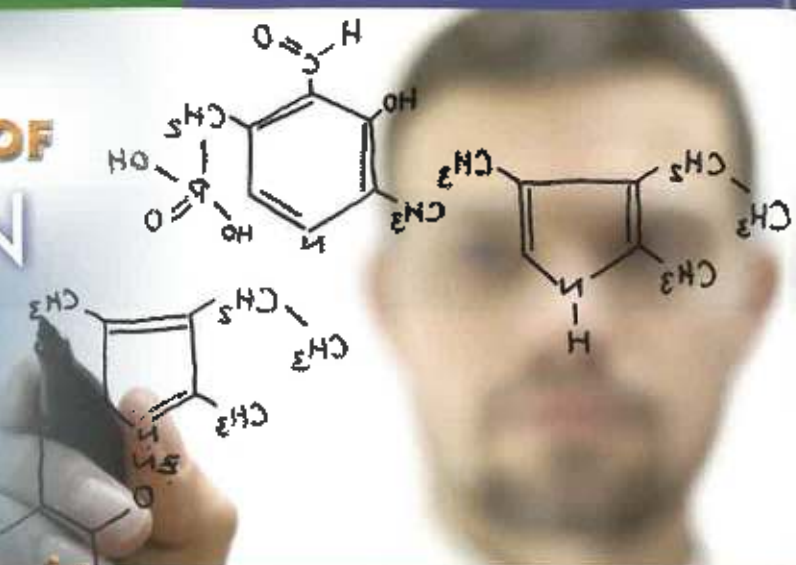


THE CHEMISTRY OF CONSTRUCTION

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The construction industry relies heavily on chemical technology to provide many of the functional properties expected of construction materials. The chemical industry, in return, generates a significant amount of sales on products designed for this market sector. It is not surprising, therefore, that most leading chemical companies offer construction chemicals and building materials and are willing to continually invest in innovation to expand design and performance possibilities.

A single family housing unit consumes on average over \$15,000 worth of chemicals per year, according to the American Chemistry Council in its *Year-End 2010 Situation and Outlook* report, published in December 2010. Residential construction, along with commercial construction and infrastructure, comprise the three major segments of the industry. Although commercial construction is the largest, all three segments use chemicals and building materials in a vast array of product types.

The U.S. construction chemical industry is valued at \$7.7 billion and is growing at a rate of 3.4% through 2013, according to a January 2010 report published by market research firm The Freedonia Group. Meanwhile, the global construction chemicals market is predicted to surpass \$34 billion by 2015, according to Global Industry Analysts (GIA) in an October 2010 report. The recession continues to affect the housing industries in the U.S. and Europe, but signs of recovery have been noted in both regions. Strongest growth will be experienced in countries in the Asia-Pacific region, Latin America, and Eastern Europe, where urbanization is a key driver for building construction. Sustainability is also impacting investment in new chemical technologies for the construction industry.

Photos courtesy of Dow Construction Chemicals.

Construction chemicals account for 2.3% of the overall construction cost. Widely used products include concrete admixtures; cement and asphalt additives; protective coatings and sealers; concrete surface treatments; waterproofing materials; wall cladding, including exterior insulated finish systems (EIFS); adhesives; sealants; grouts and mortars; flooring components; and sprayed polyurethane foam. Currently, protective coatings and sealers are the largest product segment, according to GIA, while cement and asphalt additives are the fastest growing segment. Leading players include BASF, Grace, Henkel, PPG Industries, The Dow Chemical Company, and RPM International.

The specific functions of these different construction chemical products are numerous and varied. Overall, they all serve certain common purposes. "Whether construction chemicals or building materials are intended for residential, commercial, or infrastructure projects, the goal of these products is to provide value-added benefits in terms of improved productivity and performance," states Andrew Bonham, president of Grace Construction Products. "At Grace, we see ourselves as providing the specialty chemical component to building materials. Our products are based on value-added, technology-driven chemistry designed specifically to improve the performance of a whole range of products used to build homes, commercial buildings, and infrastructure."

More specifically, says Javier Banos, strategic marketing manager with Dow Construction Chemicals, "Construction chemicals are specialty ingredients in construction products that are designed to help those products more effectively safeguard buildings and infrastructure from the elements, extend the lifetimes of structures, make production processes faster and easier, reduce energy consumption, and otherwise increase the sustainability of the building industry."

Some examples include polycarboxylates, lignins, cementitious formulations, polyurethanes, epoxies, acrylic dispersions, silicones, silanes, SBR, and others. Dow Construction Chemicals, for instance, offers three technology platforms: liquid acrylic emulsions that help improve adhesion, water-resistance, and weatherability; powdered cellulose ethers that can act as thickeners and water absorbers, affecting the viscosity, workability, and strength development profile of cement-based mortars and adhesives; and redispersible latex powders, or latex polymers in dry form, that carry the benefits of the liquid emulsions with the convenience of a powdered product.

"One trend in the industry is the growing interest in pre-mixed, powder formulations where only the addition of water is needed," observes Nicholas

Adams, vice president and general manager of Euclid Chemical, a business of RPM International. Powder products provide both convenience and reliability. Eliminating the need to mix multiple ingredients results in more consistent product performance and also simplifies storage and handling issues at the plant, according to Banos.

A major trend and driver for the development of new chemical technology in this sector is sustainability. "Sustainability is definitely here to stay, but there are many different viewpoints on what sustainability really means," notes Konrad Wernthaler, director of development for Construction Chemicals with BASF's North American construction chemicals business. Responses have included increased use of recycled materials, development of raw materials from renewable resources, replacement of certain conventionally used chemicals such as

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formaldehyde that are now considered hazardous to human health, VOC reduction/elimination, and minimization of the carbon footprint of processes. BASF takes a life cycle approach and uses its third-party verified eco-efficiency analysis to evaluate the entire production process, including energy consumption, health effects, emissions, land use, and other factors during the manufacture of raw materials and finished goods.

One example of a product from BASF that is receiving growing attention is its Radiance™ c-0.25 Attic Barrier coating for the underside of roof decks. When applied properly, the low emissivity coating creates an effective radiant barrier that stops up to 79% of potential radiant energy transfer into the attic, resulting in lower attic and ultimately lower building temperatures and a reduced need for air conditioning. Separately, the company is developing a new insulating foam that will be more effective than conventional EPS. This is due to the unique design of the pore structure of the foam, which affects its diffusion capability and thus more effectively prevents air flow. The product will be introduced later in 2011 or early in 2012, most likely first in Europe, where regulations in place create good market potential, according to Wernthaler.

Dow has taken on the challenge of developing new building materials that eliminate potentially harmful chemicals but still provide the same or better performance while also exhibiting similar handling properties. One example is a new resin for sealants. RHOPLEX™ 4400 enables the formulation of sealants without the need for plasticizers. Conventional sealants contain plasticizers to keep the material flexible, but these compounds often leach out, reducing the performance of the seal-

ant. In addition, they affect the aesthetics of the building due to the increase in dirt accumulation of the sealant and the change in color properties of the coatings that cover those sealants, according to Banos. The company also now offers AQUASET™ acrylic thermosetting resins as a formaldehyde-free alternative for binding fiberglass fibers in the insulation and high-performance nonwovens markets. "This product provides improved indoor air quality for the end-user and enhances the safety of the plant environment," Banos comments. Dow has developed RHOPLEX™ EC-3000, an acrylic resin for use in reflective cool roof coatings to be applied in areas of high humidity and uncertain weather, where applicators have been hesitant to use acrylic roof coatings for fear of them being washed away. Coatings based on this resin form a tough outer skin within just 15–20 minutes.

Improved energy efficiency is an important aspect of sustainability that has received a lot of attention recently, both in new construction through the green building movement and in the increased interest in renovation or retrofitting of existing buildings. "In the latter case," observes Banos, "EIFS provide an effective solution to improving the energy efficiency of existing structures. They are non-invasive and can be created with customized colors, patterns, and textures." Air barrier materials are becoming more popular as well, particularly liquid-applied systems, according to Craig Merrill, vice president and general manager for Grace Construction Products' Americas business. "These products can be vapor permeable or impermeable and are sprayed on to provide a seamless protective layer, significantly reducing air flow and thereby improving the energy efficiency of the structure. Grace's residential weather barrier product, Vycor™ enV™, also contains antimicrobial agents to protect against mold and mildew," he says. Wernthaler adds that the spray applied liquid air barriers such as BASF's Enershield™ provide a more consistent coating than conventional paper-based systems, which suffer in comparison because they often tear and must be punctured in order to be attached to the building, automatically reducing their effectiveness.

The use of concrete, which is seen as a green building material, is also expanding, particularly in emerging markets for everything from infrastructure projects (roads, bridges, water and sewage treatment systems, etc.) and residential housing and commercial retail development, to construction of factories and other industrial facilities. The macro trend of urbanization lies behind this increased demand. "Urbanization is changing the profile of cities in terms of how people live, how they move within the city, and how they travel from one city to

another. All of these activities require new buildings and infrastructure as well as new materials and new ways to use existing materials," Banos says.

Interest in concrete is also increasing in developed countries. In this case, the perception of concrete as a green alternative is driving its growing use in the residential market, while there is also a raised level of investment in infrastructure. New chemical technologies are also making it possible to improve the environmental profile and performance of this important building material.

The ability to give concrete a decorative appearance has also helped drive interest in its use. "New techniques such as stamping and the availability of new pigment systems designed to function in the challenging concrete environment are making it possible to make concrete quite attractive and to customize it to fit a desired atmosphere," observes Beth Kiriol, technical manager of Exterior and Machine-Applied Coatings for PPG Industries' architectural coatings business. She adds that there have also been a lot of advances made in materials designed to further extend the life of concrete, such as densifiers that can help protect against freeze-thaw damage as well as higher performing water repellants and sealers.

PPG has recently introduced several products for decoration and protection of concrete. Its Perma-Crete Aqua-Pel is a penetrating, water-repellant concrete sealer that maintains the natural aesthetic look of the concrete while providing protection from water intrusion. Perma-Crete Vertical Concrete Stain, for structures such as concrete highway barriers and bridges, does not require a separate primer and dries in only 15 minutes, enabling easy and rapid application of two coats. Meanwhile, self-priming Perma-Crete Solvent Acrylic Masonry Coating from PPG can be applied at temperatures as low as 20°F and is designed specifically for tilt-up concrete, a substrate that can present adhesion challenges for conventional coatings.

Many concrete manufacturers are looking for ways to improve the environmental profile of concrete, which is produced from a mixture of sand, cement, and various other ingredients. Cement, which is produced in kilns, is the most significant contributor to the carbon footprint of concrete, and thus much work has focused on finding supplementary materials, according to Adams. One example is fly ash, which otherwise would be a waste material but can be used as a filler or even as a way to add cementitious quality to the concrete. Many other materials that would be considered waste or are recycled products are also finding their way into concrete. "Wood fibers are being used to make cementitious materials such as fiber cement and composites that exhibit characteristics of both wood and cement

and can even possess a wood-grain look," explains Kiriol. Even clean glass waste material and recycled, crushed concrete are being used today. Recycled concrete in particular is a challenge because it is not neutral like natural aggregates.

BASF's Green Sense Concrete™ technology, launched in late 2009, is an advanced concrete mix design program used to determine the optimal combination of recycled materials and tailor-made chemical admixtures needed to improve the desired slump, setting characteristics, strength, and durability of concrete, according to Wernthaler. The Green Sense Concrete program leverages new admixtures that allow reduced usage of cement in concrete mixes, which can in turn enable reductions of 50–70% in carbon dioxide emissions. "With our Green Sense technology, we can optimize the mix design of cement, aggregates, and sand and customize the most effective blend of admixtures that will provide the desired performance and environmental profile of the final concrete," he says.

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Admixtures are in fact very important to the performance of concrete. They are formulated blends of specialty chemicals that are designed to control the placeability, finishability, and setting time of concrete, according to Adams. "The beauty of construction chemicals is that they allow for the development of customized performance mixes tailored to meet the specific needs of each project given considerations such as the geographic location, the time it takes to get the premixed concrete to the job site, the configuration of the job, and the end use application." Bonham also notes that admixtures provide the ability to change the characteristics of concrete, which enables the versatile use of raw materials and helps varied materials function effectively together. "Through chemistry, concrete can be given different physical properties. The flowability can be increased, the cure time can be accelerated or slowed, and the lifetime of the concrete can be extended," he notes.

Construction chemical producers are also making it possible to extend the life of aggregate quarries by developing products that enable the use of lower quality materials. Sand, for example, contains varying amounts of clay, which can have a negative impact on the properties of concrete.

New chemical technologies from Grace are making it possible to use sand with higher clay content without affecting the performance of the concrete. A new product is currently being validated and the company anticipates launching it on the market later in 2011, according to Merrill.

Replacement of key materials is not limited to hazardous chemicals or cement. Even the reinforcing steel often used to add strength can be replaced with novel chemical technologies. Grace has developed a synthetic fiber that does not corrode and is very lightweight. STRUX[®] is an innovative, high-strength reinforcement for resisting and controlling temperature and shrinkage cracking in concrete. It is a suitable and economical replacement for welded wire fabric (WWF), steel fibers, light rebar, and other secondary reinforcement. "With its properties, the new synthetic fibers allow for more versatility in the possible shapes of concrete structures while also increasing the corrosion resistance and reducing the overall cost, which adds up to real value for the end users," notes Bonham.

Other admixtures known as superplasticizers or high-range water reducers have gained rapid acceptance in the building industry, which typically is quite conservative and very slow to adopt step change technology. These admixtures are used in self-consolidating concrete (SCC), a highly fluid mixture that stays cohesive, while allowing for re-

duction in water content, which leads to improved strength of the concrete. The acrylate-based systems disperse the aggregates evenly and prevent them from settling out. This results in improved compaction and reduction of voids, thus minimizing cracking. Because the concrete flows better, it also gets into nooks and crannies more easily, and often the need for vibrating equipment to get the concrete to flow is eliminated. Furthermore, with its superior strength and increased fluidity, the concrete can be pumped up for use in the construction of very tall buildings. Examples of these admixtures include Grace's ADVA[®] superplasticizers and BASF's Glenium[®] high-range water-reducers. Dow provides some of the ingredients for the formulated products.

Other admixtures are specifically designed to improve the workability of concrete. When a batch of ready-mix concrete is prepared at the plant, it has the desired workability. By the time it reaches the job site, however, that workability is often reduced. If water is added to temper the concrete, the resulting concrete has reduced strength and exhibits other issues as well, according to Wernthaler. To address this problem, BASF recently launched its RheoTEC[™] Z-60 workability-retaining admixture, which increases the workability time for concrete to up to 90 minutes so that even after that time has passed, the workability of the material is the same as when it was first made at the plant.

As concrete ages and protective systems break down, water penetrates concrete structures through its pores and capillaries carrying chlorides along with it. These chlorides attack the reinforcing steel within the concrete causing it to rust and expand. This expansion causes excessive cracking and deterioration of the concrete. As repairs are made, certain protective measures can be taken to ensure the life of the repair and the surrounding concrete. Euclid Chemical has recently introduced SENTINEL SILVER and SENTINEL GOLD galvanic anodes to accompany their existing SENTINEL GL anode. These anodes contain varying amounts of zinc (GL—38 grams, SILVER—100 grams, and GOLD—200 grams) and are attached to the reinforcing steel within the repair area. Chemical activators within the anodes slowly disintegrate the zinc, which in turn emits a small electrical charge that protects against corrosion, according to Adams. This protection exists not only in the repair area, but in the surrounding concrete that has not been repaired yet. Even though the reinforcing steel in the surrounding concrete has already started to deteriorate, it generally has not reached a level yet where it is detrimental to the concrete. The Sentinel's self-generating electrical charge shuts down the corrosion cycling for up to 20 years.



Also for concrete repair is new ZERO-C[®] Concrete Repair Technology from BASF, the first line of cementitious repair mortars that exhibits no cracking. The technology not only incorporates shrinkage-reducing compounds but balances the chemical reactions during the cement hydration process in a way that minimizes the development of stress in the repair mortar. The system was designed as a single-base mortar whose consistency is changed through the addition of different liquids, making it simple for the user to adapt the material to the changing needs of the project.

Waterproofing is another important issue that concerns builders and architects, and several different types of construction chemicals and building products are available to ensure that structures are protected from damage due to moisture. Interest is growing in sheet membranes as replacements for more traditional coatings or spray-applied materials, according to Merrill. Preprufe[®] from Grace is a unique, patented, pre-formed membrane installed before the structural slab is poured, or prior to casting foundation walls against soil retention systems. The polyethylene film is combined with a specially formulated proprietary adhesive that bonds to the concrete as it cures. "The unique Preprufe bond ensures a fully adhered system, preventing water migration between the waterproofing and the structure," Merrill explains.

The company also offers a dual self-adhesive membrane for installing tiles that is targeted at the do-it-yourself (DIY) market. The Bondera[™] Tile MatSet is a membrane that has adhesive on both sides, allowing it to stick to the wall and making it easy to place tiles. It has no VOCs and contains an antimicrobial agent to prevent mold and mildew. The waterproofing performance is effective enough that the membrane can be used in the shower, according to Bonham. PPG is also looking to extend sprayable membrane technology to the DIY market. "We are developing new sprayable membranes that can be applied with typical spray equipment, and in some cases even a garden sprayer," notes Kirol. "The DIY market has grown significantly as a result of the recession, so there is good incentive to adapt these advanced chemical technologies in such a way that the average homeowner can apply them and also benefit from their properties," she adds.

The professional workforce is also changing, and these changes are presenting challenges for suppliers of construction chemicals, according to Werntaler. Many applicators today do not speak English as their primary language, but most technical literature for construction chemicals and building materials is prepared in English. At the same time, the products are becoming more technologically



advanced, and architects and builders are requiring applicators to participate in training, and often times official certification programs. "This trend will continue, and communication between suppliers, specifiers, and applicators will be an issue that will need to be addressed," he says.

Communication clearly is very important for suppliers of construction chemicals. Because there are so many different product types used in so many different applications, it is critical for suppliers to understand their customers and their specific needs in order to be able to provide chemicals and materials that ensure the performance and productivity they expect. "Innovation is key to success in the construction chemical sector," asserts Banos. "Experience has clearly shown that advances in chemical technology can create tremendous opportunity for further innovation in the construction and building sector. That is why successful construction chemical producers work closely with their customers to develop new chemistries and materials designed to meet future needs," he concludes. **11**