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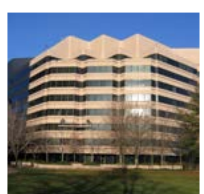


# Cement & Concrete

## Still Outperforming in the Sustainability Era


**by Michael Stanzel and Natalee Sembrick**

Photo © Carole & Roy Timm Photography

**SUSTAINABLE DESIGN IN CONSTRUCTION IS MOTIVATING DESIGNERS AND BUILDERS TO RE-EVALUATE THE MATERIALS, METHODS, AND METRICS USED IN CREATING GREENER COMMUNITIES.** SUSTAINABLE STRUCTURES MUST BALANCE THE ENVIRONMENTAL FOOTPRINT, SERVICE LIFE, SOCIAL ASPECTS, AND ECONOMIC FACTORS. AS MODERN SOCIETY SHIFTS TO A CIRCULAR, CARBON-NEUTRAL BUILT ENVIRONMENT, CONCRETE CONTINUES TO DELIVER 'BEST-IN-CLASS' PERFORMANCE AS A BUILDING MATERIAL.

A typical cement production facility.
Image courtesy Lehigh Hanson

One of the most important challenges facing the world today is meeting the habitation and food needs of a growing world population, while mitigating climate change. With the construction, operation, and decommissioning of structures and infrastructure accounting for approximately 40 percent of all man-made greenhouse gas (GHG) emissions, it is self-evident construction practices need to change and buildings must become low-carbon and more resilient to the changing climate.[1]

Over the past few years, there has been considerable discussion about concrete construction and its impact on global warming. Concrete is the most widely used manufactured material in the world. Each year, more than 20 billion tonnes of concrete are produced globally.[2] The environmental impact of concrete is due primarily to its widespread utilization as a building material. Concrete is, in the authors' opinions, a relatively low-impact material, not only due to its durability, long service life, and recyclability, but also because of increasing investments in sustainable manufacturing technologies. It is locally available, and a good material for most applications, such as building foundations and structural or architectural elements, dams and bridges, schools and hospitals, pipe and water treatment facilities, residential homes, curb and sidewalk, pavement, etc.

**Importance of life-cycle assessment**

To build greener communities, a growing number of designers are relying on life-cycle assessments (LCAs) to measure the environmental impacts of construction projects at all stages, from raw material extraction and processing, transportation, and installation to use in service, and, if necessary, disposal.

"Emission Omissions: Carbon accounting gaps in the built environment," a landmark study by the International Institute for Sustainable Development (IISD) argues LCA is the best approach to measure carbon emissions in buildings, but that more data, transparency, and robust standards are needed (Figure 1, page 7).[3] All sources of carbon must be considered to ensure a big picture approach in prioritizing material and energy efficiencies and long service life in designs.

The study identified the omissions of emissions related to concrete, wood, and steel building products. It also identified forestry products as the material with the greatest carbon accounting uncertainties, with up to 72 percent of carbon emissions unaccounted for in current LCAs (Figure 2, page 7). When these emissions are included, concrete's carbon footprint could be up to six percent less intensive than that of wood products, giving designers and policy-makers reason for pause when making decisions about building materials.

P. Purnell, a professor at the University of Leeds, United Kingdom, argues many of the analyses on the embodied carbon of structures are simplistic and do not take into account the utility of each material and the structural purpose of the element.[4] Purnell recommends defining a 'functional unit' that allows comparisons of like with like. As an example, a column designed to resist a particular compressive load at a specific height should evaluate the mass of carbon dioxide ($CO_2$) per unit load capacity per unit height. For many structural member dimensions, reinforced concrete provides a competitive carbon footprint compared to other materials.

Studies from the Massachusetts Institute of Technology (MIT) demonstrate the passive energy efficiency of concrete's thermal mass combined with smart design and the long service life of these structures results in the lowest annual operating costs and global warming potential (GWP).[5] In some cases, particularly with insulated concrete forms (ICFs), the total life cycle GWP can be as much as eight percent lower than alternative designs and materials and could potentially be less than 14 percent with the increased use of low-carbon cementitious products.

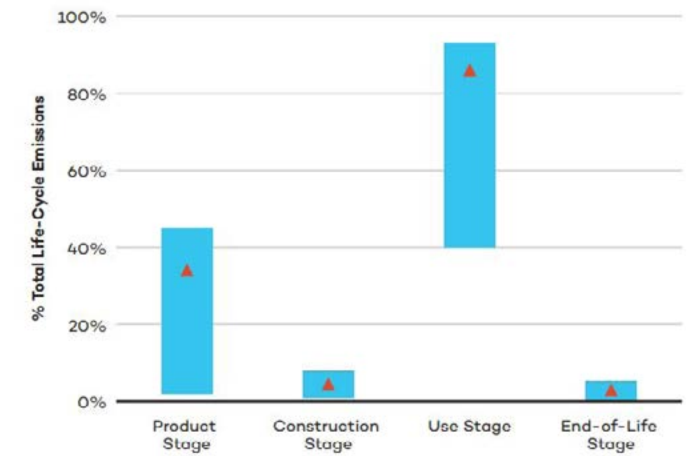
## A sustainable solution

Continued global growth and the trend toward urbanization means building material solutions must be abundant, affordable, and easily adapted to meet future needs. Concrete is a sustainable solution striking a strong balance between the social, environmental, and economic aspects of the communities' infrastructure needs (Figure 3, page 8).

*Strength*

Concrete offers good compressive strength for the cost and weight of materials, where other structural characteristics can be enhanced through reinforcing materials. While the compressive strength of conventional concrete is typically less than 50 MPa (7 ksi), high performance concrete mix designs used in high-rise construction can have compressive strengths of up to around 100 MPa (14 ksi), and ultra-high performance concrete (UHPC) can have compressive strengths of more than 180 MPa (26 ksi). By carrying loads more efficiently, the quantity of materials and overall

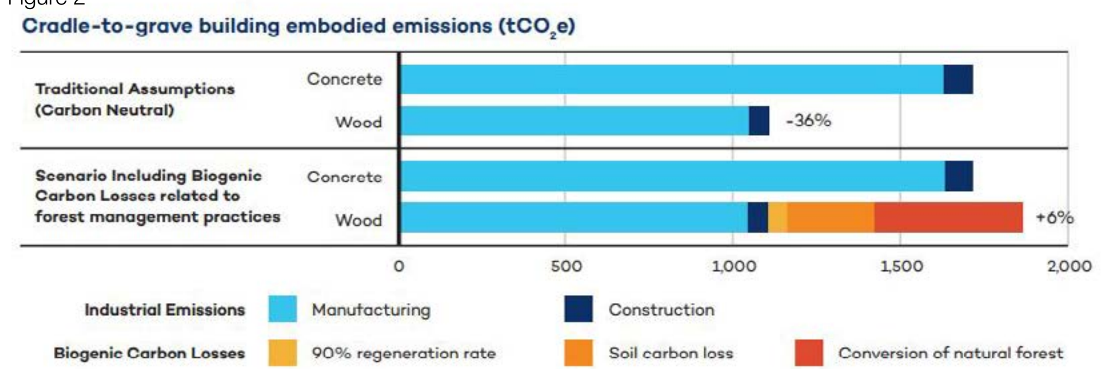
Figure 1




The range and average contribution of life-cycle stage emissions to overall total building emissions, as per "Emission Omissions: Carbon accounting gaps in the built environment," by the International Institute for Sustainable Development (IISD).

Images courtesy International Institute for Sustainable Development

Figure 2




According to the IISD study, when combined factors, such as forest regeneration rates, soil carbon loss, and primary-to-new-growth-forest-conversion, are accounted for, the cradle-to-grave embodied emissions for a wood building could be six percent greater than for a concrete building.

costs for a structure can be reduced. Similarly, lower strength and lower density concrete made with lightweight aggregates produced from recycled materials can help reduce the dead load of buildings.

*Versatility*

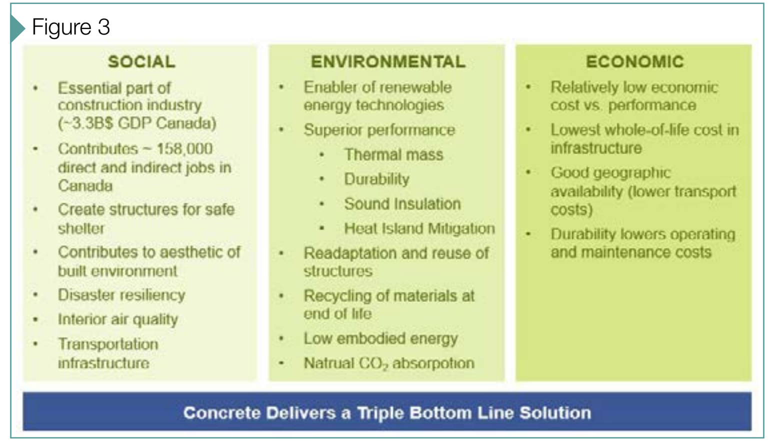
Concrete is flexible, robust, and workable. Mix designs can be adapted to optimize performance and concrete can be placed in a variety of conditions by various methods while offering reliable and predictable performance. Due to its initial plastic state and workability, concrete is able to fill any shape or form to create elegant straight lines or complex geometries, offering a plenitude of architectural and structural options to the designer and owner.

*Raw materials*

The materials used for concrete construction are locally sourced, and readily available and mined from the earth's crust, resulting in low-impact resource extraction and transportation. Aggregate, which comprises the largest proportion of material in concrete, requires little processing and is naturally occurring and locally available. Mineral extraction is tightly regulated, and sites can be restored to deliver a biodiversity gain to the surrounding environment.[6]

*Durability and resilience*

Concrete is durable and able to provide a long service life in a variety of natural climates and environments, resisting weathering action, chemical attack, moisture, and abrasion while maintaining its engineering properties. Additionally, reinforced concrete offers resistance to natural disasters and a changing climate. Concrete is sometimes used in areas where it is exposed to substances that can cause deterioration. In such situations, high-durability mix designs using a low water-to-cement materials ratio and a high quantity of supplementary cementitious materials (SCMs) can be enhanced by application of protective coatings or membranes.[7] However, consideration must be given to the Living Building Challenge's Red List.




Benefits of concrete construction toward sustainable development goals.

Images courtesy Lehigh Hanson

*Energy efficiency and healthy living environment*

Concrete offers advantages to energy performance such as reduced heating and cooling costs through its excellent thermal mass, with a high heat capacity for storage (around 1000 J/kg°K) and moderate thermal conductivity (around 0.5 to 3 W/m°K). Additionally, concrete can result in mitigation of the urban heat-island effect, and increased lighting efficiency due to an albedo reflectance of around 0.35 and solar reflective index greater than the threshold value of 29 required for hardscape in most green building standards and rating systems.[8] It also offers improvements in air quality due to negligible levels of volatile organic compounds (VOCs) and elimination of uncontrolled through-wall infiltration, which can be enhanced through the use of photocatalytic cements that remove and decompose contaminants from the air. Concrete also offers effective sound attenuation, with concrete masonry units (CMUs) offering sound transmission classes (STCs) from 40 to over 60 depending on thickness, density, and design.[9]

*Adaptability*

The use of concrete not only reduces maintenance and operational costs of buildings over their service life, with up to 10 percent lower annual operating GWP than alternative designs, but also provides the option to repurpose, reuse, or recycle structures and the materials at the end-of-life, decommissioning stage.[10]

*Absorption of $CO_2$*
Just like trees, concrete naturally absorbs $CO_2$ from the atmosphere. Science shows concrete absorbs the equivalent of up to 25 percent of the emissions generated in creating it over its lifespan.[11]

*Low-carbon innovation*
Innovations in the cement sector ranging from lower carbon cements and low-carbon fuels and materials from the waste stream to investment in carbon capture utilization and storage technologies are putting concrete on a path toward carbon neutrality. These effects could even transform the material from a significant emitter of carbon into a carbon sink.

## Environmental impact of concrete

The primary environmental concerns regarding concrete are related to its $CO_2$ footprint and the amount of energy required for manufacturing. These impacts are predominantly associated with concrete's active ingredient, cement. Concrete is formed when cement is mixed with water, which binds the aggregate into a strong, cohesive structure. Cement production is energy- and $CO_2$-intensive, but the product itself accounts for only 10 to 15 percent of the volume of a concrete mix. The other ingredients in concrete consist of aggregates, taking up 60 to 75 percent of the volume, and water, which accounts for around 15 percent of the volume (Figure 4).

Cement is manufactured by heating a mixture of ground limestone and other minerals containing silica, alumina, and iron up to around 1450 C (2642 F) in a rotary kiln. At this temperature, the oxides of these minerals chemically transform into calcium silicate, calcium aluminate, and calcium aluminoferrite crystals. This intermediate product, called clinker, is then cooled and finely ground with gypsum (added for set-time control), limestone, and specialized grinding aids, which improve mill energy consumption and performance to produce cement (Figure 5, page 10). Those calcium silicates chemically react with the mixing water in concrete, through a process called hydration, to form an extended network of bonds. These bonds bring the aggregates together and give concrete its characteristic strength and durability.

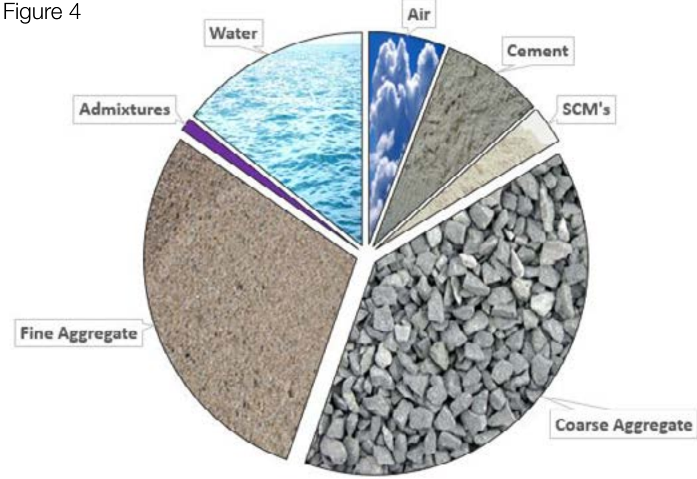
On average in the United States, 1 tonne of cement results in a global warming potential (GWP) of approximately 1040kg $CO_2$-eq.[12] Approximately $^1/_3$ of this is from the energy and heat requirements for manufacture, and $^2/_3$ is from the calcination of calcium carbonate into calcium oxide and $CO_2$.[13]

## How is the industry addressing sustainability?

The $CO_2$ impact of concrete construction is due to the sheer volume required to keep up with global needs.

While the cement and concrete industry has long been committed to providing responsible and sustainable high-performance options, there has been a stronger focus on enhancing concrete's inherent sustainability in recent years.

Figure 4




Typical concrete composition by volume.

*Cement*
Cement producers have made significant strides in operational efficiency and heat recovery, plant modernization, and recycling of industrial byproducts as raw material sources. The cement industry is investing in many innovative technologies, products, and research projects on its journey towards carbon neutral concrete before 2050. Finding ways to reduce both the energy needs and reliance on fossil fuels is a top priority for cement companies and they have been making measurable progress since the early Seventies (more than a 40 percent).[14]

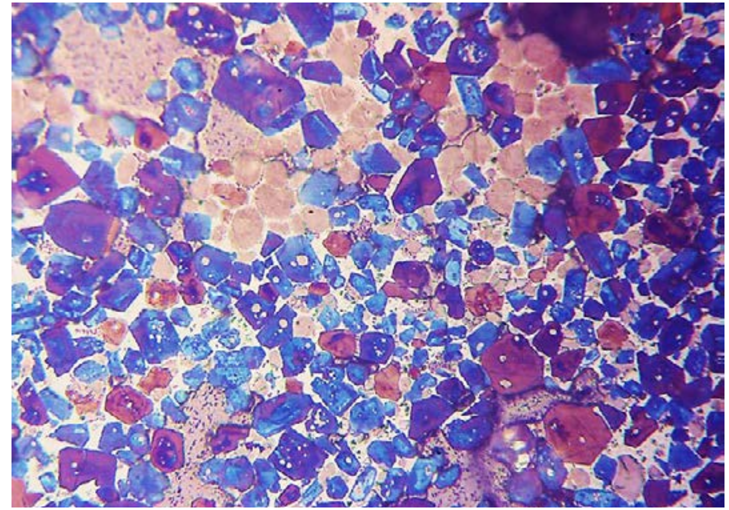
On top of this, manufacturers are offering lower carbon products. Portland-limestone cements are specially formulated to provide performance equivalent to traditional Portland varieties, but with a portion of the limestone diverted past the pyro-processing stages and incorporated directly into the product. This avoids around 10 percent of the $CO_2$ emissions from calcination and combustion.

SCMs, such as ground slag, are recycled materials that react with relatively inert byproducts of the hydration reaction (mainly calcium hydroxide) to form compounds that densify the cementitious matrix and enhance later age strength and permeability. SCMs are added to concrete as part of the total cementitious system, and judicious use is desirable not only for the technical advantages, but also environmental benefits. In Canada, it is common to see 25 percent replacement or more of the cement in concrete with these materials—this corresponds to a comparable reduction in manufacturing energy consumption and GHG emissions, as captured in environmental product declarations (EPDs). Due to these benefits, the industry is trying to increase SCM utilization and investigate new sources of potential materials.

The substitution of traditional fossil fuels with lower carbon alternatives derived from non-recyclable waste, including single-use plastics and waste biomass, has the potential to reduce the industry's carbon emissions by 20 to 30 percent across Canada.

Finally, breakthrough carbon capture, utilization, and storage (CCUS) technologies could yield, when scaled, carbon-neutral or even carbon-negative cement and concrete.

Figure 5



Clinker microscopy showing the various mineral phases (blue equals alite and brown is belite).

*Admixtures*
Admixtures are small quantities of various chemicals or nanomaterials added to concrete to improve both performance and efficiency. They can provide air entrainment, control setting characteristics, and improve the workability and constructability of fresh concrete. For hardened concrete, they can increase compressive strengths, reduce shrinkage, and help lower permeability. Admixture producers are evolving their technology to enhance concrete's durability and longevity, while reducing the need for higher quantities of environmentally intensive and costly materials within a particular mix.

*Concrete*
Concrete producers develop and optimize mix designs to balance the performance requirements of a project while minimizing the environmental impact, resource use, and waste. Several concrete associations in Canada and internationally have developed eco-certification programs for their members.

The industry has also been diligent with developing independently verified regional EPDs for various mix designs to communicate transparent and comparable information about the life-cycle impact of products.

The academic research community is at the leading edge of testing and developing new materials and innovative technologies. This involves working with the standards community to identify requirements for material properties and use, developing appropriate test methods to measure performance, and ensuring the fitness of these products. This includes CCUS-related innovations, such as replacing virgin aggregate with alternatives manufactured from captured carbon as well as various methods for injecting carbon directly into the concrete mix as it sets.

### Ensuring sustainable concrete

Sustainable concrete meets the performance requirements of the owner, designer, contractors, and the material supplier while minimizing energy consumption, GHG emissions, virgin material extraction, and waste generation. It will also take advantage of local and recycled materials and have high durability and a long service life. Specifications for concrete should not restrict the concrete mixtures that are being supplied to the jobsite from being more sustainable.

During a project, several parties will be involved in the production and construction process. The custody of the concrete will change hands several times, with each party having the ability to affect the material's final performance. Problems can arise when conflicts exist between the specification and performance requirements. Fundamentally, these issues arise due to unfamiliarity with the most current and appropriate standards and lack of knowledge regarding local materials, communication, and planning.

The options for specifying concrete are prescriptive and performance-based specifications or a combination of the two.

With prescriptive specifications, the owner stipulates material types, sources, quantities, air content, slump, and construction processes, while the contractor plans construction methods around those parameters. The concrete supplier then verifies the concrete complies with those criteria. The specifier assumes responsibility for concrete performance.

Ensuring clear specifications and proper planning are keys to a successful and sustainable project. Shown here is construction of the Brantford, Ontario, Canada YMCA building and retaining wall.

Under the performance option, the owner specifies the structural and durability requirements and other performance criteria. The contractor is responsible for procuring concrete and working with the material supplier who will establish mix proportions to meet the plastic and hardened requirements. With performance-based requirements, the concrete supplier assumes responsibility for material as delivered. The contractor is responsible for the concrete as placed. This option provides an advantage as the involved parties are free to use their expertise to innovate and ensure the most efficient, economical, and sustainable product is finally used.

There are a number of obstacles to achieving sustainable construction, but the two most significant and easily managed issues are:

- removing barriers in specifications and opening them up to allow more sustainable options; and
- avoiding poor construction practices onsite.

*Sustainable specifications*

It is important to ensure sufficient time is allowed for project bidding so material suppliers and contractors can discuss requirements, evaluate options, develop and test mix designs, and conduct any necessary prequalification testing and optimization.

Prescribing mixture proportions or specific materials should be avoided as restrictions on material types or source often result in the use of unfamiliar products, greater overdesign (*i.e.* material inefficiency), potential material incompatibilities, and increased transportation distances.

Outlining the details of construction methods should also be avoided as this falls within the contractor's realm of expertise and experience. Slump specifications, in particular, are best addressed by the designer, supplier, and contractor discussing construction requirements and working together.

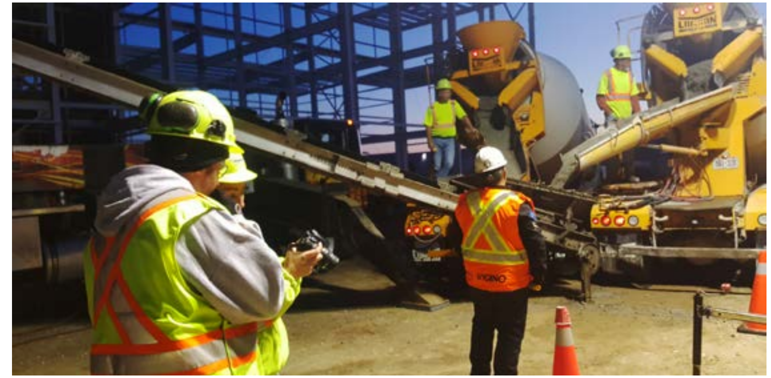
It is also important to not insist on faster construction schedules than required unless there is a tangible and measurable benefit to the project. Sometimes, the more sustainable option may be using a concrete with slower strength development.

Restrictions on reasonable changes to concrete mixture proportions should also be avoided as slight adjustments throughout a project might be necessary to maintain performance as material and environmental conditions change over time.

Planning and communication are keys to success. It is important to discuss concrete performance requirements with the producer and contractor to allow them to optimize mix designs. It is advisable to ask them how they can contribute to the project's sustainability as they can often see the whole picture related to material efficiency and can come up with solutions providing a win for all the involved parties.

*Best practices onsite*

Onsite testing should be carried out by a competent agency following proper ASTM testing procedures. False negatives in test results lead to greater overdesign and material waste. It is important test results are shared with all parties in a timely fashion to allow control and optimization of concrete mixes for performance and sustainability.



Ensuring sustainable construction requires planning and teamwork with clear expectations and responsibilities.

Improper scheduling and estimates or insufficient labor and resources on the project can lead to delays onsite and excess waste generation, while undersized loads increase vehicular emissions. It is critical the site is adequately prepared, access and traffic plans are in place, and designated staging and washout areas are established to avoid delays and potential safety impacts or site damage.

Concrete must be properly protected and cured to reach its potential. Curing is necessary for the hydration reaction between the cement and water to continue. A lack of curing significantly reduces the durability and service life of concrete. Additionally, pouring during extreme weather conditions without proper precaution can result in delays and increased energy consumption to maintain favorable concrete conditions and risk of failure of an element.

It is important to follow the American Concrete Institute (ACI) specifications and guidelines to ensure the proper design is followed, reinforcement is properly spaced, jointing is timely, and excessive water addition beyond the design parameters is avoided.

Pre-placement and routine update meetings, site-specific plans, risk assessments, and procedures for document control and inspection and verification practices must be established to ensure all parties contributing to a project are on the same page.

### The final word

Sustainable design in construction is motivating designers and builders to re-evaluate the materials, methods, and metrics used in constructing greener communities. A focus on the material's performance allows each of the parties involved to bring their knowledge, expertise, and innovation to the table. Concrete offers a robust, reliable, and sustainable solution in many applications as it consumes minimal materials and energy, and when designed and placed correctly, is very durable. **CS**

### Notes

[1] Consult the "2018 Global Status Report: Towards a zero-emission, efficient, and resilient buildings and construction sector" by the Global Alliance for Buildings and Construction at globalabc.org/uploads/media/default/0001/01/3e7d4e8830bfce23d44b7b69350b2f8719cd77de.pdf.

[2] Refer to "the Cement Sustainability Initiative: Recycling Concrete Executive Summary," by the World Business Council for Sustainable Development at www.wbcsd.org/contentwbc/download/2410/29973.

[3] To access the study, visit www.iisd.org/library/emission-omissions.

[4] For more information, read the paper "the carbon footprint of reinforced concrete. Advances in Cement Research Purnell," by P Purnell at eprints.whiterose.ac.uk/78456/1/adcr25-0362.pdf.

[5] Read the 2011 report "Methods, Impacts, and Opportunities in Concrete Building Life Cycle," by the Massachusetts Institute of Technology (MIT) Concrete Sustainability Hub at rediscoverconcrete.com/assets/files/MIT-Buildings-LCA-Report.pdf.

[6] Visit en.wikipedia.org/wiki/Crust_(geology) and www.quarrylifeaward.ca/what-quarry-life-award.

[7] Refer to the "Effects of Substances on Concrete and Guide to Protective Treatments" by Beatrix Kerkhoff.

[8] Visit www.cement.org/docs/default-source/sustainabilty2/hwu_sustainablecement_adv15-digital-(002).pdf?sfvrsn=2&sfvrsn=2.

[9] For more information, visit www.ncma-br.org/pdfs/5/TEK%2013-01C.pdf.

[10] See Note 5.

[11] Read "the Role of Cement in the 2050 Low Carbon Economy" at cembureau.eu/media/1500/cembureau_2050roadmap_lowcarboneconomy_2013-09-01.pdf.

[12] Details at www.cement.org/docs/default-source/sustainabilty2/pca-portland-cement-epd-062716.pdf?sfvrsn=2.

[13] Visit ghgprotocol.org/sites/default/files/co2_CSI_Cement_Protocol-V2.0_0.pdf.

[14] For more information, read "U.S. and Canadian Labor-Energy Input Survey 2012."

## ADDITIONAL **INFORMATION**


**Authors**

Michael Stanzel is the technical sales representative for GCP Applied Technologies for cement additives in Canada. Stanzel holds a bachelor's degree in chemical engineering from Queen's University, with more than 18 years of experience in both cement and concrete quality and operations. He is a member on the Canadian Standards Association (CSA) A3000, *Cementitious Materials Compendium*, and an associate member on CSA A23.1, Concrete materials and methods of concrete construction. Stanzel can be reached at michael.stanzel@gcpat.com.

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**Key Takeaways**

Over the past few years, there has been considerable discussion about concrete construction and its impact on global warming. Concrete is, in fact, a relatively low-impact material, not only due to its durability, long service life, and recyclability, but also because of increasing investments in more sustainable manufacturing technologies. It is locally available, and a good building material for most applications. Continued global growth and the trend toward urbanization means building material solutions must be abundant, affordable, and easily adapted into use. Concrete is a sustainable solution striking a strong balance between the social, environmental, and economic aspects of the communities' infrastructure needs.


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**Key Words**

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# Design Considerations for Rail Post Anchorage into Concrete

**by Robert C. Haukohl, PE, Bartosz Lipinski, PE, SE, and Matthew L. Wagner, SE**

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**RAILING SYSTEMS ARE UBIQUITOUS IN THE BUILT ENVIRONMENT, AND AS SUCH, THEIR APPEARANCE IS MORE HIGHLY CONSIDERED THAN FUNCTIONALITY.** MINIMUM LOADING REQUIREMENTS FOR RAILING SYSTEMS HAVE BEEN PART OF CODES FOR ABOUT AS LONG AS THESE STANDARDS HAVE BEEN IN EXISTENCE, AND ALTHOUGH RAILING SYSTEMS MAY BE BUILT AND TESTED TO MEET CODE LOADING REQUIREMENTS, AND MANUFACTURERS PROVIDE GENERIC MOUNTING DETAILS, RAIL POST ANCHORAGES STILL NEED TO BE DESIGNED EITHER BY THE DESIGNER OF RECORD OR BY A SPECIALTY ENGINEER RETAINED THROUGH THE DELEGATED DESIGN PROCESS.

Rail post anchorage design is often not properly emphasized, or is altogether forgotten during the design process. The design and installer/manufacturer teams often see anchorage design as the others' responsibility. Critical design and coordination issues are either not considered or left to be resolved in the field. Someone needs to verify the anchorage is capable of supporting code required loads, coordinate the trades involved so the anchorage does not interfere with other construction, and ensure post holes will not explode (Figure 1). This person can be the architect, engineer of record (EOR), delegated designer, contractor, or all of the above depending on project size and delivery method.

The authors see the same design and construction errors made repeatedly, including:

- the use of expansive grout or grout that weathers or disintegrates with repeated exposure to water;
- lack of consideration of detail-specific design constraints, such as edge distance and anchor size; and
- absence of coordination with embedded items, mostly reinforcement steel.

If the drawings and/or specifications are incomplete or unclear, or if not clarified through the request for information (RFI) process, the anchorages may not meet code, resulting in spalled concrete, loose railings, or severed reinforcing steel.

## EOR or delegated design

The root cause of most rail post anchorage issues is a failure to identify the team responsible for anchorage design, or even that rail post anchorages need to be designed at all. It is not enough to simply specify a railing system without consideration for anchorage and without the EOR's input on whether loading from the selected system can successfully be transmitted to the structure. No one seems to want to do the design for capability, liability, or cost reasons.

A disconnect between the design and installer/manufacturer teams often occurs because the language in the specification or referenced standard either does not mention anchorage design directly or implies the inclusion of anchorage design in the manufacturer's installation instructions. ASTM E985, *Standard Specification for Permanent Metal Railing Systems and Rails for Buildings*, provides guidance specific to metal railing design. It says, railings shall be installed per manufacturer's specifications. However, do those specifications include anchorage design? Manufacturers generally make sure the railings themselves meet code loading requirements and provide generic mounting details, but do not offer anchorage design.

One option the architect may select is to delegate the anchorage design to a licensed specialty structural engineer retained by the installer, supplier, or fabricator of the railing system. Before rail post anchorage design can be delegated, the EOR should review the proposed rail post architectural details, locations, and spacing to confirm a proper load path is present and the structure is capable of supporting the code-required railing loads. Although a delegated designer may be able to identify potentially problematic anchorage configurations, they are not required to confirm the structural capacity of the supporting members the railing assemblies are being

Figure 1

'Exploded' rail post pockets.

Images courtesy Raths, Raths & Johnson, Inc.

anchored into. As the EOR has a better understanding of the structure as a whole, and his/her specifications and reviews are in many ways redundant to the specialty engineer's design, it may be simpler and more cost effective to have them perform the anchorage design, thereby reducing overall effort, mishaps, and miscommunication.

For proper delegation of design, the contract documents need to clearly define acceptable project material requirements and project-specific conditions and constraints. The specifications should include items such as:

- design loads meeting or exceeding code requirements;
- maximum post spacing as determined by limitations of the supporting structural element;
- geometry of the supporting concrete member (including minimum edge and corner distances);
- whether supplementary reinforcement and cracked or uncracked concrete are assumed; and
- compressive strength of concrete.

Submittals from the delegated designer should include calculations and sealed shop drawings to be reviewed by the EOR to ensure there are proper load paths to the supporting structural elements, the structural element can support the proposed rail post base reactions, and the anchorage locations are coordinated with embedded items in the concrete.

Figure 2

Rail post set in grouted post pocket.

## Rail post anchorage 101

The design of railing systems begins with the building code. The *International Building Code (IBC)* provides minimum required loading on railing systems and their anchorages: A concentrated force of 0.89 kN (200 lb) or 0.73 kN/m (50 plf) applied in any direction to the top horizontal rail. When rail post spacing exceeds 1.2 m (4 ft), the 0.73 kN/m force will govern it. These loads must be transmitted to the post anchorages and from there into the substrate. The choice of anchorage configuration and the substrate—curb, slab edge, etc.—affect the transmission of these loads.

The two most commonly used rail post anchorage configurations are:

1) embedment of the post in grout in a sleeved or core-drilled pocket (Figure 2); and
2) a surface-mounted base plate with post-installed anchors (Figure 3, page 18).

Variations of these two configurations can be found in several resources, including the "Construction Details" section of the National Association of Architectural Metal Manufacturers' (NAAMM's) AMP 521, *Pipe Railing Systems Manual including Round Tube*. For non-pipe railing systems, reference should be made to manufacturer's details that may require additional design. Wall brackets are also common, but typically only offer lateral support locally at the railing terminations. Both embedment and surface-mounted configurations have their comparative advantages in design and constructability, and the choice often depends on cost, substrate configuration, project sequencing, or a combination of all three. With the base plate configuration, the anchor type and design parameters are critical. The grouting material is important for the embedded rail post configuration. With both arrangements, avoidance of interference with other embedded objects (most commonly reinforcing steel) and edge distance are critical. Allowable edge distance is greatly affected by the presence/absence of confining steel reinforcement between the post and the edge.

The 2018 *IBC* refers to Chapter 17, "Anchoring to Concrete," of the American Concrete Institute (ACI) 318-14, *Building Code Requirements for Structural Concrete and Commentary* (Appendix D in earlier versions of the standard), for the structural design of anchoring to concrete. Surface-mounted rail post base plates resist horizontal rail loadings by means of a moment couple between tensile loads in the anchors and compression bearing between the base plate and the concrete surface. While the surface-mounted base connection can be easily designed by following the provisions in ACI 318 (Chapter 17) and AMP 521, the design of an embedded rail post can be more challenging.

With the embedded rail post configuration, the horizontal rail loading is resisted by a shear couple in the implanted portion (Figure 4, page 18). Engineers often struggle with, and the industry provides little guidance for, the calculation of the imposed shear load on the concrete. One methodology used by the authors was developed by the Precast Concrete Institute (PCI) and is described in a *PCI Journal* article authored by Charles H. Raths in 1974. In this article, a methodology is offered for determining the distance between and position of the embedded shear couple (Figure 4). Once the shear force (CF) at the top of the embedment is determined, provisions in Chapter 17 can be used to determine if the surrounding concrete can resist the imposed shear force.

Figure 3

Rail post with base plate anchored with post-installed anchors.

### Concerns persist

Some rail post anchorage configurations are simply not buildable if they are to accommodate all the various construction tolerances that need to be considered. For example, design of a rail post set in a concrete curb needs to accommodate railing setting tolerances (typically fixed by the manufacturer), reinforcement steel placement tolerances, and cover requirements (ACI 117, *Specification for Tolerances for Concrete*

*Construction and Materials*), post edge distances (determined by design), and deviation of formed surfaces (ACI 117). A 200-mm (8-in.) wide curb is too narrow to accommodate a 100-mm (4-in.) wide embedded hole, or provide enough edge distance for an anchored base plate.

Similarly, thin concrete balconies also present issues if the post anchorage is not coordinated with reinforcement steel location and slab thickness. Figure 5 depicts an embedded rail post with a 150-mm (6-in.) edge distance (dimensioned from the slab edge to center of the rail post). Considering a preferred edge bar placement at the top location (before the bend radius), a clearance of 20 mm ($^{3}/_{4}$ in.) remains to account for construction tolerances. Moving the railing post closer to the slab edge would require the relocation of the edge bar or elimination of the edge reinforcement all together, but the removal would decrease the concrete breakout capacity.

### Post pockets should not explode

This is, unfortunately, quite common. The concrete around a rail post pocket cracks, then spalls, quite spectacularly in some cases (Figure 1), creating falling hazards and rendering the post connection worthless. Not all post pockets fail this way. In some cases, the grout within the post pocket simply weathers or turns to rubble (Figure 6, page 20).

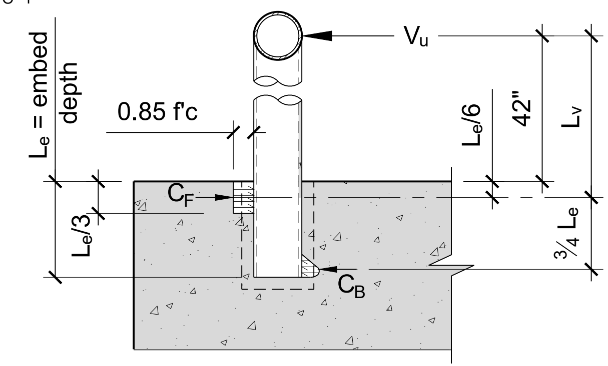
The detail is deceptively simple: Set the post into a hole sleeved or core-drilled into the concrete and fill the hole with grout.

As explained, the 'explosion,' or expansion of the contents of the pocket, can crack and spall the surrounding concrete, and sometimes thrust the rail post out of the pocket (Figure 7, page 20). There are three general mechanisms by which this occurs:

- use of expansive grout in a wet environment;
- freezing and expansion of water in the pore structure of the grout; as well as
- corrosion of embedded metal, such as reinforcement steel, post sleeve, or the post itself.

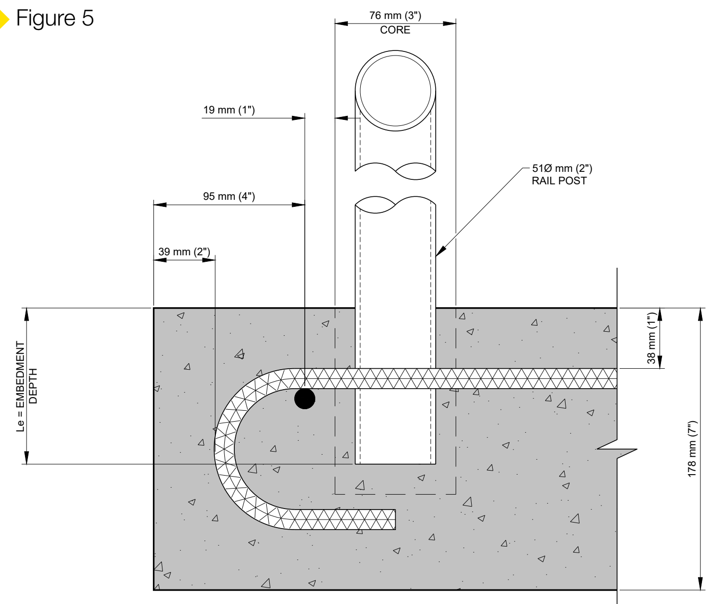
All three mechanisms result from the use of inappropriate grout, and it is common for all three to occur within the same pocket. Exposure to

Figure 4




Embedded rail post detail, according to the Precast Concrete Institute (PCI) methodology.

Figure 5




An example of design running afoul of construction tolerances.

chlorides from de-icing agents and marine environments can significantly exacerbate the problem. In the authors' view, a lot has been written about 'non-shrink' grout and its use for setting rail posts and stone cladding anchorage, yet it continues to be used largely because many of these products are marketed as appropriate for outdoor use. Though the product may be advertised for outdoor use there are several conditions listed in the fine print that must be met, and above all, the grout must not get wet—a highly suspect requirement for a material intended for the outdoors. If compliance with ASTM C1107, *Standard Specification For Packaged Dry, Hydraulic-Cement Grout (Nonshrink),* is specified, it should be with the caveat the grout be demonstrably appropriate for outdoor, exposed, wet, and freeze-thaw conditions.

Non-shrink grout, as the name implies, typically incorporates shrinkage compensators to offset the normal dry shrinkage of cementitious grout during initial cure. Gypsum or hydrated calcium sulfate is often used as an expansive additive (or in some cases as the primary binder) to balance the shrinkage of the grout during curing, making it non-shrinkable. Gypsum is mildly water soluble and tends to be unstable under prolonged exposure to moisture. The transformation of the sulfate mineral to a chemical structure with higher water content results in volume instability of the grout, thus creating an expansive force. Gypsum can re-crystalize on drying, but in a weaker, less-compact form, and causes expansion. Over time, this cycling turns the grout into rubble. The problem worsens in freeze-thaw environments where water penetrates the grout and freezes, providing another expansion mechanism. Worse still, with gypsum in the pore solution, the pH is approximately neutral and not high enough to provide passive resistance to the corrosion of the embedded steel, another expansion mechanism. Even a small amount of inappropriate grout can be problematic, as shown in Figure 8 (page 20) where not all of the material had been removed from a post pocket. The small amount left at the bottom of the pocket expanded and blew out the side of the wall.

Absolute avoidance of gypsum is impossible, as it naturally occurs in trace amounts in Portland cement and some aggregates. Even though the product literature may say "no added gypsum," it is not necessarily gypsum-free (it should be noted ASTM C1107 does not preclude grouts with added gypsum). Cementitious grouts without added gypsum and tolerable to wet environments and freeze-thaw cycles are available. Epoxy-based grouts are effective and qualify as non-shrink, but can also be relatively expensive. The designer should decide whether non-shrink grout is really needed for the application. Shrinkage cracking within the grout is unacceptable but avoidable if it is properly mixed and cured. Many grouts are very specific about the degree of mixing and the required amount of water. It is recommended to

Figure 6

Weathered grout with biological growth.

Figure 7

Expansive grout pushing post upward.

always stick with a proven, commercially available product, and avoid mixing and matching grouts, even from the same manufacturer.

Taking measures to reduce the exposure of the grout to moisture is also desirable. It is advisable to fully fill the post holes so water cannot pond (and freeze and thaw) in incompletely filled post holes. Crowning the grout to shed water is an option, as is installing a sealant bead around the base of the post to cover the grout. Sealant, however, is fallible and a regular maintenance item.

Most railing systems are hollow, and condensation within the system should be weeped out at the post base. The weeps should be set such that the post base does not hold water. A pourable sealer can be used within the post to fill the hollow portion of the post up to the level of the weep. Some railing systems have condensation sleeves or diverters.

### Did we just hit steel?

Most railing systems are not field-adjustable. Therefore, coordinating rail post anchorage locations with other embedded items becomes extremely important. Installing sleeves for post pockets prior to pouring the concrete has the advantage of avoiding interference with other embedded items and avoiding the messy core drilling step. However, the locations of the rail posts need to be known early in the project, well before concrete placement. The railing and reinforcement installers and concrete subcontractor all need to be involved with coordinating the sleeve locations. Any errors in locating the sleeves lead to core drilling or expensive alterations of the railing system.

Core drilling post pockets or drilling for post-installed anchors is generally favored over sleeve or embed installation as it gives the railing installer flexibility about post location, is cheaper, and eliminates the pre-pour installation processes. However, lack of coordination of anchorage locations can lead to interference with embedded items. Further, field modifications made to accommodate the interference can be problematic. Installed anchorages can conceal a multitude of sins, such as severed steel reinforcement, shortened rail post ends, and cut post-installed anchors. On one project investigated by the authors, reinforcement was hit on nearly

Figure 8


Side of wall spalled due to small bit of expansive grout.

Figure 9


Rail post cut short to accommodate reinforcing steel.

every post hole, with the installer opting to either sever the steel or cut off the end of the post (Figure 9, page 21), shortening the post, and reducing the embedment, thereby weakening the anchorage. Resolving the issue involved:

- removal of the railing assemblies;
- cleaning out the (inappropriate) grout;
- chipping out the concrete at each post location;
- installation of supplemental reinforcing steel;
- placement of new concrete; and
- installing base plates on each post (Figure 10).

This situation can be avoided by taking the extra step to specifically require the coordination of rail post locations with embedded items prior to casting concrete. Shifting and adjusting rebar and conduit locations can be done with much less effort than repairing it after the concrete has been placed.

## Recommendations

Rail post anchorages need to be designed; they cannot simply be selected, or worse, ignored. Questions to be asked in the design phase include:

- are there proper load paths to the supporting structural elements;
- can the structural element support the proposed rail post base reactions;
- is the edge distance adequate;
- can all construction tolerances be accommodated;
- if the design is delegated, have all the requirements been properly conveyed to the delegated designer; and
- has the delegated design been properly checked by the EOR?

It is best to not use gypsum-based grout in an exterior application. The specifications should preclude grouts with gypsum-based binder. A product may be unsuitable for outdoor use if it cannot get wet. Many materials meet the non-shrink criteria and are suitable for outdoor, freeze-thaw environments.

Lastly, it is recommended to predetermine post anchor locations and coordinate the locations with embedded items. It is pertinent to note railing system installation is an integrated process requiring input from and coordination of more than one party. **CS**

Figure 10

Replacement base plate for rail post.

### Two Things about Aluminum

When aluminum base plates have welded attachment flanges, or are to be welded to the post, the welding process reduces the allowable strength and may not be structurally adequate to transfer loads from the post to the plate.

Additionally, aluminum railings should be kept from contact with cementitious materials or dissimilar metals by the use of appropriate separation materials or specified coatings, such as a heavy-bodied bituminous paint, methacrylate lacquer, zinc chromate, or other coatings to prevent an aluminum-concrete reaction or an electrolytic action between aluminum and dissimilar metals. The design team needs to run the numbers and check compatibility of the specified materials. **CS**

## ADDITIONAL **INFORMATION**

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### Abstract

There is more to anchoring guard rail posts than the simple grouted post pocket or bolted base plate. The same design and construction errors, such as the use of expansive grout and the lack of consideration of detail-specific design constraints, are being repeated across projects. Anchorage design is not properly emphasized or altogether forgotten during the design process, with railing installation often subject to field decisions and modifications. If the drawings and specifications are unclear, the anchorages may not meet code, resulting in spalled concrete, loose railings, under-designed anchorages, and severed reinforcing steel.

### MasterFormat No.

01 33 00–Submittal Procedures
03 10 00–Concrete Forming and Accessories
03 15 19–Cast-In Concrete Anchors
03 20 00–Concrete Reinforcing
03 30 00–Cast-in-Place Concrete
03 32 50–Post Installed Concrete Anchors
03 62 00–Non-shrink Grouting
05 52 13–Pipe & Tube Railings

### UniFormat No.

B1010.30–Balcony Floor Construction
B2080.50–Exterior Balcony Walls and Railings

### Key Words

Divisions 01, 03, 05
ACI 318
Anchorage to Concrete
Cast-in-place concrete
Concrete anchors
Core drilling
Delegated design
Expansive grout
Non-shrink grout
Railing systems
Rail post anchorage design
Rail post embedment in concrete

### References


- *International Building Code (IBC)*, International Code Council (ICC), 2018.
- The American Concrete Institute (ACI) 318-14, *Building Code Requirements for Structural Concrete.*
- "Embedded Structural Steel Connections" by Charles H. Raths for *PCI Journal*, May-June 1974.
- ASTM E985, *Standard Specification for Permanent Metal Railing Systems and Rails for Buildings.*
- ASTM C1107, *Standard Specification For Packaged Dry, Hydraulic-Cement Grout (Nonshrink).*
- ASTM E1481, *Standard Terminology of Railing Systems and Rails for Buildings.*
- The National Association of Architectural Metal Manufacturers' (NAAMM's), AMP 521-01 R2012, *Pipe Railing Systems Manual including Round Tube,* fourth edition (2001, revised 2012).
- The United States Code of Federal Regulations (CFR), Title 29 Part 1910.23, *Guarding Floor and Wall Openings and Holes.*


# Solving the Conflict between Division 3 and Division 9 Floor Flatness Tolerances

# Case Study: Swedish Hospital – Seattle, WA

General contractors have discovered the LATICRETE® SUPERCAP® floor leveling system helps them to be more productive by achieving installations in days rather than weeks. It's ideal for starting early in new construction and when major renovation projects uncover severely compromised concrete slabs. The SUPERCAP system helps clear up the age-old disparity between concrete flatness and floor flatness (FF) tolerances in both Division 3 and Division 9. The results are shorter build schedules and improved GC margins while delivering better outcomes for owners. Installation is fast and silica dust free leaving the substrate flat, dry and ready for finished floor goods.

LATICRETE®

## Project Results / Key Metrics

Project completed 4 months ahead of schedule and $35MM* under budget

SUPERCAP® directly credited with construction schedule reduction and 25% of gross budget savings = $8,750,000

**Floor Flatness (FF)**

| | |
|---|---|
| Specification: | FF 35.0 / FL 25.0 |
| Actual Result*: | FF 94.1 / FL 43.9 |

**Shell Core Construction Cost***

| | |
|---|---|
| Budget Cost: | $135 / sq. ft |
| Actual Cost: | $ 75 / sq. ft |

**Construction Time***

| | |
|---|---|
| Scheduled: | 28 months |
| Actual Time: | 24 months |

**Plan Percent Complete (PPC)**

| | |
|---|---|
| Industry Avg: | 54% |
| Actual Avg: | 90% |

*Complete Case Study:
https://cdn.laticrete.com/~/media/files/supercap/project-spotlights/2014/swedish-hospital-case-study.ashx?vs=1&d=20191127T124031Z

500,000+ SF of slab is poured

The slab is bull floated

SUPERCAP® is proactively placed after the base slab was bull floated in Division 3

# RETHINKING Concrete

## Proactive methods and materials for the 21st century

**by Chris Bennett, CSI**

Photo courtesy Adidas

**IN THE CLASSIC 1967 FILM, *THE GRADUATE,* THE CHARACTER MR. MCGUIRE FAMOUSLY TELLS BENJAMIN BRADDOCK ONE WORD: PLASTICS.** THIS ICONIC SCENE REFERS TO A THEN-NEW MATERIAL AFFECTING ALL ASPECTS OF LIFE. PLASTIC WAS EVERYWHERE; IT WRAPPED FOOD, REPLACED WOODEN TOYS, SWAPPED OUT METAL IN AUTOMOBILES, AND DISPLACED COTTON THREAD IN FIFTH AVENUE FASHION.

This cultural change also manifested itself in the construction industry, not least among which was concrete. Acrylics, epoxies, and various ethylene-based materials began to enter the construction landscape in the 1960s. Even the marketing around concrete in construction was modified to encourage "plasticity." Designers were influenced into employing high-range water reducers that went by the modern and keenly American-sounding name, "superplasticizer."

At that time, construction methods gained a speed and flexibility with "plastic." However, it is now apparent replacing cement, rock, and water with plastics has unanticipated negative effects, such as shorter life cycles as a result of deterioration and corrosion, which have affected buildings, bridges, and highways.[1] The concrete of *The Graduate's* era has not proven to be resilient, as is evidenced by the colossal budgetary allocations governments have requested for infrastructure repair.[2] Building professionals compound this problem by adding even more plastic-based materials—epoxy skim coats above, vapor barriers below, and all manner of patch and repair materials in-between—when concrete fails.

In fact, tens of millions of acres of concrete are wrapped in "plastic bags" today, despite obvious negative effects to the environment (from using fossil fuels) and a property owner's checkbook. Fears of failure and risk responsibility are partly to blame, but there are also those who have taken advantage of this fear to foster the continued use of 50-year-old slab designs that use plastic, now a billion-dollar commodity industry in concrete.

Fortunately, many discoveries have advanced the concrete sector in the last 50 years, with millions of square feet standing as evidence to post-1960s engineering and science. This article will briefly touch on a few technologies making a significant impact in lowering the use of plastic in the field of concrete: reactive copolymerizing solids (RCS), thinner control joints, hydro-demolition, and corrosion inhibitors.

### Reactive copolymerizing solids

Concrete's strength comes from calcium silicate hydrate (C-S-H). It is sometimes referred to as the "glue of the built environment." Traditional concrete is quite porous, allowing moisture, vapor, and contaminants through the open spaces in the C-S-H, and can necessitate the use of additional materials (*e.g.* plastic) to make up for this weakness. RCS describes a technology type that reacts with concrete to naturally close those spaces and encourage growth of additional C-S-H throughout the material's life cycle. It is mostly employed in commercial applications but can be applied topically to any existing concrete surface or as an internal cure in new construction, eliminating the requirement for all additional curing methods and materials by making the concrete itself control water loss.

Wet refinement of architectural concrete floors keeps silica dust down, accelerates construction schedule, and reduces material use during installation. Surface refinement should be achieved with commercial polishing equipment. Proper refinement and concrete curing cannot be achieved with janitorial equipment, finishing equipment (a.k.a. trowel polishing), or topical sealers.

Photo © Chris Bennett

Builder Meyer Najem (CallisonRTKL and BSA Life Structures) employed integral RCS solutions to eliminate moisture mitigation products at the 11,334-$m^2$ (122,000-sf) Community Cancer Center North in Indianapolis, Indiana. This technology contributed to cost savings during initial construction. Additionally, due to less vapor transmission, early strength gains in the concrete allowed for mobilization of other trades on an accelerated schedule—tile installation began 72 hours after the slab was poured, and complete polished floor sections were finished within seven days. By taking eight weeks off the construction schedule the project team was also able to positively impact the environment by lowering the use of diesel generators for equipment and lighting. The cancer center will also operate with lower maintenance costs because of a stronger concrete matrix.

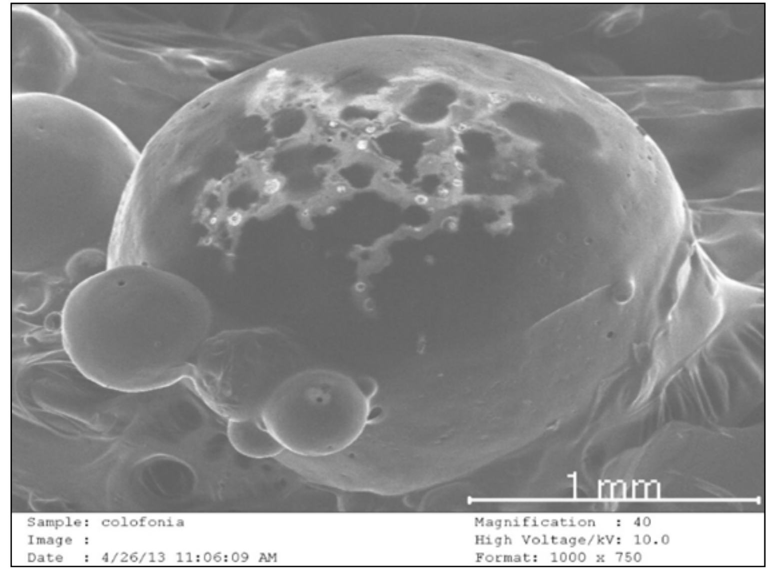
Brian Harlow, vice-president at Fiat Chrysler Automotive (FCA), decided to move away from epoxy-coated floors for both operational and sustainability considerations. With more than 18-million $m^2$ (200-million sf) of property under his care, this is understandable. By using an RCS technology at the award-winning Kokomo Casting Plant (KCP) in Indiana, FCA put an end to the need to routinely strip, prep, and repour epoxy, as the concrete itself can now be made to prevent hydraulic fluids, oils, and other contaminants from entering the automotive facility's slabs.

In New York City, constructing Adidas' flagship location downtown on Fifth Avenue meant contending with build-outs as well as maintaining the original building's existing finishes to reduce the need for new materials. RCS was applied topically on both new and existing slabs to create a sustainable floor in an aggressive "Big Apple" timeline. Adidas AG and architect Gensler NY received many awards for this project, including the 2017 Retail Week Interiors Awards for best international store. However, a more significant reward was realized by reducing the project's carbon footprint with a decrease in material usage.

### Thin joints

Control joints are necessary in concrete slabs to control the cracking that occurs as the new slab moves due to thermal and volume changes while it cures. The 1960s-influenced concrete contracts or shrinks at a rate of nearly 25 mm (1 in.) per 31 m (100 ft) as it cures. While modern curing systems are less susceptible to volume changes, they are still at the mercy of thermal factors. Traditionally, most of the contraction happens in the first 90 days, but concrete continues to expand and contract with changes in temperature and humidity many years after being poured and placed.

Control joints are typically cut as soon as the slab can support the weight of the equipment and the saw operator to help reduce random cracking. However, the control joints raise additional maintenance considerations throughout a facility's life cycle. With hard-wheeled traffic from pallet jacks, loading carts, and forklifts as well as foot traffic, control joints are subject to abuse, resulting in maintenance costs for owners. This is especially true in industrial and distribution warehouse facilities. It is not uncommon for some property owners to complain more than 70 percent of their floor maintenance costs come from having to constantly clean and repair joints.




Natural resin microcapsule corrosion inhibitors hold enormous potential to increase concrete resiliency and reduce dependence on patch and repair materials.

Images courtesy David Bastidas/ University of Akron

The standard control joint blade for many years was around 3 mm (1/8 in.) wide because the technology did not exist to make them thinner, but the late engineer Art McKinney, PE, SE, a fellow at the American Concrete Institute (ACI), pioneered the use of the now more common thinner control joint blade (around 1.6 mm [1/16 in.]) in North America.[3]

McKinney's premise is thinner joints in a working facility better distribute the weight of rolling loads, thus reducing the amount of wear and tear on the joint areas. Minimal damage to joints means they last longer, so owners spend less time, materials, and money repairing these areas. Further, thinner joints require less joint filler material. This might not seem like substantial energy and material reduction to the carbon footprint of a facility, but hundreds of millions of acres of concrete slabs are being created. This change could influence millions and millions of lineal feet of joint space. The healthy impact to our environment by using half the "plastic" of current methods in this area of construction—achieved by simply making control joints half as wide as is currently being done—could be very substantial.

## Water

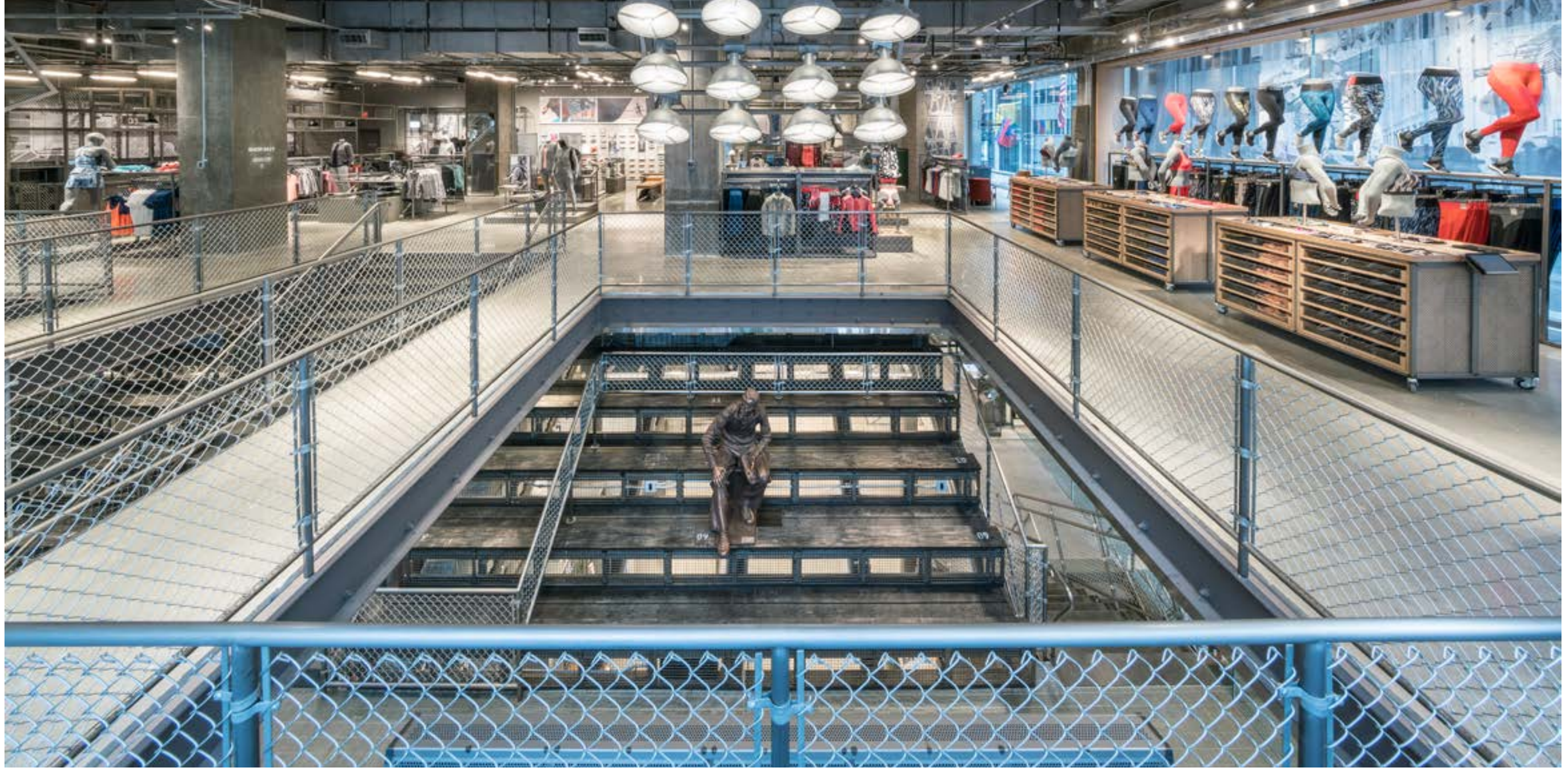
Concrete is the world's second most used material in construction. Water is the first. Water reacts with cement and aggregate to create concrete but it is also essential for the material's demolition or refinement. Hydro-demolition technologies use high-powered streams of water to remove concrete. Unlike mechanical demolition using tools like jackhammers, hydro-demolition removes material on a bridge, road, or building without creating micro-fractures in the surrounding matrix. This helps the concrete structure to remain intact longer while reducing the need for patch and repair materials.

Water is also essential in refining existing concrete surfaces. When the contracting firm Desco took on the task of surface preparation and architectural concrete floor installation at a 55,741-$m^2$ (600,000-sf) Rolls Royce facility, a wet refinement process was chosen to reduce material use and meet the client's schedule. Polishing the floors dry would have meant using additional latex and epoxy grouts and potentially heavy coats of acrylic sealers as well as the extra time and labor necessary for installation.

There are additional benefits of a wet polishing. The accelerated installation means reducing the operation of diesel generators and their impact on our air while powering commercial grinding and polishing equipment. The air at the worksite is made safer in another way by trapping silica on the surface of the concrete in a slurry instead of letting it become airborne.[4] Dry polishing requires specialized air filtration systems and frequent filter cleaning to reduce the amount of silica dust making


Floorcoverings were applied without any additional mitigation prep methods and construction groups took advantage of the accelerated timeline at Community Cancer Center North in Indianapolis, Indiana.

Photo courtesy Meyer Najem Construction



Sustainability was prioritized at Adidas' flagship store in New York City by maintaining the building's existing finishes and deploying a reactive copolymerizing solids (RCS) technology, which reduced demand for additional materials and helped create new benchmarks in environmental and experiential design.
Photo courtesy Adidas

its way into the air. Occupational Safety and Health Administration's (OSHA's) new regulatory requirements can mean heavy fines for contractors and even jobsite shut downs.

"Grinding wet means we know we will always maintain a safer worker environment and be able to meet OSHA's new regulatory requirements on allowable airborne silica and finish fast. We do not cut or polish dry anymore," says Brandon Godbey, head of Desco's polishing division.

**Cutting-edge technologies**

At the National Center for Education and Research on Corrosion and Materials Performance (NCERCAMP) at the University of Akron in Ohio, David M. Bastidas and his colleagues from the chemical and biomolecular engineering department are advancing another type of eco-friendly concrete science at the micro level. Although still in the early stages, studies related to smart micro-encapsulated corrosion inhibitors are investigating concrete corrosion, specifically in areas where steel rebar makes contact with the concrete matrix. Corrosion is reduced by using time-released "pills" containing natural colophony (rosin) from California pines. Rosin or "Greek pitch" is a solid state of resin made from pine and other coniferous trees. This system of limiting the corrosion and degradation of concrete comes from allowing the progressive and efficient release of resin inhibitors throughout the life cycle of the concrete.

Corrosion inhibitors are one of the most efficient methods to prevent corrosion in concrete, but historically they have been plagued by high cost as well as the contaminant nature of some of the compounds themselves. This upcoming technology is attractive because unlike concrete corrosion prevention from the 1960s the micro-encapsulation in the natural resin coating makes it environmentally sustainable as well as effective. The corrosion inhibitors consist of a core-shell structure containing combinations of hydroxides and nitrites from different metals, forming a microcapsule. The inhibitor releases according to the pH of the surrounding matrix and the presence of aggressive agents like chlorides and carbonates. This could mean substantially less "plastic" in many reinforced concrete structures while still enjoying the benefits of inhibitors. Since the pine resin is not soluble in water (it has a hydrophobic nature) it will only react with corrosion agents and not simply in the presence of moisture.[5]

## Conclusion

Concrete production makes up six to eight percent of total manmade greenhouse gasses (GHG).[6] Further, many of the raw materials for several epoxies and resins used in coatings and patch material are largely derived from petroleum. The carbon footprint is substantial. The effect after 50 years of employing The Graduate-era concrete methods is bridges are falling apart and buildings are cracking. Building professionals understand replacing the elements creating C-S-H (water, aggregates, and cement) has a cost.

It is not to say plastics are not useful or do not have their place, for they have, of course, been helpful in many ways. When building a waste water treatment plant and designing spaces to house fluoride tanks, one must have epoxy coatings on the concrete floor or soon the facility will not have any concrete at all. The author is not questioning the function of plastic, rather if its use is necessary at all times, given the high stakes regarding construction costs and the environment and with successful alternative technologies being readily available. For example, the concrete in the lobby of the waste water treatment plant does not need the same coatings as the tank room.

All of us would like to see concrete last longer, enjoy a smaller carbon footprint, and require less material waste. This will not happen by

Hydro-demolition can remove old concrete while doing repair work without creating micro-fracturing and the future need for additional patch and repair materials.

Photo courtesy Aquajet

Using thin or "skinny" blades (1.6 mm [1/16 in.] thickness) reduces joint failure, spall, and maintenance throughout a facility's life cycle. Creating thinner control joints also means using half the amount of filler materials than the older 3-mm (1/8-in.) wide joints during initial construction.

Photo © Chris Bennett

RCS technology replaces epoxy at Kokomo Casting Plant (KCP) in Indiana, thereby reducing the cycle of stripping and installing coatings that in the past would head to landfills and incinerators.

Photo © Chris Bennett

maintaining the same 50-year-old benchmarks in construction documents. It will not happen by avoiding hard conversations or repeating mistakes of the past. However, it can happen by exploring new possibilities, beginning new conversations, and learning from each other. To paraphrase Mr. McGuire, there is a great future in concrete. **CS**

## Notes

[1] For more information, visit transportation.house.gov/calendar/eventsingle.aspx?EventID=398627.

[2] Visit thehill.com/opinion/technology/363166-to-address-americas-crumbling-infrastructure-follow-britains-lead.

[3] The author worked with Art McKinney, PE, SE, on a number of large projects where "skinny" or "thin blade" technology was utilized.

[4] Consult www.osha.gov/dsg/topics/silicacrystalline for Occupational Safety and Health Administration's (OSHA's) regulatory requirements.

[5] A more in-depth overview of this technology will be presented later this year at the concrete symposium at University of Akron's National Center for Education and Research on Corrosion and Materials Performance (NCERCAMP.). Visit www.uakron.edu/ncercamp for details.

[6] For more information, visit www.constructionspecifier.com/renaissance-of-roman-concrete-cutting-carbon-emissions.

## ADDITIONAL **INFORMATION**


**Author**

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**Abstract**

In the 1960s, construction methods gained speed and flexibility with "plastic." Acrylics, epoxies, and various ethylene-based materials began to enter the construction landscape. Designers were influenced into employing high-range water reducers aka "superplasticizers." However, it is now apparent replacing cement, rock, and water with plastics has unanticipated negative effects, such as shorter life cycles as a result of deterioration and corrosion, which has affected buildings, bridges, and highways. Fortunately, many discoveries have advanced the concrete sector in the last 50 years. Technologies such as reactive copolymerizing solids (RCS), thinner control joints, hydro-demolition, and micro-encapsulated corrosion inhibitors can help lower the use of plastic in concrete.



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Control joints
Plastic
Reactive copolymerizing solids
Micro-encapsulated corrosion inhibitors


# LATICRETE® SUPERCAP® Flies High with TWA

If one word describes the historic TWA terminal at New York's John F. Kennedy (JFK) International Airport, it's "cool." Under the auspices of architect Eero Saarinen and Howard Hughes, the terminal was constructed in 1962. Otherwise known as the TWA Flight Center, the terminal evoked every element of 1960's style designed with soaring ceilings and unique tube-shape pedestrian corridors. In 1994, the terminal was designated a New York City Landmark and by 2005, it was listed on the National Register of Historic Places. After more than 15 years of vacancy, due to the inability to accommodate modern air travel, the TWA Flight Center is currently undergoing a huge transformation.

Open for business in Summer 2019, the terminal is a fully operational hotel, spanning across 200,000 square feet. Partnering together, MCR Development, Jet Blue and the Port Authority of New York and New Jersey are leading this project. The TWA Hotel, as it is referred to, is the only hotel inside the JFK airport. The overall design provides all the amenities for modern day lodging - hundreds of guest rooms, multiple bars and restaurants, a 50,000 square foot event center, an observation deck and pool.

To help maintain the building's historical design, the construction process required new floors that were durable, safe and level. In addition, the floors were to be installed quickly to meet tight deadlines and minimize disruption of other construction areas within the building.

The project's general contractor, Turner Construction – New York, turned to Pyramid Floor Covering and the LATICRETE® SUPERCAP® System to deliver and meet these requirements.



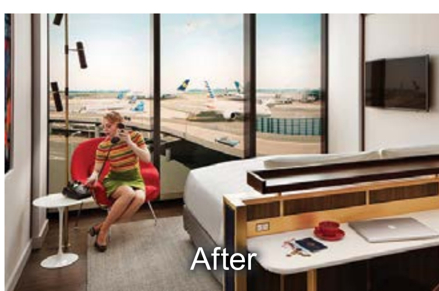

Peter Vecchione, Turner Construction Project Supervisor said, "JFK is a very complex location to operate. We have to work with the Port Authority and Jet Blue all day, every day to get materials, equipment and manpower in and out of the job site. It's a mountain of planning and logistics. Having LATICRETE® SUPERCAP® shortened our logistics challenge tremendously. No fixed stationary pumps, no hand mixing, no small bags, no waste. We're compliant with the new OSHA silica dust rules, helping to keep our workers and job site safe".

> *"It's a great experience. This product saves days on a schedule; the payback is saving weeks and months in the long run."*
>
> – Peter Vecchione,
> Turner Construction Project Supervisor

Vecchione went on to say, "You're walking on the floor by the end of the day. It's amazing. It allows all the other trades to get back on the floor the next day. They are a nimble team, in and out with virtually no disruption. That's not the norm on a construction site. The time savings is tremendous. We only have to shut down each 16,000 SF floor for one or two days, versus a week or more." Vecchione continued to state, "The flatness of the floor is great. They survey, pin and pour. No grinding, no flash patching, no bumpiness – those conditions can kill a job." Familiar with LATICRETE products, this was Vecchione's first direct experience with LATICRETE SUPERCAP.

LATICRETE® SUPERCAP®
Perfectly Flat Floors. Delivered.™


Before


After

# Sealant Joint SOLUTIONS

**by Arthur L. Sanders, AIA, and Lawrence E. Keenan, AIA, PE**

All images courtesy Hoffmann Architects

**IN NEW CONSTRUCTION AND REHABILITATION PROJECTS, SEALANT JOINTS ARE OFTEN GIVEN SHORT SHRIFT WHEN IT COMES TO TIME AND ATTENTION, AS WELL AS BUDGET.** SEALANTS GENERALLY COMPRISE THE LOWEST PERCENTAGE OF A PROJECT'S OVERALL COST—THIS IS SURPRISING CONSIDERING ALL THESE PRODUCTS ARE ASKED TO DO.

Façade sealant replacement begins with complete removal of existing sealant and backer rod.

The photo above is an example of adhesive failure where the sealant pulls away from the substrate.

As modern buildings have moved away from mass walls toward lighter, more pliant construction, designers rely on sealants to buffer those moving parts. With their multiple wythes and drainage channels, mass walls were designed to absorb and shed water before it reached the inner surface of the wall. Curtain walls and lightweight cavity walls depend on sealant joints to not only accommodate movement, but also to help keep the building interior dry. This is a lot to ask of a building element, especially one usually afforded only passing consideration.

Precast concrete construction relies on sealant more than any other building type. Parking structures, in particular, have miles of sealant joints that must be maintained and, periodically, replaced. These joints frequently suffer from poor design and/or installation, as well as damage from high-heeled shoes and snowplow blades.

When sealant joint failure occurs, it can wreak havoc on the building envelope. Many joints are difficult to repair, and some concealed joints may be impossible to fix without demolition and reconstruction. Therefore, it is critical to design joints correctly, and to specify and properly apply an appropriate sealant. Before having a handyman attack cracked or missing sealant with a caulk gun, one must consider the substantial costs of rehabilitating water damage should the caulk fail. In the bigger picture, it is worth spending the time and energy on well-designed sealant joints to prevent premature degradation of building materials.

### An age-old problem

Although naturally occurring bitumen- and asphalt-based materials have been used as building sealers for centuries, modern polymeric sealants were developed relatively recently. Acrylics and polyurethanes emerged in the 1930s, while water-based epoxies and silyl-terminated polyethers were not developed until the 1980s and 1990s, respectively. New sealant types, including proprietary mixtures, regularly appear on the market, each claiming to surpass the performance of previous generations of sealant products.

Modern sealants are composed of two basic elements: an elastomeric compound for flexibility, and some type of filler. During the mid-20th century, asbestos was a common sealant component, and poly-chlorinated biphenyl (PCB) was often added to impart desirable properties to the sealant. Unfortunately, subsequent research has linked both compounds with cancer, and the resultant cleanup process has led to no end of trouble for building owners and rehabilitation teams alike. (See "PCBs in Sealant," page 37.)

Elastomers do just what their name says: they stretch. Sealants are usually polymers, composed of more than one type of elastic material. These pliable compounds bridge gaps at moving joints, where two building elements that move differentially intersect, as well as at static joints, which are relatively stable. Today's sealants vary in composition to accommodate different applications, whether a high-movement expansion joint, a structural glazing seal, or a concrete control joint.

## Sealant types and properties

For residential and commercial applications, the six most common types of sealants are:

- water-based latex;
- solvent-based acrylic latex (acrylics);
- butyl;
- polysulfide;
- silicone; and
- polyurethane.

No one sealant type is universally better or worse than another; some are better-suited to a given application than others due to their physical and chemical properties.

*Latex sealants*

These sealants are popular for residential use because they are easy to apply, adhere well to most substrates, and are generally paintable. For low-movement applications, they are an economical option that gets the job done. Where they fall short is in situations where a high movement capability is necessary, such as for high-rise buildings and moving joints. Latex is also prone to shrink, pulling away from the substrate and leaving open gaps where water can penetrate.

*Acrylics*

Acrylics are mainly used in exterior applications, where their ultraviolet (UV) stability puts them at an advantage over water-based latex. They are also less likely to shrink over time. On the downside, acrylics can be difficult to tool, and they do not perform well in high-movement areas.

*Butyls*

Adhering well to a wide variety of substrates, butyls can be difficult to apply due to their stringy consistency. These sealants also have poor resistance to abrasion and shear forces, which limits their performance in demanding applications.

This is an example of cohesive failure where the sealant tears within itself.

A sealant is being misused to repair mortar joints in this building.

*Polysulfides*
Polysulfides can accommodate submerged applications, such as in a fountain or pool. They have excellent flexibility, even at low temperatures, and they exhibit little shrinkage or UV degradation. However, they are expensive, and tend to have high levels of volatile organic compounds (VOCs). At 10 to 20 years, the long life expectancy for polysulfides may help compensate for the upfront costs, particularly considering the difficulty of re-sealing an underwater surface.

*Polyisobutylenes*
With similar properties to natural rubber yet significantly better aging characteristics, polyisobutylene resins are used in sealant formulations because they resist degradation due to aging and chemical attack, and they have low permeability. Often the primary seal in insulating glazing unit (IGU) window applications, they resist vapor transmission and prevent the inert gas between glass panes from leaking. Typically, a silicone secondary seal is employed in conjunction with the polyisobutylene for durability and long-term adhesion. Usually formulated as hot-melt sealants, polyisobutylenes melt mix with ease.

*Silicones*
Silicones have excellent thermal resistance, dynamic movement capability, and good adhesion, but silicones are easily vandalized and tend to collect dirt. For some substrates, staining may be an issue. In addition to general sealant applications, silicones are also commonly used as structural glazing sealants, securing sheets of glass to framing elements. Of all the common sealant types, silicones tend to be the most expensive—however, they also have the longest service life.

*Polyurethanes*
These sealants adhere well to most surfaces with little substrate preparation, making them the go-to sealant of many contractors. Their excellent resistance to abrasion and shear forces, along with strong adhesion and movement capability, make them a good choice for applications such as plazas, which demand durability and resilience.

## Properties of sealants
When selecting a sealant, one must consider the properties most impacting the specific application at hand. Here are the key sealant properties one must evaluate.

*Consistency*
Sealants are available in pourable or non-sag formulations. Pourable sealants have a fluid consistency for use in horizontal joints, where they are self-leveling. Non-sag sealants are thicker and will not run down sloped or vertical joints.

## PCBs in Sealant
Polychlorinated biphenyls (PCBs) were a common additive to sealants from the 1950s until they were banned in the United States in 1979. Thanks to their elasticity and chemical stability, they were added as plasticizers to building sealant used for windows and masonry. Exposure to PCBs can cause cancer, as well as endocrine disruption, immune suppression, liver damage, reproductive system failure, and neurotoxicity.

PCBs are regulated under the Toxic Substances Control Act, but state and regional regulations vary as to their safe disposal. Since PCBs can leach into the surrounding substrate or soil, abatement may involve demolition and/or excavation, adding substantial time and expense to a sealant replacement project. At a minimum, containment measures must be put in place during rehabilitation to prevent PCB-containing dust from becoming airborne. Site access should be limited, and workers must wear appropriate protective clothing and respiratory equipment. Removal methods should minimize heat generation, as PCB gases may be released into the air in response to high temperature. Also avoid grinding, which produces dust and may lead to aspiration of PCBs.

PCBs can be a formidable obstacle to sealant joint rehabilitation. However, the potential health consequences of negligence outweigh the inconvenience and expense of proper abatement. **CS**

*Durability*
The expected service life of a sealant under ideal conditions may not be the same as the actual field lifespan, especially if the sealant was misapplied or incompatible with the substrate. Generally speaking, silicones have the longest service life, estimated at 20 years or more, while some acrylics and butyls last little more than five.

*Hardness*
The harder a sealant, the greater its resistance to traffic and vandalism. However, as hardness increases, flexibility decreases, so the trick is to find the right balance of damage resistance and movement capability for a given situation.

*Exposure resistance*
The best exterior-grade sealants perform well in response to sun, temperature extremes, and moisture. Measures of exposure resistance include flexibility at low temperatures, freeze-thaw resistance, UV stability, and susceptibility to heat aging.

*Movement capability*
The higher a sealant's movement capability, the more elongation or compression it can withstand without failure. Movement capability is expressed as a percentage of the joint width. For example, a sealant with ±10 percent movement capability in a 25-mm (1-in.) joint can stretch to 28 mm (1.10 in.)—or contract to 23 mm (0.90 in.)—and recover.

*Modulus*
Short for 'modulus of elasticity,' modulus refers to sealant stress at a given elongation. Low-modulus sealants usually have high movement capability, and vice versa, although this is not always the case. Low-modulus sealants are generally used for delicate substrates, for which it is desirable to have low stress at the joint edge. High-modulus sealants are best used for static, non-moving joints, because they exert a very high force on the substrate when stretched. Medium-modulus sealants

Special additives and hardeners are manufactured specifically to resist damage from high heels because they can puncture sealants at joints.

Failure to maintain sealant joints can lead to severe deterioration and water entry.

are general-purpose products balancing stress at the adhesion surface with stiffness of the sealant.

*Adhesion*
The ability of a sealant to adhere to construction materials is an essential property to consider. Test methods such as ASTM C794, *Standard Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants*, can evaluate the adhesion of elastomeric sealants. Manufacturers also provide data on sealant adhesion for various substrates.

*Staining*
The components of some sealants may leach into porous substrates, particularly natural stone, leaving a visible stain. To evaluate compatibility with the substrate, even sealants rated as non-staining should be tested in an unobtrusive area before use.

*VOC content*
Emission of volatile organic compounds from building products is regulated at the state and regional level. For occupied buildings, VOCs are a particularly important consideration. While most manufacturers have developed low-VOC sealants, some types have lower levels than others. Solvent-based sealants tend to have higher levels of respiratory irritants and environmental toxins, but VOC content varies widely by product.

*Ease of application*
Curing characteristics and toolability are the two major factors affecting a sealant's ease of application. Toolability refers to the ease of achieving a smooth surface of correct geometry. Curing properties vary widely, from fast-curing sealants to those, such as polyisobutylene, that are designed to remain uncured.

*Cost*
As is the case with most building products, cheapest is not usually the best. In general, higher cost means higher performance. However, opting for a high-performance sealant when a less expensive alternative would do the job may mean one is overspending. Scrimping on sealants is not likely to do the prudent building owner any favors, though, as replacing failed sealants is nearly always more expensive than selecting the right sealant in the first place.

Peel tests are used to evaluate sealant elongation and adhesion.

### Causes of sealant failure

One of the most common causes of sealant failure stems not from the sealant itself, but from the size and spacing of the joints, which must be sufficient in number and in spacing to allow for seismic forces, thermal cycling, and differential movement of substrate materials. Different sealants have differing abilities to accommodate shear stress, caused by the faces of the joint sliding past one another, along with expansion and contraction as fluctuating temperatures cause the joint to widen or narrow.

Joints spaced too narrow or widely may force sealant to stretch beyond its capacity, which can cause the sealant to pull away from the substrate (adhesive failure) or to tear within itself (cohesive failure). Expansion of the substrate may compress the sealant beyond its tolerance, causing it to extrude out of the joint. An excessively wide joint may not be able to accept sealant at all, as it is likely to slough out of the large gap.

Properly designed sealant joints generally have a 2:1 width-to-depth ratio, a configuration allowing the joint to accommodate movement most effectively. Additionally, many manufacturers stipulate maximum and minimum dimensions for the sealant bead to perform within its movement capability.

### Inappropriate selection

In addition to correct joint design, selection of a sealant product with the ability to withstand anticipated building movement is critical to avoid premature failure. Inadequate provision for movement, either by underestimating the amount of movement or by using a sealant with insufficient movement capability, can cause even correctly proportioned joints to fail.

Fountains, parking garages, plazas, schools, and other sites subject to vandalism, water, and weather conditions demand sealant with superior abrasion resistance. High-heeled shoes—the bane of the precast concrete parking garage owner—are notorious for puncturing sealant at joints. Special additives and hardeners are manufactured specifically to resist damage from high heels. Pick-proof sealants can withstand vandalism, but these harder materials tend not to accommodate much movement.

Substrate compatibility is another major consideration when selecting a sealant. Some products can leach chemicals, discoloring or degrading porous substrates, such as brick masonry and stone. Under stress, a sealant stronger than its substrate, can cause cracks and spalls, as force is dissipated within the weaker material. This phenomenon is common with exterior insulation and finish systems (EIFS).

Existing coatings can also prove problematic for sealant performance. Fully removing such coatings—or selecting a sealant compatible with the existing product—is necessary to achieve adequate adhesion. As many surface sealers are clear and, therefore, difficult to detect, it is important to conduct a field adhesion test before full-scale sealant replacement.

Compare the non-staining sealant at the top of this image with the sealant at the bottom, which has discolored the substrate.

### Improper application

The number one concern in the sealant application process is surface preparation. Given how often sealant failures relate to poor surface preparation, and how costly such failures can be to rehabilitate, it would be reasonable to assume a top consideration for sealant installers would be the diligent and thorough cleaning and, if required, priming of joint surfaces. However, this is not necessarily so. Especially for workers who have "always done it this way," manufacturers' recommendations for preparing the substrate may have little bearing on what is actually done in the field. At a minimum, surfaces must be clean and dry. Too often, though, even this simple stipulation is ignored. Dirty rags, incorrect or contaminated solvent, lint, and residue from existing sealant are just some of the many ways in which a sealant joint can be compromised.

A number of sealant types require surface primers prior to application, depending on the substrate. Primers can enhance adhesion, prevent the sealant from diffusing into the substrate, and emulsify dirt particles remaining on the surface. The advantage to using a sealant that does not require a primer is there is less room for error on the part of the installer, and skipping the priming step cuts down on application time and cost. However, some of the sealants requiring a primer perform better overall than their direct-application counterparts, so the additional time and oversight required for primer use may be worthwhile in the long run.

Weather conditions on the day of application can affect sealant performance. A significant percentage of sealant failures may be attributed to noncompliance with manufacturer instructions regarding installation. Ideally, sealant should be installed at the median of the design range, meaning the sealant has room to elongate or compress to accommodate fluctuations in temperature. If the sealant is installed in very cold weather, for instance, the substrate has shrunk and the joint is at its widest. As the weather warms and the substrate expands, compressive forces may exceed the sealant's tolerance, leading to failure. The converse is also true; sealant installed in hot weather may stretch beyond capacity as the weather cools and the substrate contracts. Sealant installed at moderate temperatures retains the flexibility to accommodate the upper and lower ends of the design range.

Sealant viscosity also varies with temperature. If the temperature is very hot, sealant may sag; cold sealant, on the other hand, may be thick and difficult to tool. High humidity, frost, dew, or dampness can also lead to failure, as sealant will not adhere properly to a surface that is not dry.

Correct joint preparation and tooling are essential. Using a backer rod prevents three-sided adhesion for moving joints, and it helps to achieve correct sealant depth and profile. Without a bond-breaker at the back of the joint, sealant adheres to all three sides, leading to adhesive or cohesive failure—or both. To understand how this works, picture stretching a rubber band. This is how a sealant joint is meant to operate: one's hands are the substrate, stretching and relaxing the rubber band, which represents the sealant. Now imagine grasping the rubber bands with the hands very close together, leaving only a tiny bit of the band to stretch and contract. Similarly, three-sided adhesion restricts elongation, as the bond area imposes additional stress on the sealant.

Insufficient joint preparation can compromise sealant adhesion. Debris and residue must be cleaned prior to new sealant installation.

Sloppy tooling may result in voids, gaps, and irregular sealant thickness, causing stresses to act unevenly along the joint. Ideally, sealant should follow the curve of the cylindrical backer rod, with a concave tooled surface, such that it resembles an hourglass in a cross-section.

## Reversion

Some organic sealants, especially polyurethanes, have the potential for reversion failure, in which they return to an uncured or gummy state in response to UV light exposure and moisture. Although manufacturers became aware of this problem more than a decade ago and have modified their products accordingly, owners and managers of buildings with older sealants should be on the lookout for signs of reversion. Keeping tabs on the consistency and performance of sealants should be part of a routine maintenance program.

## Imprecise specification

Sometimes, incorrect sealant use is not entirely the installer's fault. For instance, contradictions between drawings and specifications, or instructions going against relevant design standards or manufacturers' guidelines, may cause unnecessary confusion. Careless material specification may stipulate particular sealant properties, while specifying sealant products without those properties. Drawings and documents may be unclear as to which sealant types are to be used in which locations. Any number of other errors and inconsistencies in the contract documents can leave the installation open to guesswork—with a high potential for failure.

## Performance testing

Before embarking on a sealant replacement project, it is prudent to assess the suitability of the sealant product for the given application. A good place to start is manufacturer verification. Is the sealant compatible with the substrate? Will the product meet adhesion and elasticity requirements for the estimated joint movement? Is the sealant prone to discoloration or staining? Manufacturers can answer these and other general questions to verify the properties of a sealant under consideration. However, field conditions vary, and it is a good idea to test products onsite whenever feasible.

Peel tests for adhesion involve applying sealant to a test area, allowing it to cure, and evaluating the elongation prior to fracture or loss of adhesion. Especially for older buildings, it is important to assess multiple substrates and locations, as aging may cause different areas of the building to respond differently to the same sealant product. Multiple tests comparing different surface preparation methods can help determine the best balance between efficiency and good sealant-substrate bond.

Laboratory testing may provide more in-depth and detailed information than a field test. In the lab, it is possible to vary conditions for application and curing, so a sealant product may be tested in many possible scenarios. The downside is lab testing is not done under actual field conditions, which may vary from those simulated in a laboratory setting. Plus, many manufacturers require adhesion tests performed onsite, which means lab testing would need to be done in addition to, not in lieu of, field testing.

## Sealant joint rehabilitation

Where feasible, sealant replacement projects should begin by resolving original design flaws in joint dimensions and spacing. Joint preparation should involve removal of existing sealant, dirt, and debris through the use of grinding, compressed air, or wire brushing, as appropriate. Non-porous substrates may be cleaned with solvents, using the two-rag method: one rag for solvent application, followed immediately by a second clean, lint-free rag to dry the surface.

Next, appropriate primer may be applied according to the manufacturer's recommendations. Surfaces should be primed before

Sealant investigation at this glazed curtain wall uncovered application deficiencies compromising the weather integrity of the façade.

backer rods are inserted into the joint. The backer rod provides resistance to the pressure applied during tooling, helping to achieve the correct width-to-depth ratio and a smooth sealant surface. Typically composed of polyethylene or urethane foam, backer rods are categorized as open- or closed-cell. Open-cell backer rods allow air to circulate behind the sealant, permitting even curing; however, these are not appropriate for horizontal or submerged joints, where they can absorb and retain water.

Other pitfalls to avoid include:

- using sealant that has reached or exceeded its shelf life;
- storing sealant in a location subject to extreme temperatures;
- mixing multicomponent sealants incorrectly; and
- applying irregular pressure and flow with the sealant gun.

The number and variety of occasions for error in a sealant replacement project make it especially important to have a project team member tasked with onsite quality control, to see installation meets the manufacturer's warranty requirements for testing and inspection. If problems are identified straightaway, they may be rectified before it is too late.

## Sealant success

The limited lifespan of sealants means they inevitably need to be replaced. Achieving the full expected service life of a sealant requires a combination of correct joint design, appropriate sealant selection, product performance testing, appropriate surface preparation, and conformance to manufacturers' guidelines and industry standards. A good reference is ASTM C1193, Standard Guide for Use of Joint Sealants, which provides in-depth information on joint design and sealant installation.

Sound sealant joints are necessary to a building's ability to resist water infiltration and respond to movement. Although they may seem to require little more than a shot from a caulk gun, sealant joints demand care and attention if the building envelope is to perform as intended. **CS**

## ADDITIONAL **INFORMATION**

**Authors**

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Lawrence E. Keenan, AIA, PE, is director (engineering) with Hoffmann Architects and serves as manager of technical staff for the Connecticut office. With multiple patents for innovative joint design in precast concrete parking structures, he has presented papers at conferences of the Precast Concrete Institute (PCI), the Society of Structural Engineers, and the International Concrete Repair Institute (ICRI), where he is president of the Connecticut Chapter. A graduate of the University of Connecticut School of Engineering, he is both a professional engineer and a registered architect. He may be reached at l.keenan@hoffarch.com.

**Abstract**

In new construction and rehabilitation projects, sealant joints are often given short shrift when it comes to time and attention. These joints frequently suffer from poor design and/or installation, as well as damage from high-heeled shoes and snowplow blades. When sealant joint failure occurs, it can wreak havoc on the building envelope. Many joints are difficult to repair, and some concealed joints may be impossible to fix without demolition and reconstruction. Although they may seem to require little more than a shot from a caulk gun, sealant joints demand considerable attention to design, product selection, and installation if the building envelope is to perform as intended.

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B2010.90–Exterior Wall Opening Supplementary Components

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**Key Words**

Division 07

Acrylics

Butyls

Latex sealants

Polysulfides

Polyurethanes

Sealants

Silicones