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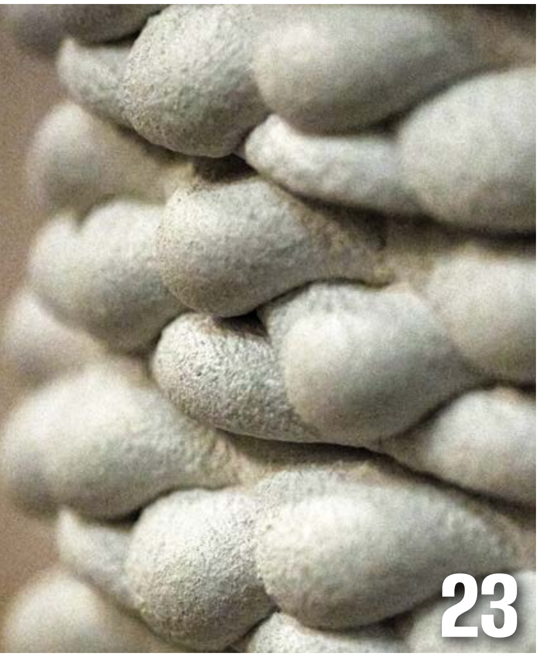

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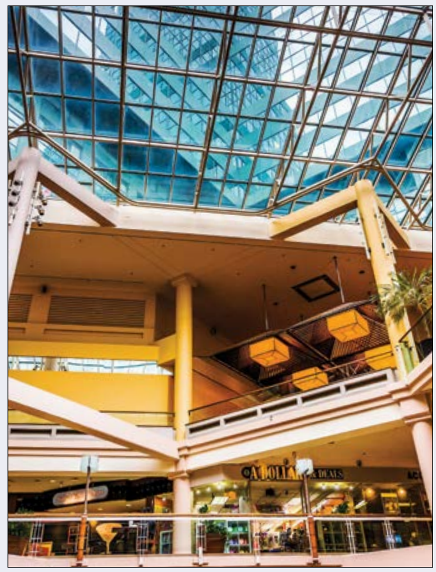

On the cover:

Skylights, like the monumental sloped glazing shown here, enhance interior spaces with natural light while contributing to energy performance and design appeal. Proper installation techniques, along with rigorous lab and field testing, are essential to ensuring long-term durability and watertight performance. Field testing under real-world conditions helps verify that even well-designed systems perform as intended once installed.

See article on page 8.

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The CSI Board of Directors' Insights Committee started a new question of the month post in the CSI-Connect online community to gain perspective on how CSI can better serve you.

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(Note: You must log in to the CSI website to access this post. Anyone can view the conversation, but commenting is a members-only feature.)

Bright Ideas Ahead

The Skylight Edge

By Glenn Ferris

PHOTO COURTESY SHUTTERSTOCK

Skylights can be used to provide significant energy savings and enhance the aesthetic appeal of buildings, flooding interior spaces with the warmth and illumination of natural light. Well-designed skylights can take maximum advantage of solar heat gain co-efficient (SHGC) in winter to reduce energy consumption, as well as reduce lighting heat load on cooling systems in summer. These benefits make skylights a welcome addition to buildings.

Skylights may be specified in a variety of sizes and shapes to match nearly any building's needs. They range from simple rectangles to complex polygons. They can be small to fit between rafters or large enough to run the length of a building. When selecting a skylight, the client's needs must first be considered. Appearance, lighting requirements, energy performance, structural performance, ventilation capability, and egress requirements play a role in selecting the most appropriate type of skylight for a project. Unit skylights and tubular daylight devices (TDDs) are used for smaller rooms or to evenly distribute light over large open areas such as big box retail and warehouse spaces. Sloped glazing is typically associated with large, monumental applications and can provide an architectural feature as well as deliver natural lighting to a building.

The use of high-quality skylights, materials, and good installation practices will result in a sound, long-lasting, leak-proof installation. However, the very nature of a skylight—being a penetration through the roof—introduces a potential vulnerability: water leakage. Ensuring the long-term, leak-proof performance of a skylight relies heavily on rigorous testing protocols, which can be broadly categorized into laboratory testing conducted on the product itself and onsite (field) testing performed after installation.

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When performing a water test to accurately determine the cause of leakage and location per AAMA 501.2 and/or AAMA 503, observers must be placed inside the building as the water spray is slowly distributed methodically from below the skylight first, working up to the skylight, and then above the skylight.
PHOTO COURTESY INTERTEK ATI

Installation component considerations

Curbs, water diverts, ice breakers, sealants, fasteners, and other components are necessary for the proper installation of skylights.

Prefabricated and site-built curbs

A separate roof curb is sometimes used to raise the skylight above the roof deck surface to reduce a skylight's exposure to water and snow on the roof deck, including ponding or standing water, and large volumes of water moving through the skylight location. The roof curb also provides a means of flashing the roof penetration created by a skylight by effectively integrating it with the roofing system. Roof curbs can also be used to modify the slope of the skylight relative to the roof.

Roof curbs are anchored to the roof deck or framing in a manner that ensures they can handle the design loads of the application. Constructed on the job site, roof curbs are typically made of wood. Prefabricated steel and aluminum roof curbs can also be used. Steep slope roofs generally warrant lower roof curbs. Low-slope and flat roofs sometimes require higher roof curbs as water levels on the roof surface increase. In all cases, the roof curb should fit the requirements of the application regarding proper height, materials, and anchoring.

Water diverters

In situations where a substantial volume of water will flow onto the skylight due to either a large, sloped roof area above the skylight's location or contributing roof areas draining into and through that location, it would be beneficial to include a water diverter or cricket above the skylight to reduce the volume of water running into the head area of the skylight. These devices will ensure standing water does not accumulate on the roof, as it can degrade bonded roofing material joints over time.

Ice breakers

When the building is in an area that experiences heavy snowfall in winter, a high volume of snow can collect on the roof. In these situations, it is possible for ice and snow to break loose during milder temperatures and slide through the skylight. Ice breakers can help protect the skylight from the tremendous force a large ice slide typically generates. Metal roof applications are most susceptible to this force.

Sealants

Where required, the proper use of sealants plays an important part in skylight installations. Sealants need to meet performance requirements such as:

- They must not adversely react with or weaken the material they contact.
- They must have good long-term adhesion, so always follow manufacturer recommendations about surface preparation, cleaning procedures, and primers.
- They require corresponding service temperature performance in installations involving elevated temperatures.
- They must be capable of maintaining the required flexibility and integrity over time.
- They must have the correct bead size and adhere to other application details to ensure a well-performing joint.

Fastening and anchoring

The following considerations should be taken into account for fasteners or anchoring devices:

- Use anchors intended for the substrate involved.
- Select the type and size of anchor in sufficient quantity and spacing to meet the structural requirements (*i.e.* wind loads, snow loads, etc.).
- Choose corrosion-resistant fasteners.

Skylights can be used to provide significant energy savings and enhance the aesthetic appeal of buildings, flooding interior spaces with the warmth and illumination of natural light.
PHOTO COURTESY DIGITAL STORM ON SHUTTERSTOCK

- Be aware of instances where fasteners may react chemically with materials they contact (*e.g.* galvanic action between metals and coatings or anti-corrosion treatments).

Installation best practices

The installation location of skylights must be properly sized, level, and square. If a site-built curb is used, it should be level and square. In all cases, the roof deck, support framing, and curb must be structurally adequate for anchoring the skylight and to withstand load reactions from the skylight.

If sealants are required, it is advisable to follow the sealant manufacturer's instructions with regards to application temperature, surface preparation, application technique, chemical compatibility, sealant location and dimensions, and ability to withstand specified movement.

AAMA 1607, *Voluntary Installation Guidelines for Unit Skylights*, provides guidance for installing pre-assembled unit skylights onto a roof. Sections 6.1 to 6.13 of AAMA 1607, a Fenestration and Glazing Industry Alliance (FGIA) document, cover pitched/steep slope applications, and Sections 6.14 to 6.19 cover low slope/flat applications. Unit skylights are typically designed to be installed at specific slope ranges, and some can even be installed at near-vertical slopes.

To ensure the integrity and performance of the entire roof system, including skylights, both the roof structure and the skylight are typically required to resist higher combined design loads when snow loads are expected. It is advisable to use skylights that are compliant with AAMA/Window and Doors Manufacturers Association (WDMA)/CSA 101/I.S.2/A440, *North American Fenestration Standard/Specification* (*NAFS*). Depending on the location, products may need to meet other performance requirements such as high velocity hurricane zone (HVHZ) conditions, per the American Society of Civil Engineers/ Structural Engineering Institute (ASCE/SEI) 7, *Minimum Design Loads for Buildings and Other Structures*. Skylights, and the roofs they are mounted in, are designed to resist the applicable environmental load requirements such as snow loads, wind loads, dead loads, and, in some cases, hurricane-induced wind-borne debris impact loads.

Lab testing

Laboratory testing of skylights is typically conducted by manufacturers prior to the product being released for sale or as part of independent certification processes. This form of testing takes place in a highly controlled environment, free from external variables such as wind and rain. This allows for focused assessment of the skylight's design and construction. Within a laboratory setting, factors such as water pressure, spray patterns, and the duration of the test can be precisely regulated and consistently replicated. This allows for a thorough evaluation of the inherent water resistance capabilities of the skylight unit itself.

Unit skylights are typically designed to be installed at specific ranges of slope, and some can even be installed at near vertical slopes.
PHOTO COURTESY MULTISHOOTER ON SHUTTERSTOCK

Limitations

A significant limitation of lab testing is that it cannot account for the complexities of real-world installation. The way a skylight is integrated into the roof structure, including flashing details,

Skylights may be specified in a variety of sizes and shapes to match nearly any building's need.
PHOTO COURTESY B BROWN ON SHUTTERSTOCK

sealant application, and the compatibility with the roofing material, are all critical factors that are not assessed in a lab setting.

Additionally, lab tests are performed on sample units and provide a general indication of the product's potential performance. However, variations in manufacturing tolerances and the specific conditions of each installation site can influence the actual performance of a skylight.

Onsite testing

Skylights often get unfairly blamed for leaks when it is almost always the fault of improper installation. Hence, it is important to conduct onsite testing after a skylight is installed.

The primary benefit of onsite testing is its ability to assess the quality of installation, which is paramount to preventing water leakage. This includes the effectiveness of flashing, sealants, and integration with the specific roof construction.

Further, onsite testing provides a specific evaluation of a particular skylight and its unique installation conditions. This accounts for the specific roof slope, roofing material, and other site-specific challenges.

When water leakage issues arise, onsite testing can be an invaluable diagnostic tool to pinpoint the source of the problem.

It is important to note that onsite testing takes place in an uncontrolled environment, where factors such as wind, temperature fluctuations, and accessibility to the roof can influence test results. Due to the uncontrolled environment, achieving the same level of precision and repeatability as in a laboratory can be challenging. Further, conducting onsite tests requires coordination after installation and access to both the interior and exterior of the building, which can sometimes be logistically complex, so it is recommended to perform tests in accordance with AAMA 501.2, *Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing System,* and AAMA 503, *Voluntary Specification for Field Testing of Newly Installed Storefronts, Curtain Walls and Sloped Glazing Systems*. Additional test methods of a more stringent nature incorporating the effects of wind can also be used per AAMA 501, *Methods of Test for Exterior Walls.*

The tests should be performed immediately after the skylight is installed, and before the installation of drywall or other interior finish materials. This can help determine water intrusion. If interior ceiling materials have been installed, they should be removed at the test area to allow visual access to check for water penetration. Alternate means of visual access can also be provided.

Water penetration resistance performance test must be performed in accordance with ASTM E1105, *Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference* using Procedure A, "Uniform Static Air Pressure Difference." The test involves applying a uniform water spray to the exterior of the specimen while maintaining the specified pressure difference. The field water penetration resistance tests should be conducted at a static test pressure of two-thirds of the specified project water penetration test pressure, but not less than 200 Pa (4.18 psf). The specifier may increase the field water test pressure to the value specified for the project. However, this should be stipulated in the project specifications.

The field installation conditions will influence product performance. Products tested in the laboratory are typically installed near-perfect for plumb, level, and square within a precision opening. Field test specimens, although installed within acceptable industry tolerances, are rarely perfectly plumb, level, and square. Shipping, handling, acts of subsequent trades, aging, and other environmental conditions may have an adverse effect on the performance of the installed specimen. Therefore, a one-third reduction of the test pressure for field testing is specified as a reasonable adjustment for the differences between a laboratory test environment and a field test environment.

Unless defined otherwise in project specifications, water penetration shall be defined as:

- Water penetration attributable to surrounding building conditions—The presence of water not contained within drained flashing, gutters, and sills, which did not originate from the fenestration product or the joint between the fenestration product specimen and the wall/roof;
- Water penetration attributable to the fenestration product specimen—The collection of up to 15 mL (0.5 oz) of water on an interior horizontal framing member surface in the 15-minute test period shall not be deemed a failure; or
- Water penetration attributable to the perimeter joint—Water not controlled by a water management system that indisputably originates at the perimeter joint.

If any of the specimen(s) do not conform to the prescribed water penetration resistance requirements, the installer must perform another detailed site inspection to determine the reason for non-compliance. Non-compliant specimen(s) must be repaired as required and retested as soon as practical.

Sample specification

To standardize and simplify the writing of field-testing specifications for storefronts, curtain walls, and sloped glazing systems, FGIA has drafted the following short-form specification that can be used by architects and specifiers:

The newly installed (________________) shall be field tested, as contractually agreed upon by the interested parties, by an AAMA-accredited independent laboratory, as engaged by (________________), in accordance with AAMA 503, *Voluntary Specification for Field Testing of Newly Installed Storefronts, Curtain Walls and Sloped Glazing Systems*.

Remedial work

Regardless of when water resistance testing is performed, it is important to properly determine the cause when a leak occurs. Guessing the cause

Good skylight design follows the principles of excellent watertight design in combination with provisions for condensation and "controlled" water collection and removal through the skylight frame to the exterior.
PHOTO COURTESY VELUX

The use of high-quality skylights, materials, and good installation practices will result in a sound, long-lasting, leak-proof installation.
PHOTO COURTESY CRYSTALITE

or charging forward with a remedy before fully understanding the cause is a big mistake. This approach will only eliminate the symptom in the short term, magnify the problem, and make correct remedial work more complex and costlier. It should be noted that a leak at the skylight does not always mean the leak is caused by the skylight or the installation. It could also be a roofing system leak or a roof/wall interface issue at some other remote location (*e.g.* chimney flashing or flashing at a parapet/roof intersection).

When performing a water test to accurately determine the cause of leakage and location per AAMA 501.2 and/or AAMA 503, observers must be placed inside the building as the water spray is slowly distributed methodically from below the skylight first, working up to the skylight and then above the skylight. Time must be given to allow for water to work its way through to reveal its entry point and pathway. If water leakage occurs and the source cannot be identified, an isolation technique, per Section 4 of AAMA 501.2, should be followed to pinpoint water entry. Once the cause is determined, the remedy is usually clear. Good skylight design follows the principles of excellent watertight design in combination with provisions for condensation and "controlled" water collection and removal through the skylight frame to the exterior. Too often, the improper use of sealants to dam up water pathways that need to be maintained only worsens the problem. Poor remedial work can destroy the skylight's ability to function as it was originally intended. In a similar manner, good installation practices can also be rendered dysfunctional. Thoughtful troubleshooting gets issues resolved simply, cost-effectively, and in a permanent manner.

Conclusion

It is evident laboratory testing and onsite testing serve complementary roles in ensuring the watertight performance of skylights. Lab testing provides a fundamental assessment of the product's inherent capabilities under ideal conditions, allowing manufacturers to develop and refine water-resistant designs. However, the ultimate performance of a skylight in a building is highly dependent on the quality of its installation. This is why onsite testing is crucial, as it validates the installed system under real-world conditions and identifies any potential weaknesses arising from the installation process or site-specific environmental factors.

With respect to proper installation and long-term performance, clear specifications for skylights are critical. Rely on available documents for best results. As mentioned earlier, lab testing assesses the skylight's inherent design, while onsite testing specifically evaluates whether the system, including the installation, is effective. The emphasis on field testing in the context of skylights underscores the fact that even a well-designed and lab-tested skylight can be prone to leaks if not installed correctly.

With respect to proper installation and long-term performance, clear specifications for skylights are critical. Rely on available documents for the best results.
PHOTO COURTESY WASCO

REFERENCES

- FGIA Documents. These are available in the FGIA Online Store at FGIAonline.org/store.
- AAMA 1607, *Voluntary Installation Guidelines for Unit Skylights*
- AAMA 501.2, *Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing System*, and AAMA 503, *Voluntary Specification for Field Testing of Newly Installed Storefronts, Curtain Walls and Sloped Glazing Systems*
- AAMA 501, *Methods of Test for Exterior Walls*
- AAMA/Window and Doors Manufacturers Association (WDMA)/CSA 101/I.S.2/A440, *North American Fenestration Standard/Specification*

OTHER RESOURCES

- American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI) 7, *Minimum Design Loads for Buildings and other Structures*, ascelibrary.org/doi/book/10.1061/9780784412916
- More on performance testing, fgiaonline.org/pages/performance-testing
- AAMA Laboratory Accreditation Program, fgiaonline.org/pages/accredited-laboratories

additional information

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Glenn Ferris is FGIA's fenestration standards specialist. He began his career with the association in 2018. He has extensive experience in the fenestration industry dating back to 1992. Ferris is a liaison for many councils, committees, and study/work/task groups guiding them in the completion of the scope of each group. He can be reached directly at gferris@fgiaonline.org.

KEY TAKEAWAYS

Skylights enhance aesthetics and energy efficiency by bringing natural light into buildings, but their performance depends heavily on proper design, material selection, and installation. Key considerations include skylight type, size, slope, and structural integration, along with components like curbs, diverters, ice breakers, sealants, and fasteners. Water leakage remains a major concern, making rigorous testing essential. Laboratory testing evaluates the product's baseline water resistance, while onsite field testing verifies installation integrity under real-world conditions. Standards such as AAMA 1607, AAMA 503, and ASTM E1105 provide guidance for best practices and quality assurance. Field testing should occur before interior finishes are installed to catch issues early. Accurate diagnosis of leaks is critical—misidentifying causes can lead to ineffective and costly remediation. Ultimately, the combination of robust product design, proper installation, and clear specifications ensures long-term skylight performance and water resistance.

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KEYWORDS

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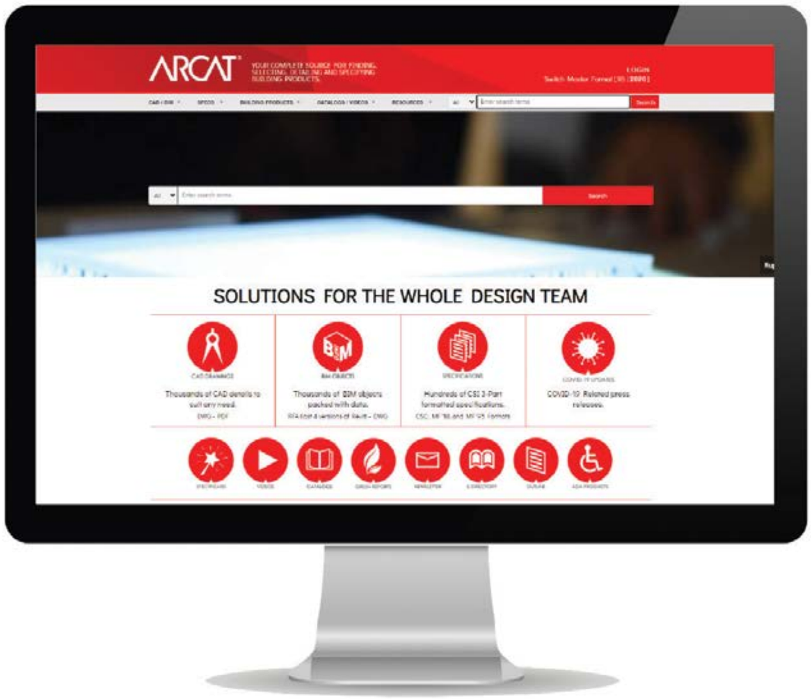

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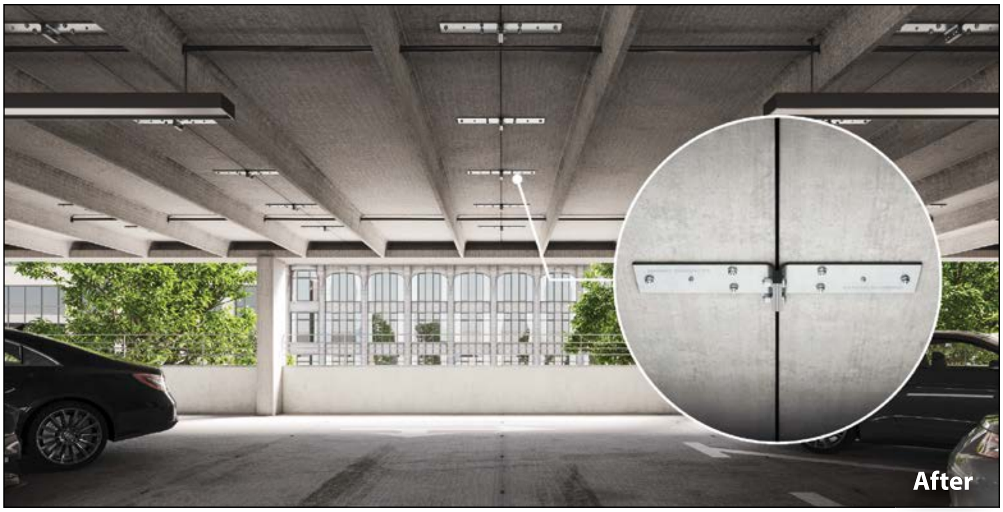

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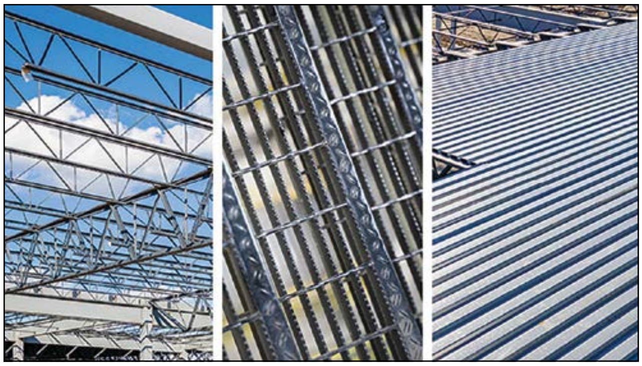

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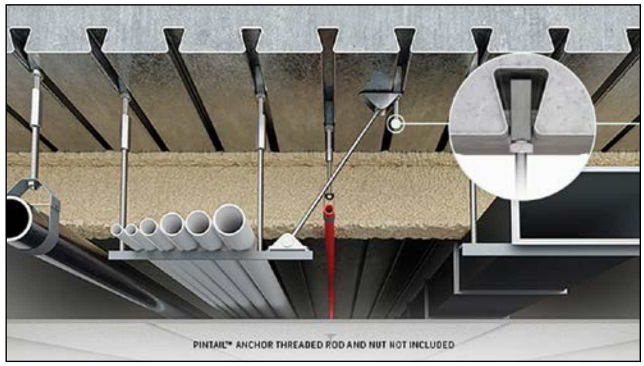

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Layer by Layer

How 3D Concrete is Reshaping Construction

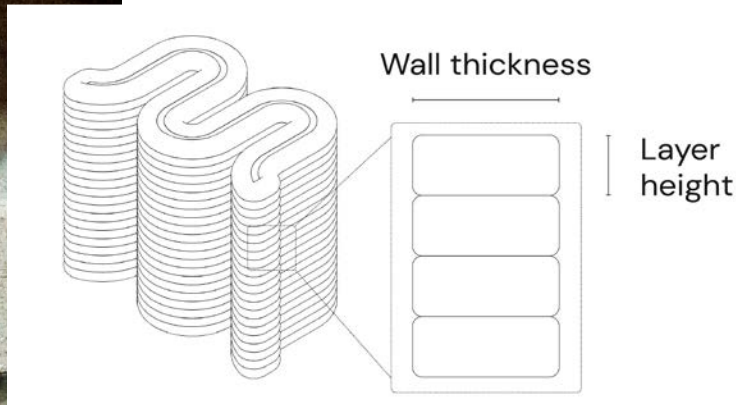
By Gabrielle Nadeau
PHOTOS COURTESY MEDUSIA

Layer stratification as an expressive tectonic language.

In recent years, 3D concrete printing (3DCP) has been reshaping the architecture and construction industries, moving beyond its experimental origins to become a viable method for producing complex, high-performance structures. Advanced digital technologies create intricate, non-standard volumes that were once impractical or impossible to fabricate with conventional materials and methods. Once the exclusive domain of skilled stonemasons, detailed and expressive architectural elements can now be produced through advanced digital fabrication, marking a new paradigm within the industry. A prime example is the first 3D-printed unreinforced concrete pedestrian bridge in Venice, built by the Block Research Group, in collaboration with Zaha Hadid Architects (ZHA). This project illustrates the ability of 3DCP to manufacture structurally efficient designs that save a substantial amount of material compared to formwork-based solutions, as no use of steel reinforcement or mortar was needed.

3DCP offers promising opportunities that align with regional environmental goals and the functional demands of northern climates. Through computational design and geometric optimization, 3DCP enables highly customizable building forms that improve thermal performance, reduce operational energy use, and enhance durability against harsh weather conditions. These capabilities are particularly relevant in northern regions, where resilience and energy efficiency are essential performance criteria. As Alami *et al.* (2023) note, "the utilization of 3D printing has the potential to enhance the thermal insulation of buildings and decrease energy usage, resulting in structures that provide improved thermal comfort. This can be achieved by printing geometries that are specifically designed for superior thermal insulation, such as cellular or lattice structures, or by altering the printing mix to include aerogels or air bubbles."[1] In addition, the technology promotes resource efficiency, generates less material waste compared to single-use custom formworks, and supports alternative low-carbon concrete mixes. In the Northern region's high-grade building codes for high-performance durability, safety, and efficiency, the application of 3D printing technology in construction necessitates a modification of these regulations. It does so, however, with fresh avenues of prefabrication and modularity. By integrating these advancements, 3DCP has the potential to redefine architectural practice in northern climates, offering a year-long solution for production.

With the construction sector currently under pressure to improve efficiency and a shortage of typically skilled labor, automated concrete 3D printing is being explored as an alternative building strategy capable of reducing construction



3D concrete printing (3DCP) layer variability.

material waste. As cement production contributes to around eight percent of the global CO2 emissions, the need for more resource-efficient approaches has never been greater.[2]

3DCP technology and advantages

Understanding 3DCP

At its core, 3DCP involves extruding specially formulated concrete layer upon layer. This process is known as additive manufacturing or, more commonly, 3D printing. Such concrete mixtures are usually made using hydraulic binders, aggregates, and additives. Generally, 3D models are processed through a slicing algorithm to produce a specific toolpath adapted to the chosen printing system. The three main technologies that account for most 3DCP are: robotic arms, gantry systems, and mobile crane systems.

- Robotic arm systems: A robotic arm system comprises multi-axis robotic arms with a specialized printhead attached to extrude concrete. They can produce complex, non-planar geometry and fine detail due to their wide range of motion, making them appropriate for custom models. The build volume is limited by the working length of the robotic arm. Therefore, larger structures may need to be prefabricated into smaller sections to assemble on-site. To increase their operational footprint, robotic arms can be installed on rail systems, enabling them to move along extended paths and fabricate larger components.
- Gantry systems: Gantry-based 3D printers operate on a Cartesian coordinate system, moving the printhead along fixed axes over a large build area. This configuration is well-suited for large-scale, repetitive building designs that produce long structural elements. The modular nature of gantry systems enables scalability, with some designs capable of constructing entire buildings in a single print sequence. Bod 2 by COBOD marks this category. However, the gantry systems may require independent foundations to generate additional constraints and costs.[3]
- Mobile crane-based systems: Systems such as the MaxiPrinter by Constructions-3D blur the line between robotic automation and construction equipment. Functionally closer to a crane than a traditional robotic arm, the mobile crane system features a long, articulated printhead mounted on a mobile tracked chassis. It can be repositioned across a prepared site, allowing for extended build areas without the infrastructure required by gantry systems. While it lacks the fine motion control of industrial robotic arms, its mobility and scale make it well-suited for large structural prints in open environments.[4]

Three critical factors contribute to the effectiveness of 3DCP: printing speed, geometry, and rheology. Rheology—the study of how materials flow and deform—is particularly focused on the material's plasticity and suitability for pumping. In concrete printing, rheology primarily involves yield stress, the minimum stress required for the concrete to transition from solid-like to fluid-like behavior, enabling extrusion.[5]

To achieve rapid solidification, essential for structural integrity, 3DCP mixtures typically contain two to three times the amount of cement found in ordinary premixed concrete. This higher cement content significantly accelerates setting times, often resulting in solidification within minutes. Due to this rapid curing, concrete must be deposited within that setting time to ensure cohesive bonding between each layer. This time span varies from one concrete mix design to another. Precise timing and rheological control are thus critical to achieving optimal adhesion and minimizing defects.[6]

While the cement proportion is elevated, the overall volume of material required per component is often significantly reduced. 3DCP enables geometrically optimized designs, such as hollow or ribbed structures that use far less concrete than conventional cast elements. As a result, the total cement consumption per project can be lower, helping offset the mix's higher concentration. This material efficiency translates into a reduced carbon footprint when assessed at the building or system level. Moreover, ongoing advances in printable low-carbon mixes and binder technologies continue to improve the sustainability profile of 3D printed concrete.

Digital tectonics and design expression

The potential of 3DCP inspires a rethinking of architectural design principles and tectonic expression. Parametric and organic shapes and structurally optimized designs become achievable, enabling novel aesthetic outcomes.[7]

The inherent layering process of 3DCP introduces a new tectonic language in architecture. Designers can use the exposed stratification and layering patterns as expressive tools, giving buildings distinct identities. This method enables an honest expression of materiality and construction process, aligning with contemporary architectural trends that focus on authenticity in materials and processes.[8] 3DCP inherently facilitates the expression of bespoke textures and patterns within the fabrication process. Controlled layer deposition creates stratified effects, while varying the extrusion path produces raised patterns, enhancing the tactile and visual qualities of concrete surfaces. This capability contrasts with traditional methods, which inevitably require additional preparation and finishing steps to achieve similar results.[9]

The precision and versatility of 3DCP make it especially ideal for custom-designed projects such as facades, urban furniture, and sculptural installations. A compelling example is Tor Alva, the world's tallest 3D concrete printed tower, designed by ETH Zurich

3D concrete printing (3DCP) layer merging.

and built in the Swiss Alps. The project demonstrates how 3DCP enables expressive architectural forms, such as twisted geometries and perforated surfaces, that would be prohibitively complex using traditional construction methods.[10]

Optimization and productivity gains

Integrating 3DCP into the construction sector has introduced significant productivity, cost efficiency, and construction logistics advances. By enabling direct fabrication from digital models, 3DCP eliminates the need for traditional formwork, a process representing up to 50 percent of total costs in conventional concrete construction. This transition lowers the material demands and the substantial workforce typically required for casing assembly and disassembly, which is especially pertinent considering the skilled labor shortage in the construction industry.[11]

The automation of the printing process facilitates continuous, precise, and repeatable fabrication. This reduces human error and increases overall productivity while maintaining the possibility of custom pieces and small production runs. This is especially beneficial on construction sites where timelines and workforce availability are constrained. Additionally, the elimination of manual formwork allows for faster lead times between design and production and mitigates delays associated with conventional construction sequencing. [12]

Moreover, eliminating casing contributes significantly to waste reduction, particularly in the context of custom architecture. While standard and linear formwork systems can often be reused across multiple projects, the growing demand for distinctive architectural forms frequently requires custom molds that are typically used only once. These bespoke formworks are rarely repurposed and often end up as waste, especially when made from plywood or expanded polystyrene. In such cases, 3DCP provides

A bio-concrete (patent pending) prototype.

a highly efficient alternative by enabling the direct fabrication of complex geometries. This not only reduces construction waste but also avoids the environmental impact of over-dimensioned components, which have cascading environmental impacts throughout a building's lifecycle.[14] The precision of robotic printing further improves build quality and reduces the need for rework onsite, thereby minimizing resource consumption.

Beyond reducing labor and construction time, 3DCP, therefore, significantly improves material efficiency by enabling the fabrication of geometrically optimized components. For example, topology-optimized slabs, columns, and beams can be produced using minimal material while maintaining or enhancing structural performance.[14]

Today, applications range from residential housing and smaller architectural elements to large-scale commercial projects. These include prefabricated structural walls, hollow columns with internal post-tensioning, and complex hybrid components that serve both structural and architectural roles.

A hybrid approach is emerging as the most practical route for large-scale adoption, combining the geometric freedom of 3D printing with traditional construction techniques. By using additive manufacturing for optimized forms and integrating conventional reinforcement where necessary, the industry can achieve both material savings and structural reliability.[15] 3DCP enables hollow forms, strategic material placement, and structural reinforcement through infill patterns. It also supports embedded features such as pockets for lost formwork, onsite casting zones, and seamless integration with reinforcing bars.

Material challenges in cold climates

Current state of materials in the American market

The North American market for 3DCP is currently expanding, with several local companies developing proprietary mixes tailored to their specific printing systems. However, manufacturers such as Sika and Mapei also provide ready-to-use premixes adapted to the demands of additive manufacturing.

The cold climate in many northern states poses additional material challenges. Printable concrete must demonstrate freeze-thaw resistance and maintain mechanical integrity under severe winter conditions. While manufacturers often claim high structural performance, including compressive strengths exceeding 30 MPa (4.35 ksi), many commercially available mixes still lack formal testing according to ASTM/ACI standards, particularly regarding fire resistance and durability under freeze-thaw cycles.[16] The complexity of 3DCP introduces another key issue: high sensitivity to variations in mix composition. Even minor deviations in water content, admixtures, or curing conditions can lead to significant impacts on printability and structural performance. These inconsistencies pose operational risks and highlight the critical importance of locally produced, quality-controlled mixes.

Toward more sustainable and high-performance building materials

When cured and cut, layers in 3DCP typically show no visible seams, except for traces left by cutting tools. The use of fine aggregates 0 to 2 mm (0 to 0.08 in.) in 3DCP significantly enhances mechanical properties, allowing compressive strength to reach approximately 50 MPa (7.25 ksi), which is almost double the strength of conventional foundation concrete.[17]

The construction industry is actively seeking innovative solutions to reduce its carbon footprint by developing more environmentally responsible materials. Among these efforts, the author's company has developed a bio-concrete with the capacity to capture 348 kg (767 lb) of CO2 per square meter, a significant improvement compared to traditional concrete mixes. It is best suited for non-structural applications and used for its isolation properties.[18]

Internationally, the use of natural materials such as clay and earth in 3D printing has gained traction as a low-impact alternative. In the United States, the practice has been notably advanced by Rael San Fratello, whose research explores large-scale 3D printing with regionally sourced soils. Through projects such as Mud Frontiers, they demonstrate how locally sourced materials and robotic fabrication can merge to produce affordable, biodegradable structures that are both environmentally responsive and culturally rooted, offering a sustainable pathway for construction in arid and rural regions.[19]

The Gramazio Kohler Research group is also exploring similar directions with its "Impact Printing" method—a gravity-driven additive construction process that uses clay instead of concrete. By eliminating the need for formwork, binders, and energy-intensive hardening processes, this technique drastically lowers the environmental impact of fabrication. Impact Printing allows for high levels of geometrical freedom, is reversible (since clay is reusable), and offers true circularity in construction workflows.[20]

In addition to structural applications, ceramic 3D printing is becoming a medium for aesthetic and cultural innovation. Studio RAP (Netherlands) exemplifies this approach with its "New Delft Blue" project, which combines algorithmic design and robotic 3D printing to create custom ceramic facade tiles inspired by traditional Dutch craftsmanship. The process minimizes waste and allows for local, small-batch fabrication using naturally derived materials.[21]

Technical aspects and regulatory framework

Reinforcement integration and structural performance in 3D printing

One of the critical technical challenges in 3DCP is the integration of reinforcement within printed structures. Unlike traditional concrete construction, where reinforcement bars are embedded in cast elements, 3DCP must contend with the layering process, which often restricts the direct integration of rebar. Researchers such as Silveira *et al.* (2024) have explored methods such as incorporating vertical reinforcement cages post-printing or developing interlocking geometries to improve cohesion between layers. Their experiments demonstrated that properly reinforced 3D printed walls under axial compression can achieve structural behavior comparable to traditional systems, provided the interface between layers and reinforcement is adequately managed.

3D printed 2.4-m (8-ft) column.

Segmentation and assembly.

Wagner *et al*. (2024) further emphasize the importance of rethinking the structural design paradigm. Rather than attempting to replicate monolithic concrete behavior with inferior layer adhesion, 3DCP allows for more efficient shell and arch-like structural logic using high-performance concrete mixes. This shifts the focus from over-dimensioned solid concrete elements to thin-walled structures where strength derives from geometry and material quality, not mass. However, such optimization requires engineers to familiarize themselves with digital fabrication workflows, parametric modeling, and the non-uniform behavior of layered materials.[22]

To illustrate, a typical 3D-printed wall composition might involve a double-skin concrete extrusion with an internal cavity for insulation or reinforcement. Post-tensioning, short-fiber additions, or metal rods inserted between layers are among the methods being tested for load-bearing performance.[23] These developments demand new competency from structural engineers, who must assess printed components not as conventional masses of concrete but as engineered shells with differentiated mechanical behavior.

Building codes and regulatory challenges

The adoption of 3DCP in the construction industry remains constrained by the absence of standardized testing protocols and formal recognition within building codes.

To support wider adoption, building codes must evolve to reflect the specific mechanical behavior of printed elements, particularly their anisotropic properties, the bond strength between layers, and alternative reinforcement strategies. Without dedicated provisions for these features, 3D-printed components remain difficult to certify under existing structural design standards. ISO/ASTM 52939:2023, *Additive Manufacturing for Construction—Qualification Principles—Structural and Infrastructure Elements*, offers an initial framework to address some of these challenges. The standard sets out quality assurance principles for non-metallic additive construction processes and applies to both load-bearing and non-load-bearing elements in residential and commercial construction projects.[24] It emphasizes the control of process conditions and quality-relevant parameters on-site to promote safe and consistent practices in large-scale 3D printing.

Continued efforts are required to adopt such standards to national contexts and align them with evolving building codes, enabling the broader industrial deployment of 3D printing technologies in construction. The *International Residential Code* (*IRC*) included an Appendix titled 3D-Printed Building Construction in 2021, but added an exception to the use of concrete in 2024.[25,26] Appendices are only enforceable when the jurisdiction that adopted the model code explicitly adopts the appendix by name in the adopting legislation or administrative rule.

Conclusion

The next steps in advancing concrete 3D printing will focus on improving reinforcement strategies, refining printable material formulations, and expanding on-site capabilities. These developments will be instrumental in transitioning additive manufacturing from a niche technology to a widely adopted construction method.[27]

Research and development are central to this transition. Standardized testing for fire resistance, freeze-thaw durability, and mechanical performance must be developed and validated under colder climatic conditions. The lack of such data currently impedes regulatory approval, even as early results demonstrate that printed structures can meet or exceed traditional benchmarks when properly designed and reinforced.[28]

To accelerate adoption, a focus on prefabrication aims to integrate this technology progressively into existing workflows. 3DCP components can already be integrated into diverse building types, from multi-family residential projects to hotels, museums, and retail spaces, as soon as today.[29] However, scaling its impact will require several key steps: the development of national certification pathways for 3D-printed elements, the promotion of pilot projects in collaboration with municipalities, and stronger partnerships between academia, industry, and regulators. With these in place, 3DCP could become a cornerstone of U.S.'s low-carbon, high-efficiency buildings, transforming how we build and define architectural and structural standards in the 21st century.

Notes

See resources/notes online at constructionspecifier.com/3D-printed-concrete

additional information

AUTHOR

Gabrielle Nadeau, M.Arch, is a project manager at Medusia. She oversees product development and marketing strategy, focusing on advancing 3D printing technology and its applications. Her work in AI explorations and 3D modeling enhances Medusia's creative approach, bringing fresh, tailored solutions that resonate with both functionality and design innovation.

KEY TAKEAWAYS

3D concrete printing (3DCP) is transforming construction by enabling complex, customized structures without traditional formwork. It enhances material efficiency, reduces waste, and supports the use of low-carbon concrete alternatives. By integrating digital design, robotic automation, and modular construction, it offers a more sustainable and efficient building method. Continued innovation in materials and updates to regulatory frameworks are essential for broader industry adoption.

MASTERFORMAT NO.

03 00 00—Concrete
03 37 00—Specialty Placed Concrete

UNIFORMAT NO.

B20—Exterior Vertical Enclosures
B2010—Exterior Walls

KEYWORDS

Division 03
3D printed concrete

The Evolution of Construction Scheduling in the Design-build Era

By Nitin Bhandari

IMAGE GENERATED BY CHATGPT/DALL-E, OPENAI

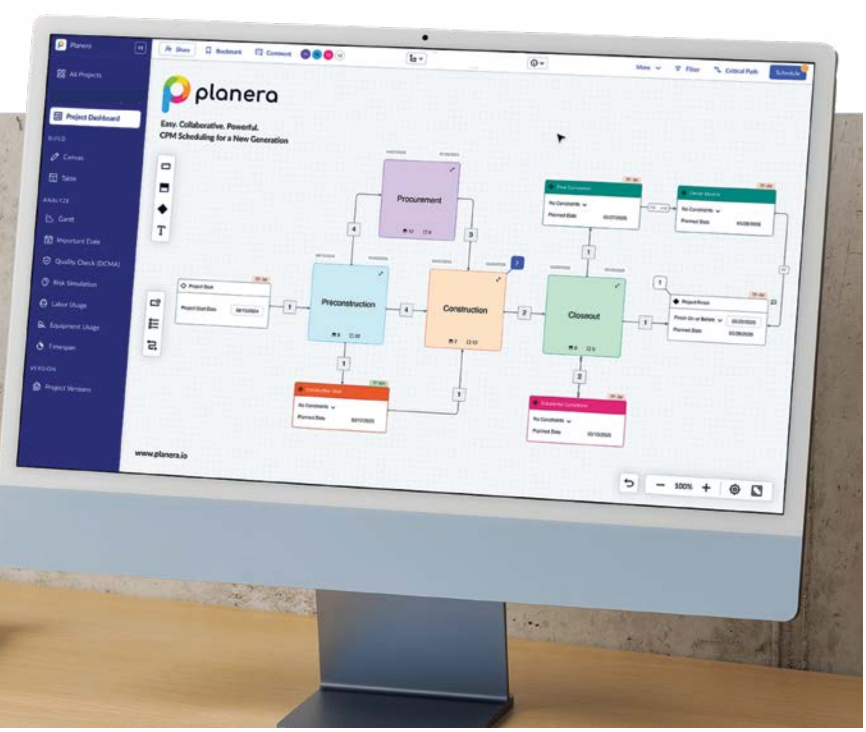
The construction industry is undergoing a significant transformation, particularly in project scheduling. Traditionally, scheduling was the domain of a select few specialists, often using general-use tools such as Microsoft Excel or complex software such as Primavera P6. However, the rise of design-build construction and the advent of more intuitive, collaborative scheduling tools are democratizing this crucial aspect of project management. This shift is not just a change in technology; it represents a fundamental reimagining of how construction projects are planned and executed.

The traditional scheduling paradigm

For decades, construction scheduling has been the purview of dedicated schedulers. While schedulers have used Excel for simpler projects, for more sophisticated projects, these experts have often turned to cumbersome software tools. Primavera P6, the industry standard for many years, epitomizes this approach. While powerful, P6 has a steep learning curve, effectively creating a "high priesthood" of schedulers who alone could navigate its complexities.

This siloed approach to construction scheduling had several drawbacks:

- Limited input—Only a small group could contribute to the schedule, potentially missing valuable insights from other team members.
- Communication barriers—The complexity of the schedules often made them difficult for non-specialists to understand and use effectively.
- Inflexibility—Updating construction schedules was time-consuming, making it challenging to adapt to the rapid changes common in construction projects.
- Resource inefficiency—The reliance on specialized schedulers often led to bottlenecks in the planning process, as these individuals became overloaded with work.



The design-build model thrives on input from various team members, each bringing unique expertise and perspective to the planning process.

PHOTOS COURTESY PLANERA

- Disconnect from field realities—Schedulers, often working in isolation, might not have the most up-to-date information from the construction site, leading to schedules that did not always reflect real-world conditions.

While functional for many years, the traditional paradigm increasingly struggled to keep pace with the evolving needs of modern construction projects, especially as these projects grew in complexity and scale.

The rise of design-build and its impact on scheduling

The design-build model has gained significant traction in recent years, fundamentally changing how construction projects are approached. This integrated method, where design and construction services are contracted by a single entity, emphasizes collaboration and teamwork. Key aspects of design-build that influence scheduling:

- Concurrent processes—Design and construction phases often overlap, requiring more flexible and responsive scheduling.
- Team integration—Designers, contractors, and other key stakeholders work closely together from the project's initial inception.
- Shared responsibility—All team members have a stake in the project's success, encouraging more collaborative decision-making.
- Streamlined communication—With a single point of responsibility, information flows more freely between all parties involved.
- Faster project delivery—The overlapping of design and construction phases often results in shorter overall project timelines.

This collaborative environment naturally calls for a more inclusive approach to scheduling. The design-build model thrives on input from various team members, each bringing unique expertise and perspective to the planning process.

The shift in project dynamics

The design-build approach has necessitated a shift in how project teams interact and make decisions. In this model, early collaboration between designers and builders is crucial. This early integration allows for more informed decision-making about project timelines, as constructability issues can be addressed during the design phase.

For scheduling, this means input is needed from a broader range of stakeholders much earlier in the project lifecycle. Architects, engineers, contractors, and even key subcontractors may all have valuable insights that can influence the project schedule from the outset.

The emergence of collaborative scheduling tools

Responding to the needs of the design-build era, a new generation of scheduling tools has emerged. These platforms are designed to be both powerful and user-friendly, enabling a wider range of team members to participate in the scheduling process. Characteristics of these new tools include:

- Visual interfaces—Intuitive, often whiteboard-like interfaces make it easier for non-specialists to understand and contribute to schedules.
- Real-time collaboration—Multiple team members can work on the schedule simultaneously, fostering better communication and alignment.
- Accessibility—Cloud-based solutions allow access from anywhere, facilitating input from diverse team members regardless of location.
- Integration capabilities—These tools often integrate with other construction technology solutions, making it easier to share information between them.
- Customizable views—Users can often switch between different schedule representations (Gantt charts, calendars, etc.) to suit their preferences and needs.

Key benefits of collaborative scheduling in complex design-build projects

The shift towards more inclusive scheduling practices brings several significant benefits to design-build projects:

Enhanced accuracy

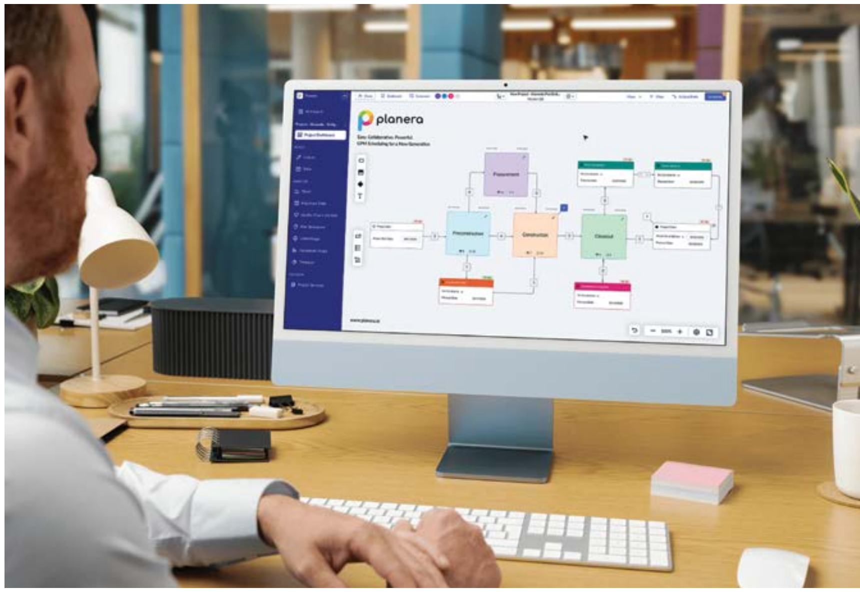
When more team members contribute to the schedule, it becomes more comprehensive and realistic. Each participant brings their specific technical expertise, whether it is a designer's insight into the time needed for certain design elements or a subcontractor's knowledge of material lead times.

Improved efficiency

Collaborative scheduling allows for the early identification of potential conflicts or inefficiencies. By involving various stakeholders from the outset, teams can more effectively optimize the sequence of activities and resource allocation.

Greater buy-in and accountability

When team members are involved in creating the schedule, they are more likely to feel ownership of the plan and commit to its execution. This increased buy-in can lead to better adherence to timelines and more proactive problem-solving when issues arise.



Responding to the needs of the design-build era, a new generation of scheduling tools has emerged. These platforms are designed to be both powerful and user-friendly, enabling a wider range of team members to participate in the scheduling process.

Visual, easy-to-understand schedules make it easier to keep clients informed about project progress. This transparency can lead to better client relationships and fewer misunderstandings about project timelines.

Faster response to changes
The collaborative nature of these new tools allows for quicker updates to the schedule when changes occur. This agility is particularly valuable in the fast-paced, often unpredictable environment of construction projects.

Better risk management
With diverse perspectives contributing to the schedule, potential risks are more likely to be identified early. This allows for proactive risk mitigation strategies to be incorporated into the project plan.

Improved client communication
Visual, easy-to-understand schedules make it easier to keep clients informed about project progress. This transparency can lead to better client relationships and fewer misunderstandings about project timelines.

Enhanced learning and knowledge transfer
Collaborative scheduling creates opportunities for less experienced team members to learn from seasoned professionals. This knowledge sharing can help build organizational capacity and improve future project planning.

Implementing collaborative scheduling: Challenges and solutions

While the benefits of collaborative scheduling are clear, implementing this integrated approach comes with its own set of challenges:

Resistance to change
Some seasoned professionals may be hesitant to adopt new tools and processes, especially if they have been using traditional scheduling methods for years.

Solution: Gradual implementation and comprehensive training can help ease the transition. Demonstrating the tangible benefits of the new approach through pilot projects can also help win over skeptics. It is crucial to involve key stakeholders in the selection and implementation process to ensure buy-in.

Maintaining schedule integrity
With more people contributing to the schedule, there is a risk of introducing errors or inconsistencies. Implement clear protocols for schedule changes and use software features that track revisions and allow for easy rollbacks if needed. Designate a schedule manager to oversee the overall integrity of the plan. Regular schedule reviews and audits can help maintain accuracy and consistency.

Balancing input
While collaboration is valuable, there is a risk of "too many cooks in the kitchen," which can lead to inefficient decision-making processes.

Clearly define roles and responsibilities in the scheduling process. Use collaborative tools to facilitate structured input, such as comment periods or review cycles, rather than allowing constant changes. Implement a clear approval process for major schedule modifications.

Integration with existing systems
New scheduling tools need to work alongside other software used in the project management process.

Choose scheduling tools that offer robust integration capabilities. Work with IT teams to ensure smooth data flow between systems. If direct integrations are not available, consider using middleware solutions. Regularly test and validate data consistency across platforms.

The future of construction scheduling is not just about better software; it is about fostering a culture of collaboration and continuous improvement.
IMAGE GENERATED BY CHATGPT/DALL-E, OPENAI

Data security and privacy
Concerns about data security and privacy may arise with cloud-based collaborative tools, especially when working on sensitive projects.

Carefully vet potential software providers for their security measures. Implement strong access controls and data encryption. Educate team members about best practices for data protection.

Collaborative scheduling in action

To illustrate the impact and results of collaborative scheduling in a design-build environment, consider this hypothetical case study.

A large commercial construction project in Seattle was facing challenges with traditional scheduling methods. The general contractor developing this 20-story mixed-use building was concerned that their schedule would slip, so the project manager decided to implement a collaborative scheduling approach using a visual, team-oriented tool.

Results:

- The initial schedule creation time was reduced by 40 percent due to simultaneous input from various team members.
- Early involvement of subcontractors led to the identification of a potential material shortage, allowing the team to adjust the schedule and avoid a three-week delay.
- The visual nature of the tool helped the client better understand the project timeline, leading to more informed decisions about phasing and occupancy.
- Mid-project changes were incorporated 60 percent faster than with the previous system, keeping the project on track despite unexpected design modifications.
- Overall project delivery was accelerated by 15 percent compared to similar previous projects, largely due to improved coordination and proactive problem-solving.
- The project team reported higher satisfaction and engagement levels, citing improved communication and a clearer understanding of project goals and timelines.

This case demonstrates how collaborative scheduling can lead to tangible improvements in project outcomes, from time savings to enhanced team dynamics.

The future of construction scheduling

As the construction industry continues to evolve, expect further advancements in collaborative scheduling:

- AI and machine learning—These technologies could offer predictive scheduling capabilities, learning from past projects to suggest optimal timelines and resource allocation. AI might also assist in risk assessment, flagging potential schedule conflicts or delays based on historical data.
- Increased integration—Scheduling tools will likely become more tightly integrated with other aspects of project management, including Building Information Modeling (BIM) and financial systems. This integration could allow for real-time cost tracking and automated schedule updates based on design changes.
- Virtual and augmented reality—These technologies could provide immersive ways to visualize and interact with project schedules, further enhancing understanding and collaboration. VR walkthroughs synchronized with the project schedule could allow teams to visualize the construction sequence in a highly intuitive manner.

product spotlight

- Mobile-first approaches—As construction becomes more decentralized, mobile-friendly scheduling tools will become increasingly important for real-time updates and communication. Field personnel could update progress directly from the construction site, ensuring the schedule always reflects current conditions.
- IoT devices and sensor integration—Internet of Things (IoT) devices and sensors on the construction site could automatically update the schedule based on real-time progress, weather conditions, or material deliveries.
- Blockchain for schedule verification—Blockchain technology could be used to create tamper-proof records of schedule changes and approvals, enhancing accountability and providing a clear audit trail for complex projects.
- Sustainability integration—Future scheduling tools may incorporate sustainability metrics, allowing teams to optimize schedules not just for time and cost, but also for environmental impact.

Conclusion

The shift towards collaborative scheduling in design-build projects represents a significant step forward for the construction industry. By breaking down the silos that have long surrounded the scheduling process, teams can create more accurate, efficient, and adaptable project timelines.

The key to success in this new paradigm lies in embracing tools and processes that facilitate true collaboration. As more projects adopt this approach, expect to see improvements in project outcomes, from better on-time delivery to more efficient resource utilization.

For design-build teams looking to stay competitive in an evolving industry, adopting a collaborative approach to scheduling is no longer just an option—it is becoming a necessity. By doing so, they can harness the collective expertise of their teams, leading to more successful projects and a more dynamic, responsive construction industry as a whole.

The future of construction scheduling is not just about better software; it is about fostering a culture of collaboration and continuous improvement. As the industry continues to face challenges such as skilled labor shortages, sustainability requirements, and increasingly complex projects, the ability to plan and execute efficiently will be more critical than ever.

By embracing collaborative scheduling, construction teams can position themselves at the forefront of industry innovation, ready to tackle the challenges of tomorrow's built environment. The journey towards fully integrated, collaborative project management may be challenging, but the potential rewards, in terms of project success, team satisfaction, and industry advancement, make it a path well worth pursuing.

additional information

AUTHOR

Nitin Bhandari is the co-founder and CEO of Planera, where he is democratizing construction Critical Path Method (CPM) scheduling with a collaborative, visual software solution. Bhandari's leadership at Planera builds on more than two decades of experience in tech innovation. He co-founded Skyfire, which was acquired by Opera in 2013, where he served as SVP and GM, overseeing operator business and new products. He also co-founded Zenlabs, later acquired by Life360, where he led strategic initiatives, including product integrations with Google and Amazon. With an MS in electrical engineering from Caltech and a rich background in both enterprise and consumer tech, Bhandari continues to drive impactful technological solutions that address real-world challenges.

KEY TAKEAWAYS

Project scheduling in construction is becoming more collaborative, moving away from specialist-only tools such as Primavera P6. Driven by design-build models and user-friendly platforms, teams now contribute in real time, improving accuracy, efficiency, and responsiveness. These tools support better communication, faster updates, and increased accountability—making collaborative scheduling essential for modern, agile construction projects.

MASTERFORMAT NO.

01 31 00—Project Management and Coordination
01 31 13—Project Coordination

UNIFORMAT NO.

A1010—Project Delivery
A1020 – Project Scheduling and Sequencing

KEYWORDS

Division 01
Collaboration
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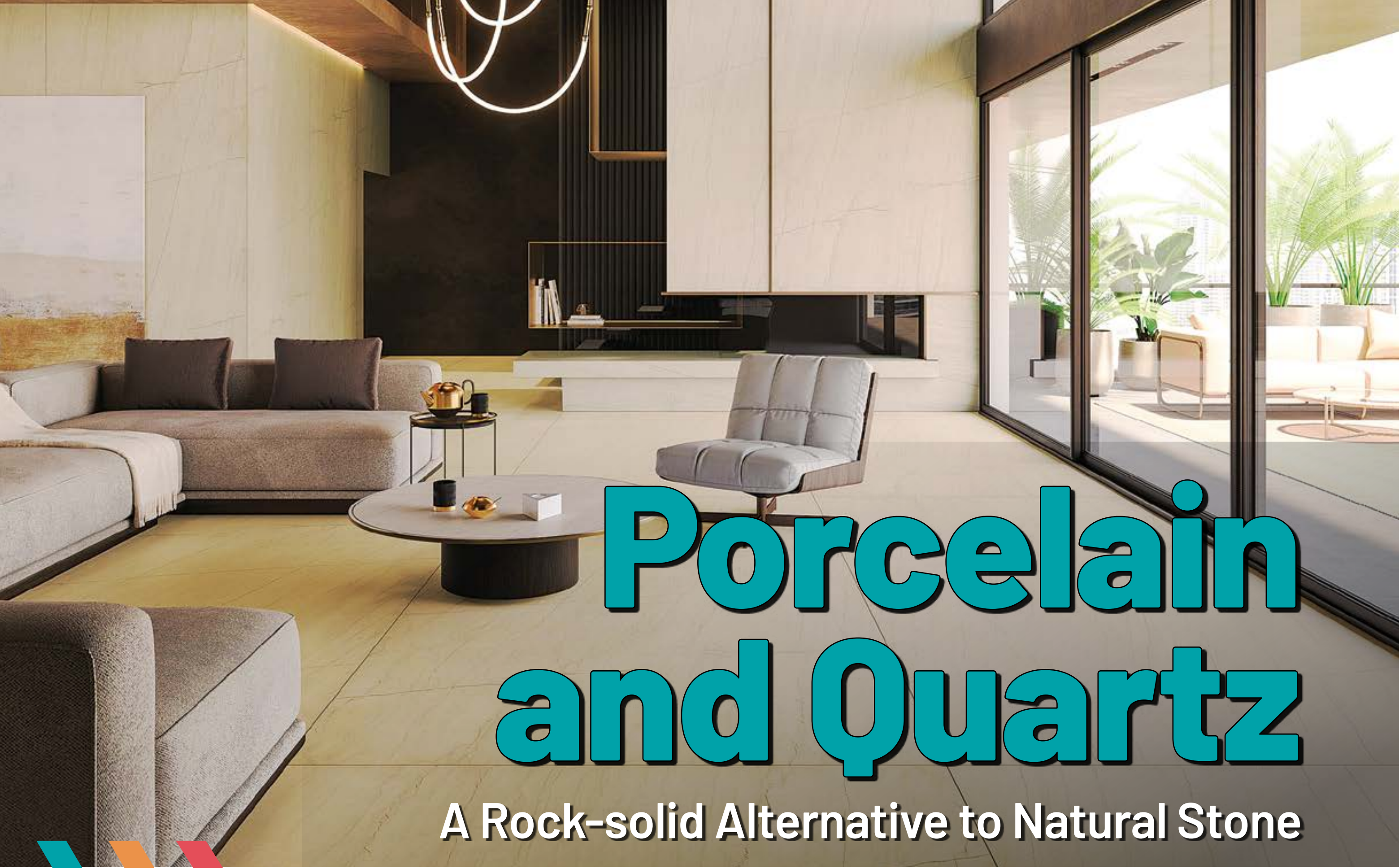


Porcelain and Quartz

A Rock-solid Alternative to Natural Stone

By Matt DiNorcia

PHOTOS COURTESY UMI STONE

As contemporary architecture continues to push design boundaries, innovations in masonry materials such as porcelain and engineered quartz are reshaping the creative possibilities. Thanks to manufacturing innovations and material advances that produce more colors, finishes, and larger slab sizes, architects and designers now have greater creative freedom in where and how they incorporate these masonry elements.

Beneath the surface

Porcelain and engineered quartz each possess characteristics that make them ideally suited for virtually any commercial application that requires a durable, attractive, and easy-to-maintain surface.

Porcelain is made from a blend of natural clay and minerals fired at extremely high temperatures. This intense firing process creates a dense, non-absorbent material resistant to moisture, stains, and scratches. Compared to natural stone, which is porous and requires sealing and long-term care, porcelain is considered non-porous and does not require these extra steps. Since porcelain can be manufactured to look like natural stone, it is a popular alternative, especially for exterior projects exposed to natural light and areas subject to high heat.

Engineered quartz is a manufactured material that contains natural quartz. Natural quartz is a hard, crystalline mineral made of silicon dioxide. Manufacturers combine 90 to 95 percent crushed natural quartz with five to 10 percent resins, polymers, and pigments to create highly durable slabs in a variety of colors and patterns. The resin content of engineered quartz provides slight flexibility that reduces the risk of cracking, while the quartz ensures a hard-wearing, resilient surface. Like porcelain, engineered quartz can mimic the look of natural stone, but it is less heat resistant than porcelain.

Seamless looks from floor to ceiling

When selecting masonry materials for a project, architects and designers weigh several factors.

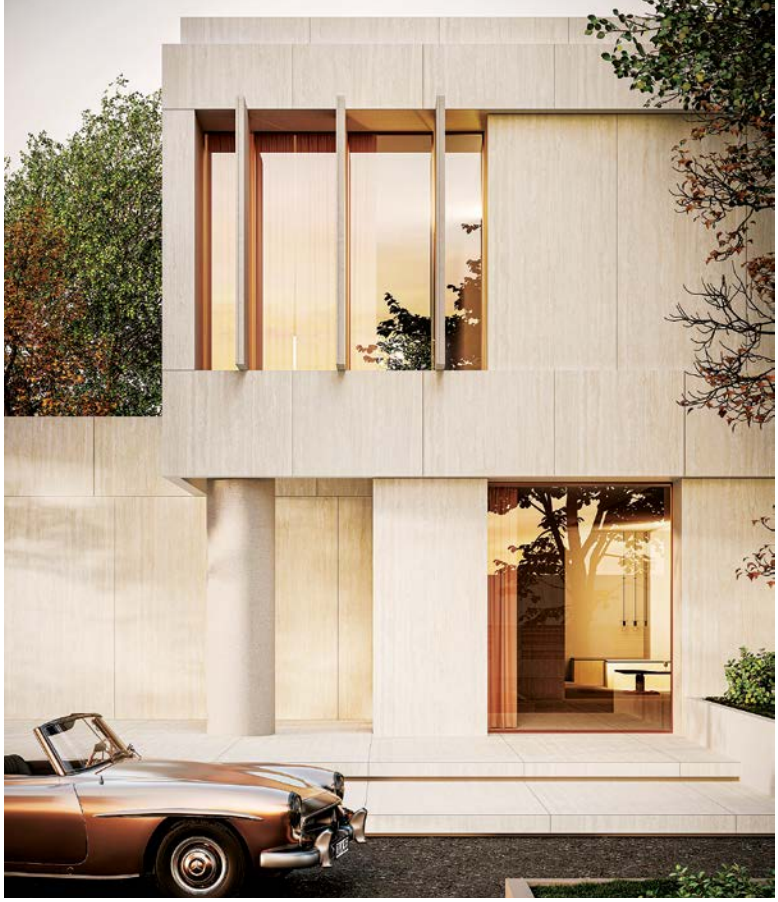
First is aesthetics, and porcelain and engineered quartz are highly versatile when it comes to design. Not only do they offer their innate visual qualities, but they can also mimic the appearance of other masonry materials. Advances in printing technology, for instance, can now render high-definition images and textures, enabling remarkable realism. Likewise, extra-large slabs can replicate the look of marble or other natural stone with uninterrupted veining patterns.

Designers can further customize their visions, choosing from dozens of colors plus a variety of finishes from matte and glossy to textured, polished, honed, or brushed surfaces.

A second consideration for selection is where the material will be used. Popular applications of porcelain and/or engineered quartz slabs include:

- High-traffic flooring—Found in shopping malls, airports, office lobbies, and hotels, porcelain is a great option that delivers attractive options with durability and easy maintenance.
- Wall cladding and feature walls—In corporate buildings, retail stores, and luxury residences, both materials are used to create sleek, seamless facades and interior decorative elements.
- Countertops and work surfaces—Porcelain and engineered quartz are common in restaurants, hotels, and commercial kitchens where hygiene, stain resistance, and long-term durability are key considerations.
- Reception desks and conference tables—Frequently incorporated into office and hospitality settings, these materials offer aesthetic appeal and long-term wear resistance.
- Vanities and shower walls—Large slabs are ubiquitous in commercial restrooms and hotel bathrooms due to fewer seams, moisture resistance, and easy upkeep.
- Exterior facades—Porcelain is the choice for office buildings, hotels, and mixed-use developments where weather resistance and UV stability are important.
- Outdoor dining and entertainment spaces—Used in patios, countertops, and bar areas, porcelain slabs stand up to the elements with high heat tolerance and UV resistance.
- Hospitality and retail displays—Applied in luxury retail counters, shelving, and boutique storefronts, both materials are visually versatile and customizable.

One reason porcelain and engineered quartz have gained popularity in these applications is that manufacturers now produce slabs in larger sizes. Engineered quartz, for example, is available in jumbo slabs that measure around 1,651 x 3,302 mm (65 x 130 in.) and super jumbo slabs of about 1,981 x 3,505 mm (78 x 138 in.). These larger slabs have earned favor because they allow designers to create monolithic surfaces with notably fewer visible seams or no seams. Larger slabs require less installation labor and are often more readily available than natural stone alternatives.



The UV-resistance and durability of porcelain make it a popular choice for exterior cladding that lasts long and will not yellow.

Other qualities that make porcelain and engineered quartz attractive for commercial applications include:

Resistance to chipping and cracking

Some natural stone materials, such as marble and travertine, are softer or naturally porous, making them more susceptible to chipping and cracking if not carefully handled or properly treated. Porcelain and engineered quartz are highly durable and can be more forgiving during fabrication, installation, and daily use. When tested to EN ISO 10545-5, porcelain demonstrates an average impact resistance value greater than 0.85. Quartz is tested to ASTM C1870-18, with typical results showing an indentation depth of ≤ 6.35 mm (0.25 in.) from a 914-mm (36-in.) ball drop and ≤ 6.8 mm (0.27 in.) from a 1,219-mm (48-in.) ball drop.

Stain and scratch resistance

Both porcelain and engineered quartz excel in stain and scratch resistance, making them ideal for high-use surfaces. Porcelain's non-porous nature ensures that spills, even from coffee or wine, do not penetrate the surface, making it perfect for countertops, work surfaces, vanities,

Porcelain slabs like this surface look like natural stone and offer minimal seams and waterproof performance ideal for bathroom applications.

and outdoor dining areas. When tested to EN ISO 10545-6, porcelain demonstrates an average abrasion volume loss of less than 145 mm^3 (0.00885 in^3)—well below the 175 mm^3 (0.01067 in^3) threshold set by EN 14411 Group G. Its stain resistance also earns a rating of Class 5 when tested to EN ISO 10545-14, indicating excellent protection against common staining agents.

Engineered quartz, with its dense and durable composition, also resists everyday wear and tear, maintaining its smooth and polished appearance even in busy spaces. It achieves a Mohs hardness rating of ≥6 when tested to EN 101:1991, demonstrating strong scratch resistance. Regarding stain performance, quartz earns a Class A rating under ASTM C1378-04:2014 (polished finish), indicating high resistance to household stains.

Heat resistance

Porcelain is highly heat-resistant, withstanding temperatures up to 650 C (1,200 F) in real-world applications. This makes it ideal for fireplace surrounds, outdoor kitchens, and countertops near high-heat appliances. It passed EN ISO 10545-9 thermal shock testing with no visible damage, confirming its stability under rapid and extreme temperature changes.

Engineered quartz, while offering moderate heat resistance, is not heatproof. Manufacturers generally advise quartz surfaces can withstand up to 150 C (300 F) for short durations. Exposure to temperatures exceeding this range, especially from hot pots or pans placed directly on the surface, can lead to discoloration, cracking, or other forms of damage due to the resin components in quartz. To preserve the integrity and appearance of quartz countertops, it is recommended to always use trivets or heat pads under hot cookware.

Long-term durability and maintenance

Porcelain and engineered quartz slabs are ultra-dense and only need basic cleaning to maintain their appearance. Compared to a natural stone (*e.g.* granite) that requires periodic sealing to prevent staining and etching, porcelain and engineered quartz offer hassle-free solutions with minimal care.

UV sensitivity

For exterior projects exposed to UV light, porcelain is a clear winner, as it remains color-stable even in outdoor settings. Natural stone can also perform well outdoors; however, some varieties use resin to smooth rough surfaces, and that resin may yellow over time with prolonged sun exposure. Engineered quartz, while durable indoors, is not suitable for exterior use. Its resin binders can begin to yellow in as little as six to 12 months when exposed to direct sunlight, with discoloration becoming more pronounced over time, especially in lighter colors.

Cost

Porcelain and engineered quartz offer a variety of price points, providing options for different budgets. Natural stone also varies in cost, with some varieties being relatively budget-friendly and others, particularly exotic marbles and quartzites, commanding premium prices.

The balance of beauty, performance, and customization makes porcelain and engineered quartz practical solutions and essential design elements in modern spaces.

Tips for choosing a manufacturer and supplier

Selecting a quality porcelain or engineered quartz manufacturer and a dependable supplier is crucial for ensuring material consistency and reliable availability. Questions to ask and qualities to look for in a manufacturer and supplier should include:

Designers use quartz to create high-end looks with veining that mimics the movement of natural stone.

Lead times and available stock
A supplier with a large selection and deep inventory ensures material availability, minimizes project delays, and provides specifiers with greater flexibility in design choices.

Consistency in material quality and color batches
Verify that the manufacturer maintains uniformity in color and texture across slabs. This is especially important for large-scale commercial projects requiring multiple pieces. A supplier with deep inventory and single-source procurement by color can expedite this verification by providing side-by-side comparisons of multiple slabs in the chosen color.

Material warranty
Choose a manufacturer that offers a comprehensive warranty covering material defects, durability, and performance over time. A strong warranty protects firms and clients from unexpected replacement costs and is considered a trustworthy sign of manufacturer integrity.

Certifications for durability, safety, and sustainability
When selecting surface materials, look for third-party certifications that verify the product meets industry standards for durability, fire resistance, safety, and environmental sustainability. Important certifications include:

- ASTM C373 for water absorption and ASTM C648 for breaking strength. Both are key indicators of durability.
- For fire resistance, materials are typically classified according to ASTM E84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, which assigns a flame spread and smoke development rating. Class A is the most fire-resistant.
- NSF certification (NSF/ANSI 51 or 61) confirms the material is safe for use in commercial food preparation areas.
- GREENGUARD certification verifies the product meets strict chemical emissions limits for healthier indoor air quality.
- Declare Label participation lists ingredients and ensures the product does not contain any materials found on the Living Building Challenge Red List.

These certifications help specifiers, designers, and builders make informed decisions about materials that are high-performing, safe, and environmentally responsible.

Customer service and technical support
Seek a supplier with a reputation for offering a seamless experience from sampling to delivery. Technical documentation, fabrication guidelines, and specification and installation

figure 1

FACTOR	PORCELAIN	ENGINEERED QUARTZ	MARBLE (NATURAL STONE)	EXPLANATION
Chipping and cracking	High risk	Low risk	Moderate risk	Quartz has resin content, reducing the chances of chipping and cracking.
Stain and scratch resistance	Excellent	Excellent	Requires sealing	Porcelain and quartz are non-porous and naturally resistant to stains and scratches.
Heat resistance	Excellent	Good	Excellent	Porcelain and marble handle high heat well; quartz can be heat-sensitive.
Durability and maintenance	Low maintenance	Low maintenance	Requires sealing	Porcelain and quartz need little upkeep; marble requires regular sealing.
UV sensitivity	UV resistant	May yellow over time	UV resistant	Porcelain and marble resist fading; quartz may yellow with UV exposure.
Extra-large slab availability	Yes	Yes	Limited availability	Porcelain and quartz come in large slabs; marble sizes depend on natural stone block availability.
Material availability	Widely available	Widely available	Varies by quarry	Porcelain and quartz are mass-produced; marble depends on quarry output.

assistance should also be part of the relationship to ensure proper material handling and application of the product.

Working with a reliable manufacturer and supplier helps ensure the material consistency and long-term performance of porcelain and engineered quartz slabs. As the industry evolves, new manufacturing techniques and innovations will only enhance these materials, making them even more valuable in modern masonry and architectural design.

Environmental stressors and material performance

Masonry materials are subjected to various environmental stressors that can impact their appearance and performance. See Figure 1 for a look at how porcelain, engineered quartz, and natural stone such as marble perform under these conditions. Cost is removed from the table because it can vary so widely with natural stone. It is tough to categorize marble as always more due to market-specific factors.

additional information

AUTHOR

Matt DiNorcia is a strategic sales manager at UMI | The Source, focusing on the southeast region. He plays an integral role in shaping sales strategy and developing internal systems to optimize customer relationships and streamline operational efficiency, ensuring seamless service and growth for UMIStone.com client base.

KEY TAKEAWAYS

Porcelain and engineered quartz offer durable, low-maintenance, and versatile surfaces ideal for commercial applications like flooring, wall cladding, and countertops. Advances in large slabs and finishes provide designers greater creative freedom. Both materials resist stains, scratches, and heat, with porcelain especially suited for outdoor applications. Compared to natural stone, these materials deliver consistent quality and fewer seams. Choosing reliable suppliers ensures project success and long-term performance.

MASTERFORMAT NO.

09 30 00—Tiling
09 63 00—Stone Flooring
12 36 00—Countertops

UNIFORMAT NO.

B2010—Exterior Walls
C3010—Wall Finishes
C3020—Floor Finishes

KEYWORDS

Division 09, 12
Porcelain
Engineered quartz

It's Just Water Weight

Where roof drains are used, Section 1502 of the 2024 *International Building Code* (*IBC*) requires that secondary (emergency overflow) roof drains or scuppers be provided wherever the perimeter construction could result in water being entrapped if the primary drains are clogged or overwhelmed. Per Section 1512 and parallel language in Section 705 of the 2024 *International Existing Building Code* (*IEBC*), the same requirements apply to re-roofing projects, unless the roof is positively sloped, and an evaluation shows the roof structure can support the weight of ponding water. Further, Section 8.3 of ASCE 7-22, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, notes that low-slope roof bays shall have adequate strength and stiffness to resist progressive deflection under rain loads. A recent structural failure shows the severe consequences that can result when these requirements are overlooked.

The subject building, a one-story athletic facility, is rectangular in plan. As constructed, the roof was supported by wide-flange steel girders that supported light-gauge Z-shaped roof purlins. The roof had a low slope down from a ridgeline at its center to built-in gutters behind parapet walls at the east and west exterior sides. While the west side built-in gutter had overflow scuppers along its length, the east side lacked scuppers. Any previously existing overflow openings on the east side were blocked when a new addition was completed several years ago.

During a recent storm that produced approximately 90 mm (3.5 in.) of rain within a few hours, leaves and other plant debris clogged the roof drains within the built-in gutters. Water began to build up within the gutters. On the west side, the overflow scuppers functioned as intended to release the water. On the east side, water filled the gutter and began to accumulate across the roof. The Z-shaped purlins deflected downward under the weight of the rainwater. As the purlins deflected, the distorted shape of the roof was able to hold a greater volume of water, leading to a progressive overload of the roof structure. The weight of the water, approximately 10 kN/m^3 (64 lb/cf), was sufficient not only to sag the small Z-purlin members but also to bend the steel wide-flange girder and pull the perimeter steel-framed wall clad with brick masonry veneer out of plumb.

figure 1

figure 2

FIGURE 1: Clogged drains allowed water to pond on the roof.
PHOTOS COURTESY WISS, JANNEY, ELSTNER ASSOCIATES (WJE)

FIGURE 2: The accumulated weight of water led to severe deflection and ultimately a partial collapse of the roof structure.

Overflow drainage provisions must be considered during the design of renovations or repairs to existing structures. When roof coverings or configurations are altered, the effect on both primary drainage pathways and secondary overflow drainage needs to be addressed to avoid failure during heavy rain events. Additionally, routine maintenance and ensuring roof drains are free of debris and not clogged are essential.

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