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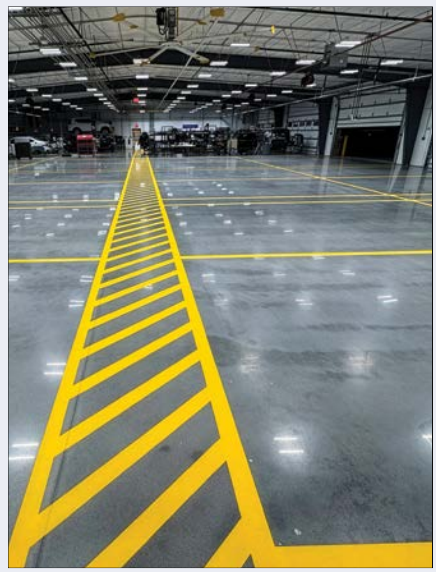

On the cover:

Concrete flooring standards are evolving as the industry shifts focus from "polished" to high-performance refined concrete. Recent debates emphasize the importance of measurable outcomes—hardness, traction, and durability—over temporary gloss. Refined concrete achieves reliable results through benchmarks and collaboration, reducing risk and costs. This approach aligns design intent with operational needs, elevating concrete to true high-performance systems.

PHOTO COURTESY NATIONAL CONCRETE REFINEMENT INSTITUTE (NCRI)

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CSI Fellows Share the Impact of Being a CSI Member

The start of a new year is an ideal opportunity to reflect on how you would like to invest in your career. Being part of CSI means you are building relationships within a community that can help you find answers faster and expand your knowledge.

Recently, we asked the 2025 class of CSI Fellows how being CSI members has informed their lives and careers.

Cam Featherstonhaugh, IV, FCSI, Lifetime Member

"It's been the single most impactful thing I've done professionally, at least from a volunteer perspective. But that volunteerism in CSI has advanced my career in ways that I could never have foreseen. The leadership experience alone gave me so many opportunities, but also the education and support helped me actually get better at my job, which my employers and colleagues have always found useful. It's a combination of nuts-and-bolts learning with leadership training that is so valuable. It allows me to keep my head in the clouds and my feet on the ground."

Randall Lewis, FCSI

"The reality that all segments of our industry are working together on equal footing to make the industry better is a bedrock principle and fits well with my service attitude. Because of this community, I have a network of trusted advisers in other fields at my fingertips."

Tom Lanzelotti, FSCI, CDT

"When I joined CSI, it was at the request of Bill DuBois. I was his buddy and mentor when he joined Gensler, and I grew to respect him as a professional and as a person. I have to say at first, I was not 100 percent on board as I took CSI for a test drive, but taking Bill's advice, I stuck with it, found my niche, and worked to make it a valuable experience. CSI has helped to put the finishing touches on me as a professional. It has filled my knowledge gaps, it has grown my network, it has given me a greater perspective, and in a nutshell, it has helped me be a better professional. CSI, in my mind, is the best professional organization for design and delivery professionals, affording the opportunity to collaborate and share a common language and vision."

Charles Hendricks, FCSI, CDT

"CSI has empowered me to be a mentor, trust in my design instincts, and value technical expertise in the construction industry. At the first National CSI Conference I attended, Bob Molseed, FAIA, FCSI, took me around and introduced me to other CSI members who greeted me, not as a young person, but as a peer in the industry I had just entered. Bob and many other CSI members taught me the importance of hearing everyone's voice around the table as an equal.

"Ray Gaines, AIA, FCSI, my first industry boss and now business partner, often said about CSI, 'If you want to see something happen, you need to put in the time to make it happen.' He encouraged me to learn leadership skills by allowing me to put time into CSI and encouraging me to take on challenges that I did not think I was ready for, such as joining the Central Virginia CSI chapter board just after graduating from the University of Tennessee.

"From being a selected speaker at National CSI conferences, to the local chapter trusting me to serve as president, to serving on a variety of local, regional, and national CSI committees, CSI has consistently shown me that they value all members of the construction industry. Each of us, no matter our level of experience or profession, is treated as an equal.

"CSI has empowered me to trust that my opinions and instincts mattered even from a young age in an industry where older voices often carry more weight. The most important lesson I have learned from CSI is that you need to build a strong network of trusted peers to advance in the industry and build a career."

CSI Membership: A New Year's Resolution You Can Keep

You've seen how CSI membership benefits CSI Fellows. Now, make a New Year's resolution that can positively impact your career. Join CSI to grow your network and knowledge, and enjoy these benefits:

- Networking opportunities by joining a local chapter near you. You also get the opportunity to attend events at other CSI chapters nationwide.
- Unlimited access to the full online archive of Tech Talks and WebReaches.
- Discounts on certification exams, study materials, events, online courses, and more.
- Professional support from fellow members via the online CSI-Connect community.

As a CSI member, you become part of a community that elevates your profession and drives innovation across the industry. Find out more at csiresources.org/joinrg/join

Refined Concrete

A Measurable Path to Performance and Sustainability

By Kristina Abrams, AIA, LEED AP, CDT, CCS, Chris Bennett, CSC, iSCS, CDT, Bill DuBois, CSI, CCS, AIA, Ken Hercenberg, Ashley Houghton, Donald Koppy, Kathryn Marek, AIA, CSI, CCCA, NCARB, SCIP, Mitch Miller, Keith Robinson, RSW, FCSC, FCSI, LEED AP, Linda Stansen, CSI, CCCA, RA, SCIP, Michael Thrailkill, AIA, CDT, NCARB, LEED AP, Vivian Volz, CSI, AIA, LEED AP, SCIP, Justin R. Wolf, Anne Whitacre, FCSI, CCS, LEED AP BD and C

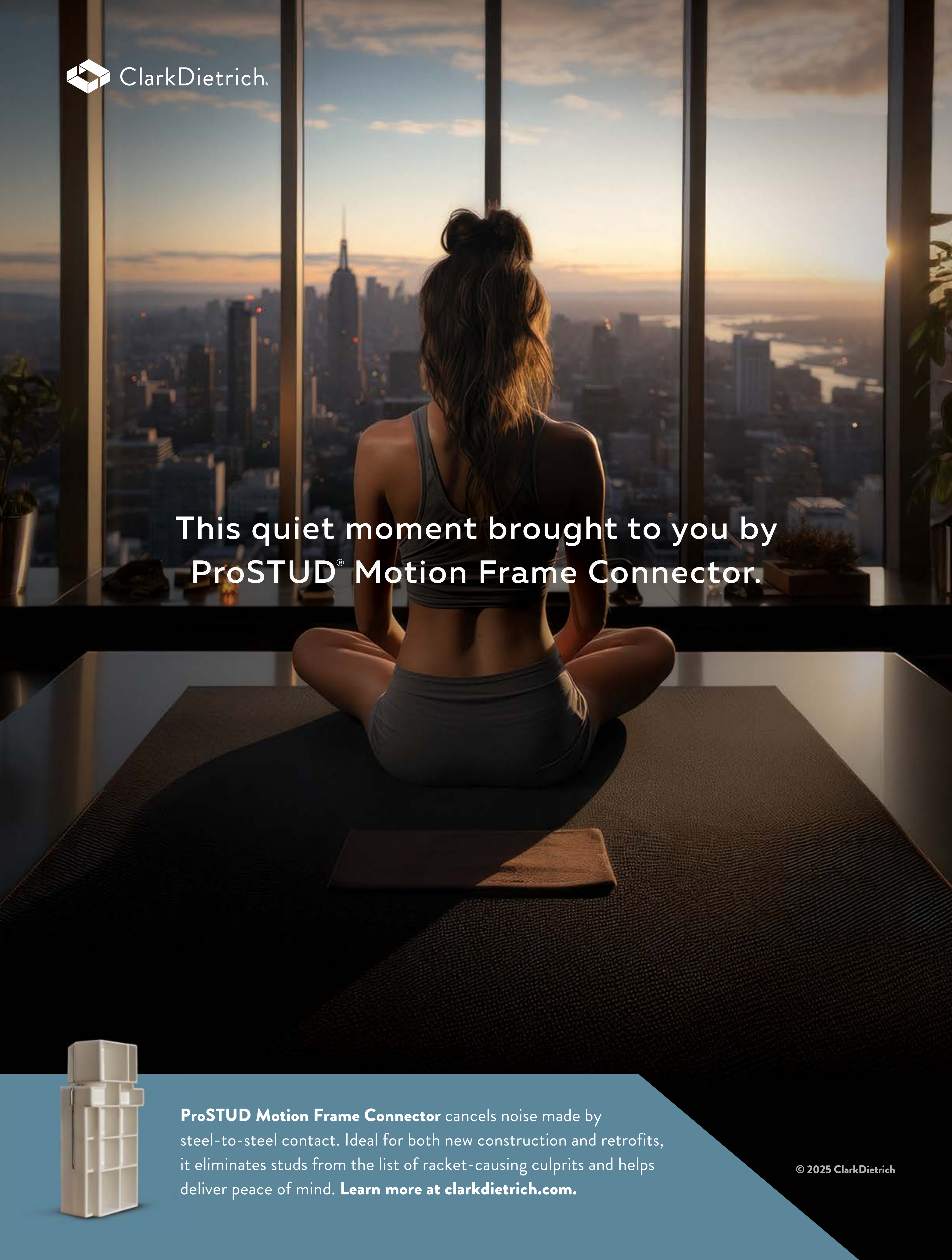
PHOTO COURTESY QTS DATA CENTERS

In the ongoing discourse on hard-surface flooring, the distinction between polished and refined concrete has moved beyond terminology and into a critical discussion about performance, durability, and accountability. Recent exchanges[1] in 2025 between the Concrete Polishing Council (CPC) and the authors of the article "Refine Versus Shine: Defining and Defending Design Intent with Refined Concrete"[2] have underscored fundamental philosophical differences in how the industry defines, measures, and delivers exposed concrete surfaces. However, the two are not the same. Polished concrete offers a variety of topical final products that lead to a gloss benchmark finish, whereas refined concrete, as defined by the National Concrete Refinement Institute (NCRI), involves the physical modification of the concrete itself to produce a floor finish.

These conversations have also clarified important distinctions not only between the two work results but also within each category, offering a clearer understanding of both polished and refined finishes.

A fundamental shift in understanding

Over the past decade or more, the term "polished concrete" has served as the industry's catch-all phrase for a floor that looks like an exposed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Many low-Mohs-hardness sealers and coatings—nicknamed "pay-juice" by contractors—are marketed as quick fixes for achieving high gloss/DOI, but do not necessarily address the concrete itself, leaving surfaces prone to premature failure throughout their service life despite meeting the gloss benchmarks. Refined concrete uses its own matrix to create a floor finish versus other types of traditional floors that get filled up and coated with polyurethane, epoxies, acrylics, and other non-cementitious materials.

PHOTO COURTESY NATIONAL CONCRETE REFINEMENT INSTITUTE (NCRI)

concrete finish. Over time, however, the label has become diluted and now encompasses a wide range of systems—including resin-bonded abrasives, film-forming sealers, grind-and-seal processes, densified surfaces, and high-build coatings—many of which merely imitate the original definition of polished concrete appearance through clear topcoats.

These softer, often short-lived materials typically do not offer the same long-term durability and performance as genuine surface refinement of the concrete itself. If these alternative systems were pigmented like traditional coatings, it would be far easier to distinguish actual concrete from a coated surface, but because these different work results look similar and are graded by identical contractual conditions (*e.g.* DOI-gloss), conflict is introduced to accountability, execution, maintenance, and risk.

"Refined concrete" restores the material's inherent integrity. It prioritizes measurable surface refinement over temporary gloss or resin sheen, redirecting focus to quantifiable outcomes: surface hardness, coefficient of friction (COF), surface texture, and lifecycle durability. In this way, it elevates a concrete finish to a robust building system.

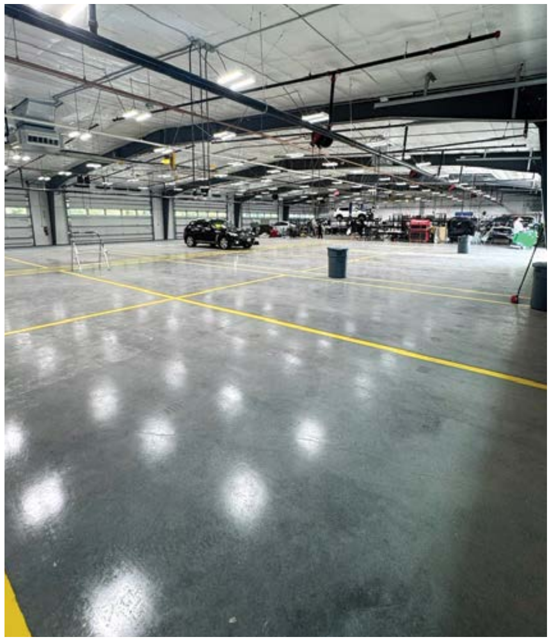
Why polished concrete became problematic

Organizations such as the CPC and the American Society of Concrete Contractors (ASCC) appropriately reference standards such as ACI-ASCC 310.1 to guide DOI gloss levels for polished concrete. However, as the authors of "Refine Versus Shine" point out, these specifications—while valuable—are often applied inconsistently and rely on subjective language. This does not mean that high-quality polished concrete floors are not being installed in some instances; rather, it underscores that, unlike most definitions of polished concrete, which are governed by similar contractual conditions, these inconsistencies introduce conflicts in execution and accountability.

Design teams and contractors interpret "polished" in widely varying ways. Many systems depend on (or even mandate) resin topcoats, epoxy grit tooling, or non-cementitious (*i.e.* polyurethane, acrylic, etc.) grout coatings that can conceal refinement deficiencies rather than actually resolving them. Others employ multiple layers of lower Mohs-hardness stain sealers—informally dubbed "pay-juice" by some contractors—as shortcuts to aesthetic

Left: Refined concrete finishes can be installed at the time of placement or on existing concrete floors. Refined concrete is not the same work result as polished, burnished, or sealed varieties of concrete. Refining stabilizes and reshapes the surface, reincorporating the concrete itself to create a denser, monolithic top layer with enhanced strength and durability.

PHOTO COURTESY QTS DATA CENTERS



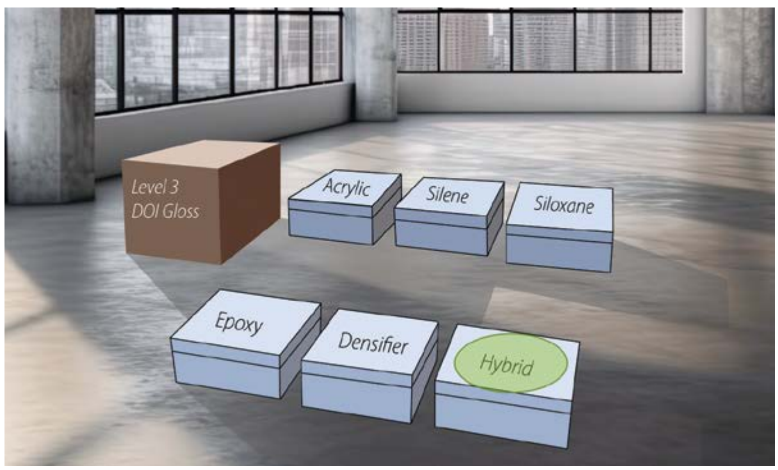
Refined concrete has a similar aesthetic to sealed or polished concrete finishes and can similarly be installed on new or existing concrete surfaces, but it is a different work result with measurable aesthetic and physical benchmarks.

PHOTO COURTESY NATIONAL REFINED CONCRETE INSTITUTE (NCRI)

distinctness-of-image (DOI) gloss targets that ensure contract disbursement, but leave owners with surfaces prone to premature failure, inadequate maintenance tolerances, and frequent refinishing during operational lifecycles. This does not mean that all polished concrete installers operate in this manner, but language vagueness can breed contractual risk: misaligned appearance or performance can trigger disputes, delays, and unforeseen costs. Refined concrete counters this with objective metrics and precise terminology to safeguard all stakeholders.

Polished and refined: What is the difference?

Polished concrete and refined concrete are fundamentally different processes that produce different results. Originally, the idea of polished concrete relied on creating a precise, methodical scratch pattern, removing more of the concrete surface through multiple passes of diamond tooling with finer and finer grit steps, similar to sanding wood. In theory, the gloss should originate from the scratch sequence itself; however, in reality, achieving this level of precision consistently across a concrete slab is extremely challenging. As a result, the measurable shine (the condition of the contract) is partially or totally derived from the application of acrylics and other sealer types, as well as resin transfer from certain epoxy tool types, rather than the tighter and tighter scratch pattern.



The inclusion of divergent work results governed by identical contractual conditions introduces conflicts in execution accountability, often leading to failures and risk.

IMAGE FROM JUNE 2025 CONCRETE SLABS: REFINING VERSUS POLISHING, LOUISVILLE, KY PRESENTATION BY CHRIS BENNETT AND BILL DUBOIS, CREATED BY GROK

Refined concrete does not depend on scratch pattern choreography to produce gloss or other performance characteristics. While grit progression and proper tooling still matter, the work product is driven by chemistry and craftsmanship, measured at every step. Re-emulsifying and rolling the surface, locking fines back into the slab to correct the surface texture, rather than grinding down the

Refined concrete, as defined by the National Concrete Refinement Institute (NCRI), is a transformative concrete finishing process that uses specified benchmarks and innovative refinement systems to enhance material science, sustainability, and lifecycle performance. It replaces subjective evaluations with objective, repeatable metrics.
PHOTO COURTESY QTS DATA CENTERS

Mockups in polished concrete, sealed concrete, or refined concrete are crucial to successful outcomes. In this photo, a refined concrete mockup was created, and surface metrics were recorded to compare to the final handover and quality control (QC) process.
PHOTO COURTESY NATIONAL REFINED CONCRETE INSTITUTE (NCRI)

surface and filling with repair materials, yields a refined finish. Surface clarity, hardness, and durability originate from the concrete itself, rather than from applied films, resinous fillers, and “pay-juice.” In polishing, surface performance reflects not only how well the scratch sequence was executed but also how acrylic and other surface films are maintained. However, with refinement, surface performance becomes inherent to the slab, achieved through mechanical control and slurry chemistry, and is not dependent on coatings.

Quantifiable refinement over gloss

Refined concrete’s hallmark is its emphasis on verifiable surface refinement, assessed through standardized metrics such as:

- Distinctness of Image (DOI) and roughness average (Ra)—Ensuring optical clarity stems from physical refinement, not coatings
- Coefficient of friction (COF)—Confirming safe traction across hard surfaces according to ANSI/NFSI B101.3
- Mohs scale of surface hardness—Targeting values above seven for superior durability, reduced wear, and extended maintenance intervals
- Roughness average (Ra)—20 µin or below as a minimum contractual threshold

Deb Suchomel, a senior project manager at QTS Data Centers, states that “using simple field benchmarks like Ra (surface roughness), DOI gloss, and Mohs helps keep the whole project team aligned.”

The Mohs scale: Comparing floor finishes

The Mohs Scale, developed by Friedrich Mohs in 1812, ranks materials from one (talc) to 10 (diamond) based on scratch resistance. Building products often exhibit hardness ranges due to composite compositions.

Refined concrete achieves higher Mohs hardness values than many coated or polished systems, resulting in reduced maintenance in high-traffic environments and eliminating the need for coatings or waxes. Coated or waxed floors, which typically have lower surface hardness, require more frequent upkeep under heavy use because they are less resistant to wear and tear.

Understanding the minimum acceptable thresholds for scratch resistance helps determine the appropriate flooring system. For example, areas with lighter foot traffic—such as office spaces—may only require a Mohs hardness of four or greater, as suggested by the CPC for polished concrete. In contrast, schools, industrial facilities, and environments with heavy foot traffic or hard-wheeled equipment may be better served by refined concrete, which routinely reaches Mohs hardness values of seven, eight, or even nine.

Project collaboration

Successful outcomes hinge on the general contractor (GC) and site supervisor fostering open dialogue among architects, designers, subcontractors, and suppliers. Clearly defined roles and shared lessons from prior projects enable proactive adjustments.

- Pre-installation meetings—Involve architects, interior designers, and structural engineers to align structural and aesthetic goals, coordinating with contractors to achieve success
- Supplier and finisher involvement—Early discussions and initial surface measurements ensure workability without compromising refinement potential. Site conditions inform curing regimes to optimize slab acceptance and setting the canvas for the refinement crews

Mockups: Where quality assurance (QA) and quality control (QC) meet

Risk management in any concrete finishes blends artistry and rigor, with mock-ups serving as the critical bridge to full-scale production success, the initial manifestation of design intent and owner needs. Refined concrete finishes, as with polished finishes, benefit from structured mock-up protocols and on-site validation to align expectations, mitigate risks, and deliver consistent results. Just as reliable standards emerge from coordinated batching and placement, the same responsible party overseeing mock-ups should also manage the full-scale refinement process.

- Personnel continuity: Assign the same skilled personnel from mock-up creation through installation to ensure expertise and accountability.
- Tangible benchmarks: Mock-ups provide physical proof that owner requirements are achievable, setting a clear standard for the outcome.
- Progressive staging for iterative review:
  - Require at least two mock-ups: the first a 3.05 x 3.05 m (10 x 10 ft) panel, the second a 7.62 x 7.62 m (25 x 25 ft) area, positioned in varied locations to assess the impact of lighting, environmental conditions, concrete quality, and finishing techniques. An acceptable Ra benchmark for finished concrete before polishing, refining, or sealing is 100 micro inches or less (as measured by ASME B46.1-2009, *Surface Roughness, Waviness, and Lay*).
  - The initial mock-up validates surface micro-texture, color, aggregate exposure, DOI-gloss, Mohs scratch hardness, and dynamic coefficient of friction (DCOF) for refinement.
  - The second incorporates project-specific elements—control joints, area drains, changes in plane, and simulated repairs—to mirror real-world challenges.
  - Larger projects may warrant additional mock-ups to evaluate performance across diverse site zones. Smaller projects may only provide for one mockup.

Attendees learn about refined concrete installation and maintenance, as well as contractual risk management and contractor wayfinding through quantifiable benchmarks.
PHOTO COURTESY BENNETT BUILD CONCRETE CONSULTING

Post-approval, a robust QA/QC program—ideally supported by a special inspector experienced in refined concrete—enforces standards through systematic inspections, surface texture evaluations, and color-consistency checks. The NCRI also provides on-site QC and documentation, and can revoke credentials for installers who do not meet the contractual requirements outlined in their boilerplate specification. Detailed documentation, including photographs and written observations, creates an audit trail that allows for rapid identification and resolution of issues.

Environmental factors, including temperature, humidity, and direct sunlight, significantly impact the quality of concrete. Controlled temporary lighting, heating, and ventilation are essential to optimize these conditions. By contractually requiring protection of the mockup as part of the final QC conditions, a team can anticipate and verify site-specific variables, ensuring outcomes align with the designer's original intent, and avoid, therefore, theoretical requests for information (RFIs) on what the mockup might have measured out at.

Thorough planning and communication—from mock-up to completion—yield refined finishes that can be verified from paper to concrete surface. This systematic approach not only enhances communication and reduces risk

High traction coefficient of friction (COF) is not only a benchmark for initial installation of refined concrete, but can also serve as a maintenance benchmark.
PHOTO COURTESY BENNETT BUILD

but also contributes to overall project success, producing surfaces that are far more durable and lower-maintenance than coating-dependent systems (*e.g.* epoxy, acrylic, urethane, or polyaspartic), which require frequent reapplication in contrast to refined concrete's inherent longevity.

Maintenance that mirrors installation

A certified refinement installer (CRI) from NCRI should understand the refined concrete approach well enough to distinguish between the various types of polished work results and refined concrete. This is critical when working with owners who have only experienced design, installation, and maintenance of various polished/hybrid concrete floor finishes. It is possible to have an owner with polished concrete floors installed in multiple buildings, each at various stages in its lifecycle, and maintenance staff executing maintenance procedures tied to maintenance materials, supplies, and equipment, all based on various polished concrete floor finishes. To this owner, a shift in approach must consider the impact on maintenance practices and supplies/equipment. The necessity of this shift is questioned when the polished concrete floor finish is not a point of critique. This is where mockups and on-site training resources are useful.

Owners who manage multiple buildings can benefit from gradually incorporating refined concrete finishing techniques. They should start with the current project in design or the floor they are interested in, and then improve previously installed polished concrete floors. This process will change them from polished to refined concrete floors, extending their lifespan and making maintenance easier. The maintenance benchmarks are identical to installation benchmarks. Ra, Mohs, DOI-gloss, and DCOF equip facility maintenance teams to monitor performance contractually. DOI-gloss and Ra correlate with COF; low DOI may also signal contamination, reducing traction. As specification consultant Larry Hale notes, "A major advantage of refined concrete is a DCOF independent of applied coatings." Tracking integral benchmarks without re-coating aids in reducing lifecycle costs, while also helping to maintain safety, health, and other performance requirements.

Reducing contractual risk

Without quantifiable specifications to define contractual requirements, project teams will continue to receive concrete floors prone to change orders, performance inconsistencies, and high maintenance costs. Designers and contractors will continue to exhaust contingencies without understanding what went wrong or how to avoid similar issues in the future.

Specifications serve not just as technical guidance but as risk instruments—and vague language invites conflict. Refined concrete offers to address this by establishing clear pre-grind criteria, including mock-ups with defined metrics for color and gloss, scratch resistance, and more. Along with verified materials and documentation. These objective benchmarks protect all parties from ambiguity and post-occupancy failures. The industry is now advancing toward accountable language and precise definitions that can be universally specified to solve concrete floor challenges reliably. The focus has shifted from describing processes to demanding results—quantifiable, repeatable, and validated through physical testing of the finished product delivered to the client, fostering alignment and confidence across the design and construction team.

Final finish

Polished concrete and refined concrete are different floor types, and the polished-versus-refined debate is structural, not semantic; as it opens up the question of whether to rely on appearance standards or adopt performance-

THE MOHS NUMBERS MATTER

The Mohs Scale of Hardness is a qualitative ordinal scale designed to assess the scratch resistance of minerals and related materials. Established by German geologist Friedrich Mohs in 1812, this scale ranks substances from 1 (softest) to 10 (hardest), according to their capability to scratch one another. When assessing building materials, it is important to recognize that products often contain a mix of substances, resulting in a range of hardness values rather than a single fixed number.

The chart illustrates the relationship between material hardness, use, durability, and upkeep. Refined concrete has a higher Mohs hardness than coated polished concrete, meaning less maintenance in busy areas and no need for coatings or waxes. In contrast, surfaces protected mainly by coatings or waxes tend to have lower hardness and require more frequent maintenance in high-traffic settings.

Material	Mohs Hardness	Composition	Application Notes	Other Hardness Scale
Soft Materials (Mohs 1 to 3): Low Foot Traffic Floor Finish Soft materials, such as limestone and wood, are commonly used in decorative, low-foot-traffic flooring applications due to their ease of shaping and aesthetic appearance. These materials are less resistant to scratching from common objects.				
Limestone	2 to 3	Calcite		
Travertine	3 to 4	Type of limestone		
Marble	3	Metamorphic limestone		
Resinous Coatings	2 to 3	Polymeric material/soft, viscoelastic	Mohs is typically not used	Shore D Hardness 70 to 90
White Oak	3	Wood species	Mohs is typically not used	Janka Scale 1,360 lbf (6,050 N)
Medium Hard Materials (Mohs 4 to 6): Medium Foot Traffic Floor Finish Medium-hard materials such as slate, ceramics, tropical hardwoods, and glass are valued for their balance of durability and workability, making them suitable for medium-foot-traffic flooring installations. These materials are resistant to scratching from common objects.				
Ipê	5	Wood species	Mohs typically not used	Janka Scale 3,684 lbf (16,390 N)
Slate	5 to 6	Often contains quartz		
Glass	5.5 to 6	Low-iron glass may be softer		
Ceramic Tile	5 to 7	Clay type and firing process		
Plain Concrete	5.5	Standard smooth troweled finish	Hardness can be improved by adding granular hardeners or liquid applied surface refinement	
Plain Concrete w/ Hardener/ Densifier	6	Sodium silicate, lithium silicate	Liquid silicate based surface treatment	
Basalt (traplock) dry-shake	6.5	Crushed aggregate	Industrial floor finish	
Hard to Very Hard Materials (Mohs 7 to 9): High Foot Traffic Floor Finish Hard materials such as granite and porcelain are preferred for high-traffic areas due to their superior scratch resistance. Very hard materials, such as dry-shake aggregate-based materials, are applied during concrete finishing to achieve a defined hardness level, offering exceptional wear protection, and are commonly used in industrial environments.				
Granite	6 to 7	Quartz, Feldspar		
Porcelain Tile	7 to 9	Extremely dense and hard		
Refined Concrete	7 to 9	Quartz or Feldspar crushed gravel		
Silica Dry-shake Finish	7	Quartz or Feldspar fine aggregates		
Corundum Dry-shake Finish	8	Crystaline aluminum-oxide fine aggregates		
Metallic Dry-shake Finish	8.5 to 9	Iron-based fine aggregates	Rusts in areas prone to wetting	
Chimeric Materials (Mohs 3 to 7+) Chimeric materials such as terrazzo display variable hardness across their surfaces due to the composition and proportion of aggregates and binders. Their resistance to scratching depends on both the degree of aggregate exposure and design choices for color and appearance.				
Cementitious Terrazzo	6 to 8	Portland cement binder	Reduced aggregate bond strength versus epoxy resin Terrazzo	
Epoxy Resin Terrazzo	3 to 6	Polymeric resin binder	Enhanced aggregate bond strength versus cementitious Terrazzo	

driven systems that safeguard owners, empower specifiers, and advance sustainability. Chris Bishop, NCRI president, remarks, "I've watched owners embrace 03 35 49[3] refined finishes for a superior look and simple, verifiable metrics that prove they're getting what they paid for, while contractors value the training and clearer design-team alignment. Owners eliminate chronic floor issues, and schedules shrink because precise measurement speeds installation."

additional information

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KEY TAKEAWAYS

The 2025 dialogue revived a key distinction between polished and refined concrete, shifting attention from appearance to measurable performance. Refined concrete prioritizes durability, clarity, safety, and long-term value using quantifiable metrics like Ra, Mohs hardness, and DOI gloss—reducing maintenance and contractual risk. Unlike polished concrete, which often depends on coatings and vague definitions, refined concrete delivers performance through its inherent properties. With clear specs, mockups, and collaboration, it restores material integrity and provides a verifiable, repeatable, low-maintenance solution for owners and specifiers.

MASTERFORMAT NO.

03 00 00—Concrete
09 60 00—Flooring

UNIFORMAT NO.

C2030—Flooring

KEYWORDS

Division 03, 09
Concrete specifications
Polished concrete
Refined concrete

Luis Adan, director of Capital Projects at North Kitsap School District, says, "As a public owner responsible for long-term facility performance, we've found refined concrete to offer a superior balance between safety, aesthetics, and lifecycle value. In high-traffic school environments, refined concrete maintains a higher coefficient of friction when wet compared to traditional polished floors, reducing slip hazards for students and staff. It also requires less intensive maintenance, with fewer burnishing cycles, lower chemical usage, and reduced equipment wear, while retaining a clean, uniform appearance. The result is a safer, more cost-efficient floor solution that aligns with both our durability standards and operational budgets."

The industry is learning that slowing down to read the floor is ultimately the fastest way to finish strong. And, as Deb Suchomel explains, "When everyone understands what's being measured—and why—it becomes far easier to deliver consistent, high-performance finishes that everyone is proud of."

NOTES

[1] Read the Concrete Polishing Council (CPC) letter to the editor in response to the authors' "Refine Versus Shine" article, as well as the authors' response on pages 7-10 published in *The Construction Specifier*'s April 2025 issue by visiting constructionspecifier.com/publications/de/202504

[2] Refer to the article Refine Versus Shine: Defining and Defending Design Intent with Refined Concrete, written by Kristina Abrams, AIA, LEED AP, CDT, CCS, Chris Bennett, CSC, iSCS, CDT, Bill DuBois, CSI, CCS, AIA, Melody Fontenot, AIA, CSI, CCCA, CCS, Kathryn Marek, AIA, CSI, CCCA, NCARB, SCIP, Keith Robinson, RSW, FCSC, FCSI, LEED AP, Ryan Stoltz, P.E., LEED AP, Vivian Volz, CSI, AIA, LEED AP, SCIP, published in *The Construction Specifier*'s January 2025 issue. Read the article here: constructionspecifier.com/prohibit-polished-concrete

[3] Refer to 03 35 49 Refined Concrete Finishing guide specification and other information, including certified refinement installers (CRIs) at the National Refined Concrete Institute's (NCRI) training and resources page, thencri.com

product spotlight

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www.reefindustries.com/vapor-retarders.php

Enhancing Community Safety

Effective Wildfire Mitigation and Building Practices

By Tony Crimi, P.Eng., MASc. and Antoine Habellion, P.Eng., M.Eng.

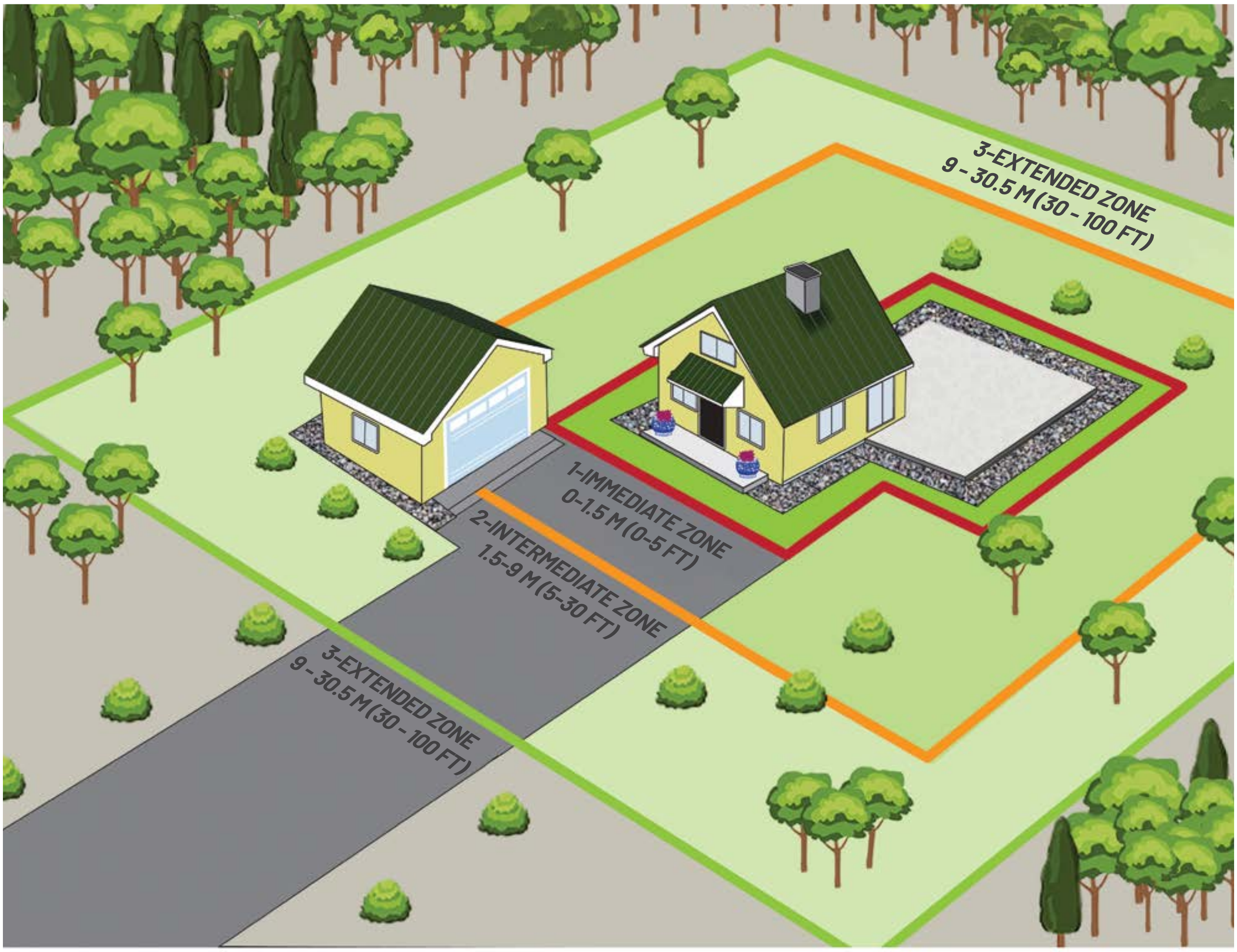
PHOTOS COURTESY ROCKWOOL NORTH AMERICA

Part one of this article in *The Construction Specifier's* December issue documented the growing exposure of Wildland Urban Interface (WUI) communities to high-intensity wildfire hazards and reviewed the mechanistic pathways by which structures ignite, notably ember and firebrand attack, direct flame impingement, and radiant heat. The technical discussion emphasized the vulnerability of roofs and exterior walls and evaluated building-level mitigations that demonstrably reduce ignition probability and damage severity—specifically, roof hardening (Class A coverings and cap sheets), ember-resistant venting, noncombustible claddings, and continuous noncombustible exterior insulation—while noting the limitations of minimum code compliance and single.

Part two builds on these findings and shifts the focus to parcel- and community-scale interventions, including the implementation of prescribed fire safe setbacks and parcel-level risk categorization, targeted retrofit strategies for existing stock, and the financing, insurance mechanisms, and policy instruments required to scale effective home hardening measures.

Implementing fire-safe setbacks

As stated previously, it is critical to ensure structures maintain a safe distance from potential external fuel sources. The primary purpose of building setbacks is to maintain fire separation distances from vegetation and other structures. In WUI areas, empirical evidence confirms that the required setback typically exceeds the



1-IMMEDIATE ZONE (0 - 1.5 M [0 - 5 FT]): Install noncombustible ground cover. Use fire-resistant or noncombustible materials for decks, porches, railings, or fences that attach to the home.

2-INTERMEDIATE ZONE (1.5 - 9 M [5 - 30 FT]): Plant trees no closer than 9 m (30 ft) to the home. Space tree crowns 5.5 m (18 ft) apart or further on slopes. Trim branches up to 1.8 to 3 m (6 to 10 ft) from ground and at least 3 m (10 ft) from structures.

3-EXTENDED ZONE (9 - 30.5 M [30 - 100 FT]): Remove vegetation next to outbuildings. For trees 9 to 18 m (30 to 60 ft) from the home, space so mature canopies are at least 3.5 m (12 ft) apart; for 18.2 to 30.5 m (60 to 100 ft) from the home, space so tree canopies are at least 2 m (6 ft) apart.

Create defensible space against wildfires by limiting fire fuels in the immediate, intermediate, and extended zones around the home.

PHOTOS COURTESY FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

setback requirements of zoning or building codes. In fact, "WUI Structure/Parcel/Community Fire Hazard Mitigation Methodology" from the National Institute of Standards and Technology (NIST), along with several other studies, have evaluated separation distances and support a minimum 9-m (30-ft) setback requirement.[1,2]

Recognizing the importance of setbacks, the Federal Emergency Management Agency (FEMA) recommends alternative strategies for homeowners when a 9-m (30-ft) setback to the property line is impractical due to factors such as parcel size, topography, or existing easements. In such cases, FEMA advises enhancing fire safety measures around the home to minimize the risk of fire spreading between structures. These recommendations are detailed in the 2023 *Marshall Fire Mitigation Assessment Team: Homeowner's Guide to Reducing Wildfire Risk Through Defensible Space*.[3]

Further, traditional WUI categories (interface/intermix) describe general community classifications and hazard profiles. However, effective mitigation for building structures must be driven by specific property-level assessments and localized evaluation of potential fire exposures. This can be aided by identifying a parcel-level WUI categorization.

Currently, WUI area risks are primarily defined by spatial separation distance (SSD), with secondary consideration given to lot size. Even if structures are located on a large lot but are clustered together on the edge of the property with a small SSD, the hazard to adjacent

Installation of exterior noncombustible insulation.

structures would remain higher than the classification would indicate. Similarly, the proximity of vegetation to a structure poses the same hazard whether parcels are large or small. Specific parcel-level assessments need to be conducted if combustible materials are to be introduced within the building envelope.

As fires intensify and spread, homes can act as additional fuel sources, potentially sparking simultaneous ignitions. In many instances, burning homes may ignite nearby structures, exacerbating the situation. Firefighter response can be quickly overwhelmed by limited equipment, personnel, and water resources. When these resources are diverted to address structure fires, the overall effectiveness of fire protection is reduced, potentially leading to significant damage or destruction affecting dozens, or even hundreds, of homes.[4]

Upgrading existing homes

An important consideration for WUI building hardening and community resilience is addressing existing buildings. Existing homes or buildings present an excellent opportunity to introduce fire-hardening measures while simultaneously making energy efficiency improvements to enhance both fire and energy performance of exterior walls and roofs.

The 2008 FEMA *Home Builder's Guide to Construction in Wildfire Zones*, "Technical Fact Sheet Series P-737," offers a foundational set of recommendations for fire hardening.[5] However, considering more recent and increasingly severe wildfire events, it is clear that additional and advanced building hardening strategies must be adopted. These newer measures could include the use of more ignition-resistant materials, noncombustible materials, the installation of ember-resistant vents, and the implementation of defensible space practices around homes and buildings. Replacing exterior wall coverings that are combustible, susceptible to melting, or can readily transmit heat can significantly enhance building safety.

Moreover, retrofitting existing structures with modern fire-resistant technologies not only mitigates the risk of fire damage but also provides an opportunity to improve overall building performance. Enhanced insulation, energy-efficient windows, and other sustainable building practices can reduce energy consumption, resulting in lower utility costs and contributing to the environmental sustainability of individual homes and communities.

Some examples of existing exterior envelope component replacements, or enhancements include:

Blowing insulation into exterior wall cavities

With the siding removed, the wall structural sheathing is exposed, allowing contractors to use the "drill and fill" method to blow insulation into the walls from the exterior. This is common practice in weatherization programs. Mineral fiber insulation, such as mineral wool, is particularly suitable for this application, as it effectively resists airflow and reduces air movement by filling wall cavities, thereby helping

Daniel Curan stands before his fire-scarred Altadena, Calif., property, January 2025, months after his insurer canceled coverage due to elevated wildfire risk.

to decrease the fire risk by limiting the amount of oxygen available to sustain combustion. Improved thermal and acoustic performance, as well as fire protection, can be achieved in a single procedure.

Installation of a continuous air barrier

Installing a continuous exterior air barrier over the exposed wall sheathing prevents air from entering the wall assembly. This practice supports enhanced fire protection, energy efficiency, and contributes to improving indoor air quality and smoke control during a wildfire by preventing the infiltration of pollutants and harmful smoke into the building.

Adding noncombustible continuous exterior insulation

Adding noncombustible insulation, such as mineral wool board, as continuous exterior insulation on top of the air barrier, enhances the energy efficiency of the home or building and helps meet or exceed energy code requirements. Because this material is noncombustible, it also provides a layer of fireproofing, protecting both the combustible air barrier and the combustible structural sheathing. Finally, the addition of exterior insulation contributes to the building structure's overall durability by elevating the surface temperature of the structural sheathing, reducing the risk of vapor diffusion or air leakage condensation.

Installing other noncombustible materials

Using noncombustible cladding and building materials provides a higher level of defense against wildfires. These materials resist ignition and prevent the spread of flames, thereby contributing to the protection of the structural integrity of the home.

Removing and preventing accumulation of combustible debris

Removing combustible debris, such as vegetation and leaves, and avoiding combustible storage (*e.g.* firewood, garbage bins) near exterior walls and foundations reduces a building's vulnerability to ignition during a wildfire.

Fire hardening accessory structures

Ensuring that accessory structures such as additional dwelling units, sheds, garages, barns, as well as fences and trellises, are also fire-hardened is critical to the overall system-wide performance of the property and can significantly reduce the risk of exposing the primary home or building to fire. The same fireproofing should be applied to these structures. For example, fences and trellises could be made of concrete or composite materials, which are more ignition-resistant than untreated wood.

As a testament to the effectiveness of hardening strategies, an impact analysis for the National Guide for Wildland-Urban Interface Fires, prepared by the Institute for Catastrophic Loss Reduction (ICLR) for the National Research Council of Canada, examined the 2018 Camp Fire in California. The analysis found that 59.4 percent of buildings constructed in or after 2008, adhering to the 2008 *California Building Code*—which introduced

advanced requirements for materials and construction methods to withstand exterior wildfire exposure—survived the fire.[6] In stark contrast, only 21.0 percent of structures built before the adoption of this code survived the wildfire. This significant disparity underscores the critical importance of adopting more stringent building codes and standards designed to enhance the resilience of structures in wildfire-prone areas.

California's wildfire insurance market

In recent years, many insurers have withdrawn from California's high-risk home insurance market,[7] significantly reducing the availability of wildfire insurance. Those that remain have often responded to major wildfire events by increasing premiums or escalating the number of non-renewals in high-risk areas, leading to an affordability and availability crisis for insurance in numerous communities, extending beyond those directly impacted by wildfires.

As a result, this imbalance between supply and demand is driving up consumer premiums and placing additional strain on government programs such as the California Fair Access to Insurance Requirements (FAIR) Plan. The FAIR Plan offers property insurance to individuals who are unable to obtain coverage through the standard insurance market due to high-risk factors, such as residing in areas prone to wildfires. Consequently, in California, it serves as the insurer of last resort.

As more insurers continue to exit or restrict their business in the state, the California FAIR Plan is experiencing an unprecedented influx of applications, approaching nearly 1,000 per day. This surge in demand has resulted in the number of FAIR Plan policies in California skyrocketing from approximately 127,000 in 2018 to an anticipated 400,000 or more by September 2024.[8] This dramatic increase underlines the critical role the FAIR Plan plays in providing necessary insurance coverage to homeowners in high-risk areas, while highlighting the growing challenges faced by the insurance market in addressing wildfire risks.

The aforementioned study, conducted by Milliman and CoreLogic for the Town of Paradise, California, found that implementing mitigation strategies could significantly decrease wildfire losses by up to 75 percent and potentially lower insurance premiums by as much as 55 percent.[9] These findings are among the first and most comprehensive to date, quantifying the aggregate risk and cost reduction benefits of various strategies that communities and individual property owners in the WUI can implement to mitigate wildfire risk. This research highlights the significant potential for well-planned mitigation efforts to not only enhance community resilience but also to make insurance more affordable and accessible in high-risk areas.

However, as of today, the existing regulatory and legislative framework for California homeowners' insurance is not easily adaptable to providing quantifiable benefits to insurers from wildfire risk mitigation. Although the California Department of Insurance has recently enacted regulations intended to stabilize the insurance market and increase coverage in wildfire-prone areas of the state,[10] significant disincentives remain for insurers. There is a need for a more flexible regulatory environment that can better accommodate wildfire risk and incentivize effective mitigation efforts.

Home hardening: A practical solution to mitigate wildfire risk

It is imperative for policymakers, builders, and homeowners to collaborate and prioritize home hardening and defensible space measures for both new and existing homes and buildings. Additionally, state laws, regulations, and policies should fund and incentivize these measures to encourage broader adoption by individuals and communities. By doing so, safer and more resilient communities that are better prepared to withstand the growing threat of wildfires can be created, which not only better protect public health and safety but also mitigate the devastating economic impacts of catastrophic wildfire events.

In February 2022, the California Department of Insurance, in partnership with the California Office of Emergency Services (Cal OES), California Department of Forestry and Fire Protection (CAL FIRE), the Governor's Office of Planning and Research, and the California Public Utilities Commission, adopted the Safer from Wildfires regulations to provide insurance discounts to homeowners who implement recommended home hardening and defensible space measures to reduce wildfire risk to their homes and properties.[11] These measures include Class-A fire-rated roofs; the creation of ember-resistant zones around homes and other defensible space measures; installation of ignition-resistant or noncombustible vents, enclosed eaves, and upgraded windows; and exterior walls that incorporate noncombustible materials at the bottom 152 mm (6 in.). The more of these measures a homeowner implements, the larger the potential insurance discount.

Critics of these incentive programs often voice concerns that the costs of implementing, in particular, these home hardening measures can often exceed the rate discount provided by insurers, rendering these programs ineffective. The 2022 report by Headwaters Economics and Insurance Institute for Business & Home Safety (IBHS), titled "Construction Costs for a Wildfire-Resistant Home: California Edition," demonstrates, however, this may not necessarily be the case.[12] Headwaters Economics and IBHS analyzed the cost differences in new home construction, comparing the costs of a baseline code-compliant home with those of "enhanced" and "optimum" homes, based on this initiative to reduce the vulnerability of homes to wildfires. It also differentiated the costs between northern and southern California. The report concluded:

- Wildfire-resistant construction increases the total cost of a new home by approximately 2 to 13 percent.
- Enhanced building materials add 2 to 8 percent to the cost, while optimum building materials add 4 to 13 percent over baseline materials.
- For northern and southern California, respectively, the difference in cost between baseline and enhanced construction ranged from $27,610 to $28,890, representing an 11 percent cost increase in both regions. In contrast, the additional cost for optimally enhanced homes was significantly higher, at 73 percent for northern California and 104 percent for southern California.

It is noteworthy that properly installed wildfire-resistant features can provide numerous advantages beyond fire protection. These benefits include greater durability, lower maintenance requirements, and potentially improved energy efficiency. Over the lifespan of a building, these advantages can help to justify the initial investment in higher-quality materials.

To help mitigate these additional costs, home and commercial property owners can also access various financial incentives to make energy-efficient and fire-hardening improvements. These incentives include federal tax credits, state and utility incentives, local tax abatements, and other financial supports. Notably, the Residential and Commercial Property Assessed Clean Energy (PACE) financing programs are a significant resource in this regard.

California law specifically permits fire hardening to be eligible for PACE financing. The PACE program, which began in Berkeley in 2007, has evolved through new state laws and federal guidance from the IRS and the Department of Housing and Urban Development (HUD). It offers a unique financing option for homeowners to fund various sustainability improvements—such as energy-efficient upgrades, water conservation projects, and home hardening against wildfires—through their property taxes.[13]

Moreover, Southern California lawmakers recently introduced two bills aimed at

Curan property lot cleared for post-wildfire rebuilding—significant reconstruction costs ahead.

incentivizing homeowners to "harden" their properties against wildfires. The legislation, authored by state Sen. Steven Choi, proposes tax credits covering half the cost of fire-resistant upgrades, such as roofs, siding, vents, decks, and fences. Another bill focuses on grants to support these home-hardening efforts. These measures aim to reduce the risk and impact of wildfires on residential properties by encouraging the use of ignition-resistant and noncombustible building materials and landscaping.[14]

Conclusion

Wildfires pose a significant and persistent threat, necessitating strategic measures to enhance the resilience and safety of communities, particularly those in WUI areas. Recent catastrophic events underscore the urgent need for comprehensive and multifaceted mitigation strategies.

Innovative solutions in wildfire risk management must transcend traditional construction methods. The use of noncombustible, ignition-resistant materials, such as mineral wool insulation, in critical areas such as exterior walls, roofs, eaves, and attics is crucial. Equally vital is community engagement and education, with initiatives like defensible spaces, fire-resistant landscaping, and home-hardening measures collectively reducing wildfire risks.

Building codes are essential to community resilience, safeguarding life and property in high-risk areas. These codes must incorporate rigorous requirements tailored to WUI-specific challenges. Policymakers play a crucial role in promoting these practices by providing financial incentives, insurance discounts, and public awareness campaigns to encourage the widespread adoption of fire-resistant strategies. Legislative efforts, such as California's *Assembly Bill 1* (*AB 1*), aim to enhance fire safety in building construction, reducing structural vulnerability to wildfires. These initiatives emphasize the importance of robust fire safety regulations, reflecting a growing commitment to fortifying communities against such threats. Flexible regulatory frameworks are also crucial to supporting and incentivizing effective mitigation efforts.

In conclusion, ongoing legislative efforts should be recommended to further these goals, with an emphasis on flexibility to adapt to evolving needs. A holistic approach that integrates these strategies will not only mitigate wildfire risks but also enhance community resilience in high-risk areas. By prioritizing stringent building codes, innovative materials, proactive community engagement, and supportive policies, we can create safer environments equipped to withstand the growing threat of wildfires.

NOTES

[1] See NIST Technical Note 2205: WUI Structure / Parcel / Community Fire Hazard Mitigation Methodology.

[2] Refer to FEMA's Marshall Fire Mitigation Assessment Team: Best Practices for Wildfire-Resilient Subdivision Planning.

[3] Refer to FEMA's Marshall Fire Mitigation Assessment Team: Homeowner's Guide to Reducing Wildfire Risk Through Defensible Space.

[4] The Firewise USA program provides simple, effective steps to help communities reduce the risk of destruction from wildfire.

[5] See 2008 Home Builder's Guide to Construction in Wildfire Zones, particularly Technical Fact Sheet Series FEMA P-737.

[6] Refer to Figure 4A (page 9) of "An impact analysis for the National Guide for Wildland-Urban Interface Fires."

[7] See "California insurance market rattled by withdrawal of major companies" on The Associated Press.

[8] Refer to Insurance Business: Wildfire lessons for Canada: courtesy of California.

[9] See the Milliman And CoreLogic Report. Town of Paradise California Resilience Challenge Task 1 to Task 4, Risk Reduction, Climate Change, and Insurance Premiums.

[10] Refer to California Department of Insurance's press release for December 13, 2024; and California Department of Insurance's press release for December 30, 2024.

[11] Refer to California Department of Insurance, Safer from Wildfires.

[12] Learn more at Headwaters Economics, "Construction Costs for a Wildfire-Resistant Home – California Edition."

[13] Refer to State of California, Department of Financial Protection & Innovation. PACE: Property Assessed Clean Energy: What Homeowners Need to Know.

[14] Visit SiliconValley.com, "California bills encourage fire home-hardening with grants, tax breaks."

additional **information**

AUTHORS

Tony Crimi, P.Eng., MASc., is the founder of A.C. Consulting Solutions Inc. (ACCS), a firm specializing in building and fire-related codes, standards, research, and product development in the U.S., Canada, and Europe. Before establishing ACCS in 2001, he spent more than 15 years at Underwriters Laboratories of Canada (ULC), where he served as vice president and chief engineer, focusing on codes and standards development, testing, and conformity assessment. With more than 30 years of experience, Crimi has been actively involved in the development of national and international codes and standards through organizations such as the International Code Council (ICC), the National Fire Protection Association (NFPA), ASTM, and other leading standards bodies. He has also authored numerous articles and papers on fire protection and facade fire safety.

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KEY TAKEAWAYS

Setbacks are essential for wildfire safety, with National Institute of Standards and Technology (NIST) and Federal Emergency Management Agency (FEMA) recommending at least 9 m (30 ft) between structures and vegetation, though alternatives exist for smaller lots. Local risk assessments matter, since spacing—not just lot size—shapes hazard levels. Retrofitting buildings with fire-resistant materials, noncombustible cladding, continuous air barriers, and ember-resistant features greatly reduces vulnerability, as does strengthening accessory structures and removing debris. Financial tools like Commercial Property Assessed Clean Energy (PACE) programs, insurance discounts, and tax credits help support upgrades, while policy updates and modernized codes remain critical for mitigation and community safety.

MASTERFORMAT NO.

02 00 00–Existing Conditions
06 00 00–Wood, Plastics, and Composites
07 00 00–Thermal and Moisture Protection

UNIFORMAT NO.

B2010–Exterior Walls
B3010–Roof Coverings

KEYWORDS

Exterior walls
Fire resistance
Roof assemblies
Wildland Urban Interface

From Vacancy to Vitality

Adaptive Reuse in Education Design

By Jeff Boone

PHOTOS BY LARA SWIMMER PHOTOGRAPHY

Over the past decade, PUBLIC47 Architects has worked with Eastside Preparatory School (EPS) in Kirkland, Wash., to transform a fragmented 1980s office park into a cohesive, pedestrian-focused educational campus. What began as a collection of two-story office buildings has evolved through a series of strategically phased projects. Each addressed unique physical constraints, performance goals, and construction challenges.

Rather than a single master plan, the campus grew through an evolving vision shaped by immediate needs and long-term adaptive reuse. Each project introduced new techniques for improving daylighting, accessibility, and circulation while creating durable, flexible spaces that could support the school's growth over time.

Working within constraints

EPS occupies a property organized as a planned unit development (PUD), where each building sits on its own parcel with strict limitations on footprint and height. These constraints required precise coordination between architects, builders, and local jurisdictions.

The design team approached these challenges by linking the campus horizontally and visually. Massing erosions, transparent ground-level connections, and a new central pedestrian plaza create a continuous experience between buildings. This plaza unites the campus, providing a clear pedestrian route from the main entry to the play courts and connecting the Levinger-Poole Commons, The Macaluso Academic Collaborative, and TALI Hall.

Managing the site's 4-m (12-ft) grade change was a central technical challenge. PUBLIC47 used a series of stepped terraces, ramps, and covered gathering zones to ensure full accessibility while maintaining natural circulation flow. The plaza's generous canopies and exterior seating areas now serve as an extension of indoor learning and gathering spaces, offering shelter during the

Left: The Macaluso Academic Collaborative (TMAC) at Eastside Preparatory School designed by PUBLIC47 Architects.

Right: The gymnasium on the top floor of TMAC at Eastside Preparatory School.

Pacific Northwest's wet months and becoming vital during the COVID-19 pandemic for outdoor dining and social interaction.

TMAC: Establishing a framework

The Macaluso Academic Collaborative (TMAC) was the first major step in the transformation.

The 2,787-m^2 (30,000-sf) building introduced a mix of program types: 1,858 m^2 (20,000 sf) of classrooms, science labs, digital fabrication spaces, and a 929-m^2 (10,000-sf) gym and fitness center.

Due to the limited footprint, the gym was positioned at the top of the building on an isolated floor system, an unusual approach for a K-12 facility that required careful structural and acoustic detailing. The floor assembly between the gym and the classrooms below required careful consideration to minimize noise transfer, especially footfall. The assembly consists of a sandwich of structural steel and a concrete floor, with a separate concrete slab on top that is raised on hundreds of spring isolators. Operable walls between classrooms allow flexible configurations for combined or divided classes and have since become a campus standard. An interior amphitheater features large slide-fold doors made of insulated glass with an acoustic rating of STC 43, extending the circulation path and serving as an assembly space.

TMAC was designed, permitted, and approved within seven months, a fast-track timeline that demanded close coordination between design and construction teams. The building opened just 18 months after design began, establishing a model for future phases of work both in process and adaptability.

TALI Hall: Connecting the Campus

TALI Hall was the pivotal project that physically and visually unified the Eastside Prep campus. The 8,919-m^2 (96,000-sf) facility connects TMAC, the Levinger-Poole Commons, and the play courts through a new pedestrian plaza that resolves a 4-m (12-ft) grade difference across the site. The building itself bridges two parcels, with an atrium serving both the structural joint and the social heart of the campus.

The project's most complex element is the 1,393-m^2 (15,000-sf) flexible theatre, which includes a set shop, dressing rooms, wardrobe storage, and a control booth. The space accommodates up to 650 people in multiple configurations, featuring retractable seating, operable acoustic glass doors, double blackout curtains, and an upward-folding partition that separates or joins the mezzanine.

By using retractable seating, the space can be arranged in different ways. It can be set up as a proscenium theater for maximum seating or for smaller, more intimate performances that need fewer seats. It can also be a flat space for events such as theater in the round, college fairs, parent-teacher conferences, or a fall festival.

For such community events, the operable acoustic wall could fold out of the way to provide a larger opening between the building atrium and the theater space, encouraging that connection. In addition, the blackout curtains can be tucked away, allowing the space to be open to daylight and views, and further transforming the black box theater into a more public and inviting community space.

An upward-folding acoustic partition separates the upper mezzanine of the theater,

Above: TALI Hall located inside Eastside Preparatory School.

Top right: The upper mezzanine opens to the main theater space. That mezzanine can be closed off and used as a separate classroom, lecture space, or dance room.

Right: Retractable mezzanine.

allowing that space to operate autonomously with its own retractable seats, a dance floor for dance or yoga classes, and its own AV system. The space can be used for separate lectures, test-taking, or, on rare occasions, can be opened up to the theater to accommodate a larger event, such as a school assembly.

The mezzanine itself is also adaptable, featuring retractable seating, integrated tablet desks, and a sprung dance floor, which enables the space to be used as a lecture hall or a performance area. To ensure high performance and low operational costs, the building envelope features high-quality glazing, over-insulated assemblies, and natural ventilation systems. The high-performing fiberglass windows feature laminated glazing, with a U-value of 0.25. The building perimeter is wrapped with rock-wool insulation to provide additional insulation and to minimize thermal bridging. The daylighting strategies reduce reliance on electric lighting, while professional-grade AV and lighting systems with a tension grid allow students to engage in hands-on theater technology.

Below the building, structured parking replaced surface parking, allowing for better land use and expanded pedestrian areas.

Middle School renovation and addition

The Middle School renovation and addition transformed one of the original office buildings into a modern educational environment.

There was an unoccupied courtyard that was infilled and an awkward exterior stair removed, both of which separated the upper floor of the existing middle school into two autonomous buildings, making circulation and supervision awkward. By occupying the courtyard, additional commons space was provided for the cramped

middle school, enabling more efficient circulation within the building. A two-story window wall also brings light into the new middle school commons.

The existing mansard roof resulted in a lack of perimeter windows for many classrooms. By inverting the pitch of the roof, higher ceilings and larger windows were introduced, improving natural ventilation. This alteration also increased the floor area in what was originally attic space. For instance, the upstairs science lab previously lacked natural light. Expanding into the mansard attic space allowed for additional space and the inclusion of windows.

Folding whiteboard walls between classrooms enable flexible teaching arrangements and accommodate larger gatherings. These are high-performing, acoustical partitions. The teachers and staff appreciate the paired classrooms because they offer flexibility for holding larger class meetings in those settings.

The design removed an exterior stair and sky bridge and infilled a courtyard to create additional interior space and better circulation. The result provides larger classrooms, improved light, and spaces for informal gathering.

Levinger-Poole Commons: Reinventing the heart of campus

At the center of the Eastside Prep campus, the Levinger-Poole Commons (LPC) functions as the

primary dining and gathering space. Originally designed as a multipurpose theater, assembly, and cafeteria, the space was reimagined following the completion of TALI Hall.

The renovation expanded the kitchen, added an elevator, and included new classrooms, as well as private dining and teaching spaces. Visual connections between levels were improved with new openings and glass partitions. The function of the space was transformed into an all-day student union for meals, study, and meetings.

During the COVID-19 pandemic in 2020, PUBLIC47 added the LPC Dining Canopy, a heated and weather-protected outdoor dining area to address public health concerns. The space is still used as an expanded year-round exterior plaza.

Building for flexibility and longevity

A guiding principle across all Eastside Prep projects is adaptability over time. Standard elements include operable walls, exposed structural elements, and mechanical systems, as well as plug-and-play in-floor power systems that can be reconfigured by campus staff. This modular infrastructure supports changes in teaching layouts, technology use, and furniture arrangements.

Durable materials, simple detailing, and easy maintenance ensure that the buildings remain functional and efficient for decades. Much of the building's structure, including its steel and concrete, is exposed, making it a key element of the design. This approach reduces the costs associated with adding additional cladding to hide the structure and means there are fewer finishing materials to maintain over time. These structural materials are built to last, featuring exposed concrete floors where suitable, minimal use of dropped ceilings, and accessible mechanical systems for straightforward maintenance.

These construction strategies not only reduce operating costs but also extend the lifespan of the compass infrastructure.

The Middle School Renovation and Addition at Eastside Preparatory School.

PHOTO BY CLEARY O'FARRELL PHOTOGRAPHY

A connected and evolving campus

Ten years in, the Eastside Prep campus is an example of how careful planning, coordination, and technical detailing can transform a series of individual buildings into a unified academic environment. Through phased construction, each project addresses immediate needs while laying groundwork for future projects. The result is a pedestrian-oriented, flexible, and durable campus designed to adapt to the next generation of students and educators. The collaboration between Eastside Preparatory School and PUBLIC47 reflects how thoughtful construction can shape a learning environment built to evolve with its community.

additional information

AUTHOR

Jeff Boone, AIA, is a partner and co-founder of Seattle-based architecture firm PUBLIC47.

KEY TAKEAWAYS

Eastside Prep's decade-long, phased redevelopment transformed a fragmented office park into a unified, pedestrian-focused campus through adaptive reuse, flexible learning environments, and technical solutions to site constraints—prioritizing daylight, circulation, durability, and long-term adaptability across all buildings.

MASTERFORMAT NO.

03 00 00—Concrete
05 12 00—Structural Steel Framing
08 44 00—Glazed Curtain Walls

UNIFORMAT NO.

B2010—Exterior Walls
B2020—Exterior Windows

KEYWORDS

Division 03, 05, 08 Adaptive reuse

The Next Generation of Shelf Angle Systems

By Mark D. Hagel, PhD, P.Eng

PHOTOS COURTESY ALBERTA MASONRY COUNCIL

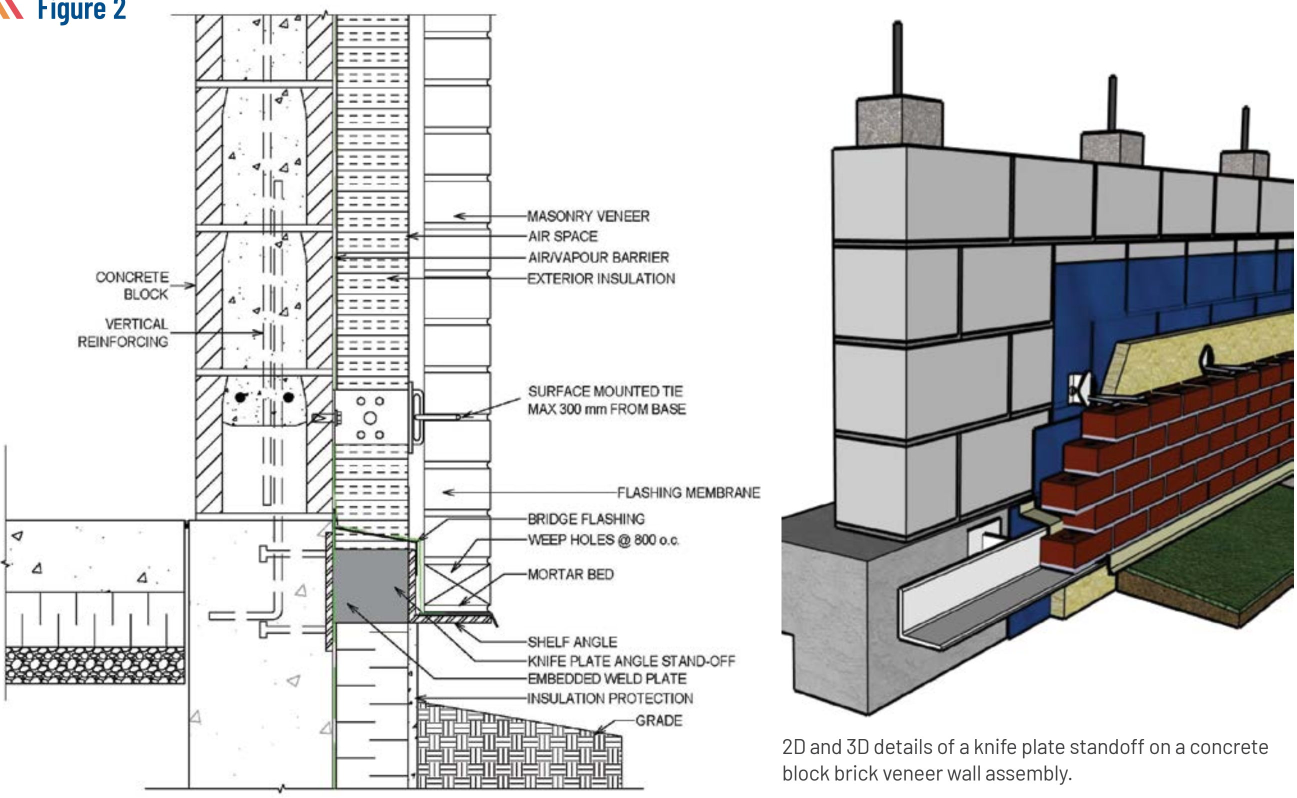
Thermal bridging is a very real phenomenon and can greatly reduce the thermal performance of a building envelope assembly. It occurs when a conductive material creates a direct path for heat to bypass insulation, resulting in increased heat loss or gain within a building envelope. On a frosty day, the dark areas located at the wood studs and floor rim boards on a wall in Figure 1 telegraph through the siding in stark contrast to the white frost between the studs, where the insulation is reducing heat loss on the home under construction. In these dark areas, the thermal bridging of the wood framing has melted the frost, creating the appearance of dampness. More heat from the home is lost through the studs than through the insulation, creating areas where the frost is melted at the location of the studs.

To become more thermally efficient, it is important to provide a break between thermal bridges. The use of continuous exterior insulation at above- and below-grade wall transitions, as well as at floor and roof transitions, has a significant impact on reducing thermal bridging in wall assemblies. For several years now, continuous insulation (c.i.) for masonry veneers has been achieved by placing shelf angles on insulation standoffs. A common method to create an insulation stand-off uses steel knife plates welded onto the shelf angle, which are then welded to concrete embed plates that are anchored to concrete

Figure 1

Thermal bridging of wood-framing on a home under construction.

Figure 2



2D and 3D details of a knife plate standoff on a concrete block brick veneer wall assembly.

foundations (or floors), as illustrated in Figures 2 and 3 (page 30). This knife plate stand-off allows for insulation to be installed behind the shelf angle, providing c.i. above and below grade with insulation that is in direct contact with the backup wall.

Alternatively, steel or fiber-reinforced polymer (FRP) hollow structural sections (HSS) stand-offs can be bolted to the structure to provide the space for the insulation to be installed behind the shelf angle, as illustrated in Figure 4 (page 30).

Lastly, proprietary pre-engineered stand-off systems can also be used, as illustrated in Figure 5 (page 30).

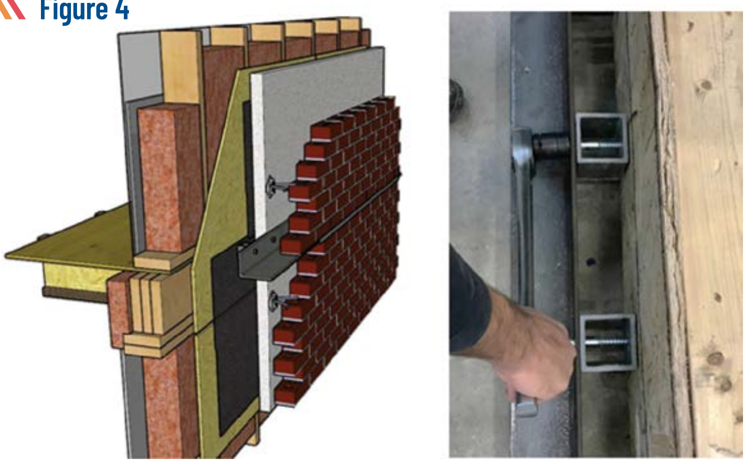
The advantage of the HSS sections or proprietary stand-offs is that they are bolted to the structure and can be installed by the mason. Bolting also avoids welding, which is advantageous when anchoring to wood structures.

Like shelf angles that are directly bolted to concrete or wood framing, the design of shelf

Figure 3

Knife plate standoff on a concrete block brick veneer wall assembly in a school.

Figure 4



Hollow structural sections (HSS) standoff detail to a wood-framed floor assembly and installation of fiber-reinforced polymer (FRP) HSS standoffs in a laboratory.

PHOTO COURTESY SHIVAM SHARMA/UNIVERSITY OF WINDSOR

Figure 5

Proprietary pre-engineered insulation standoff systems.

PHOTO COURTESY JEFFREY HUNG/ FEROCORP

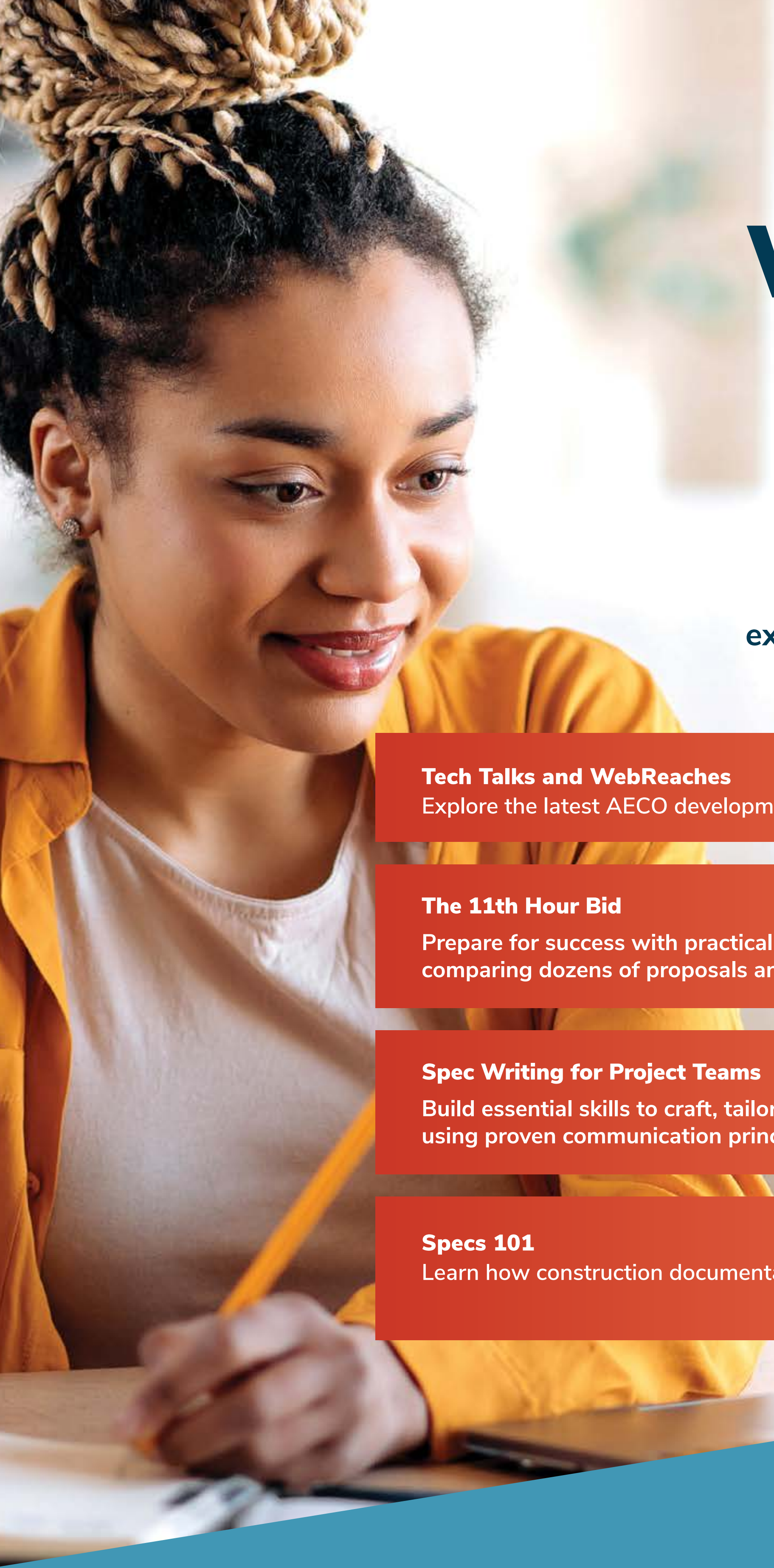
angles on insulation stand-offs represents the intersection of masonry and steel design, depending on the building's primary structural system, which can be concrete, steel, or wood. Often regarded as a "steel" design or a "concrete" design problem, rather than a "masonry design" problem, very little research or design guidance is available for the design of shelf angles on stand-offs. As with directly bolted shelf angles, this often leads to the oversizing of shelf angles, insulation stand-offs, bolts, and embed plates for shelf angles when c.i. is being used.

Recent testing and research on shelf angles anchored to concrete foundations and wood framing have provided insight into the behavior and structural capacities that can be expected from these systems.

This article provides examples and discusses testing and research results of masonry veneers on knife plate, HSS, and proprietary stand-offs. It will also discuss the resulting strategies for a more efficient design of steel shelf angles on knife plate stand-offs.

Testing results of HSS and proprietary stand-offs anchored to wood-frame floors

Shelf angles bolted to 102 mm (4 in.) long FRP HSS 76 x 76 x 6 mm (3 x 3 x 0.25 in.) and anchored to three-ply 2x12 spruce-pine-fir (SPF) No.2 rim boards on a wood-framed floor system were tested to failure between 2021 and 2023. Figure 6 (page 32) illustrates the specimen being tested.



Test specimen	Failure load kN (lb)	Deflection at failure (mm)	Factor of safety
Lag screw with 3 in. (76 mm) deep FRP HSS standoff -1	28 (6,292)	37.7	3.5
Thru-bolt with 3 in. (76 mm) deep FRP HSS standoff -1	28 (6,292)	30	3.5
Lag screw with 3 in. (76 mm) deep FRP HSS standoff -2	30 (6,742)	43.8	3.8
Thru-bolt with 3 in. (76 mm) deep FRP HSS standoff -2	49 (11,101)	69	6.1
Lag screw with 2 in. (51 mm) deep FRP HSS standoff -1	47 (10,562)	41	5.9
Thru-bolt with 2 in. (51 mm) deep FRP HSS standoff -2	72 (16,180)	72.7	9.0
*Shivam Sharma/University of Windsor			

Table 1: Test results of shelf angle on FRP HSS standoff on wood-frame floor

Figure 6

Typical specimen for shelf angles on 102 x 76 x 6.4 mm (3 x 3 x 0.25 in.) fiber-reinforced polymer (FRP) hollow structural sections (HSS) standoffs.

PHOTO COURTESY SHIVAM SHARMA/UNIVERSITY OF WINDSOR

Figure 7

Typical specimen being tested with shelf angle on a proprietary standoff.

PHOTO COURTESY AARISH KHAN/UNIVERSITY OF WINDSOR

The mode of failure was either rotation or splintering of the SPF No. 2 rim board, rather than withdrawal of the lag screw or thru-bolt. The results of the testing are found in Table 1.

The results presented in Table 1 indicate a safety factor ranging from 3.5 to 3.8 was achieved for 76 mm (3 in.) insulation stand-offs. For 51 mm (2 in.) insulation stand-offs, a safety factor of between 5.9 and 9 was obtained. This analysis assumes the weight of 3 m (10 ft) of brick veneer, which is approximately 7.99 kN (1,796 lb), is acting on the shelf angle mounted on the stand-off. This indicates 3 m (10 ft) brick veneer can be safely carried by the FRP HSS systems. It is important to note that the cantilevering of the through-bolt or lag screw through the HSS section reduces the structural capacity of the system as compared to proprietary systems that directly bolt to the SPF rim board.

The test was repeated using a proprietary shelf angle stand-off. Once again, the proprietary standoff and shelf angle were anchored to three-ply 2x12 SPF rim boards on a wood-framed floor system and tested to failure, as shown in Figure 7.

As with the FRP HSS stand-offs, the mode of failure was either rotation or splintering of the SPF rim board, rather than withdrawal of the lag screw or thru-bolt. The results of the testing are found in Table 2 (page 33).

The results presented in Table 2 demonstrate safety factors ranging from 9.2 to 12.8 for 51 mm (2 in.) insulation stand-offs without a shim. For the proprietary stand-offs with a shim providing 76 mm (3 in.) insulation, safety factors ranging from 9.6 to 10.4 were observed. These calculations were once again based upon the assumption that a weight of 3 m (10 ft) of brick veneer, approximately 7.99 kN (1,796 lb), was acting on the shelf angle on a proprietary stand-off. This indicates that the proprietary systems can also safely support 3 m (10 ft) of brick veneer. Further, the ability to directly bolt to the SPF rim board using the proprietary system significantly enhances its structural capacity when compared

Table 2: Test results of shelf angle on Fero-Fast Bracket standoff on wood-frame floor

Test specimen	Failure load kN (lb)	Deflection at failure (mm)	Factor of safety
Lag screw specimen @ 12-in. (305-mm) o.c. Fero-Fast bracket-1 (without Fero shim)	73 (16,404)	28.1	9.2
Thru bolt specimen @ 12-in. (305-mm) o.c. Fero-Fast bracket-1 (without Fero shim)	102 (22,921)	54.8	12.8
Lag screw specimen @ 12-in. (305-mm) o.c. Fero-Fast bracket-2 (with Fero shim)	77 (17,303)	44.7	9.6
Thru bolt specimen @ 12-in. (305-mm) o.c. Fero-Fast bracket-2 (with Fero shim)	83 (18,652)	52.6	10.4

*Aarish Khan/University of Windsor

Table 3: Test results of shelf angle on knife plate stand-offs

Load point	Shelf angle with brick and ties		Shelf angle only	
	Axial load (kN)	Shelf angle deflection (mm)	Axial load (kN)	Shelf angle deflection (mm)
Weight of 7 m (24 ft) of brick	15.17	0.6872	17.08	2.979
Failure load	96.84	23.99	126.6	34.3
Factor of safety	5.7		7.4	

*Cory Scott/University of Alberta

to the cantilevered lag screws and through bolts used with the HSS stand-offs. The proprietary system more than doubles the capacity of the 76 mm (3 in.) specimen, achieving an ultimate load of 77 kN (18,652 lb), compared to the HSS system's 30 kN (6,752 lb).

The conclusion is that either standoff system can be used with wood-frame floor systems to provide c.i. for shelf angles at floor transition locations in wood-frame buildings.

Figure 8

Shelf angle on knife plate standoff with masonry ties and brick veneer specimen and test setup.

PHOTOS COURTESY CORY SCOTT AND CLAYTON PETTIT/UNIVERSITY OF ALBERTA

Testing results of steel knife plate stand-offs anchored to concrete foundations

A 102 x 102 x 6 mm (4 x 4 x 0.25 in.) shelf angle welded onto 127 x 102 x 19 mm (5 x 4 x 0.74 in.) steel knife plate stand-offs that were anchored to embed plates on concrete foundations were tested to failure in 2025. In addition to using steel knife plates, stand-offs, and concrete structures, these tests also differed from the wood-floor tests in that the effects of the masonry ties and brick veneer on the deflection of the shelf angle were also explored as part of the research. The shelf angle on knife plates with masonry ties and brick veneer is illustrated in Figure 8. An axial load of 15.17 kN (3,410 lb) was applied to the top of the 813 mm (32 in.) tall brick veneer (Figure 8), which delivered a total axial load equivalent to the weight of 7 m (24 ft) of clay brick veneer on the specimen. The deflection of the shelf angle on knife plates was then measured at this load. The results are found in Table 3.

The specimen was then taken to failure. Failure occurred at a load of 96.8 kN (21,708 lb), providing a factor of safety of 5.6. The ultimate failure resulted from the embed plate tearing out, as shown in Figure 9 (page 34).

The effect of the masonry ties and brick veneer on shelf angle defection was investigated by conducting comparison tests that ignored the effects of the masonry ties. In these tests, the effects of the masonry tie and brick veneer were eliminated by applying a load of 17.08 kN (3,839 lb) to the bare shelf angle specimen, as

Figure 9

Shelf angle on knife plate standoff with masonry ties and brick veneer at failure—tear out of embed plate.

shown in Figure 10. The test method was identical to those conducted on the wood-frame floors, which also ignored the effects of masonry ties and brick veneer by applying the load directly to the shelf angle.

Failure of the specimen occurred at a load of 126.6 kN (28,449 lb). As with the shelf angle on knife plates with masonry ties and brick veneer, the ultimate failure resulted from the tear out of the embed plate, as can be seen in Figure 11.

The results of the testing are presented in Table 3 for easy comparison.

The testing demonstrated that with a service load (weight of 7 m [24 ft] of veneer) applied to the shelf angle on knife plate specimens with masonry ties and brick veneer, a deflection of 0.6872 mm (0.0271 in.) occurred. In contrast, the testing of the shelf angle on the bare knife plate experienced a significantly larger deflection at the service load of 2.979 mm (0.1173 in.) or about 433 percent more deflection. These results demonstrate that the effects of the masonry ties and brick veneer are clearly reducing the deflection of the shelf angle and should not be ignored. However, the testing also demonstrated that a full moment connection between the shelf angle and the brick veneer, when structurally analyzing the system, may be too generous, as the deflection from testing is approximately 50 percent more than the deflection predicted using a full moment connection. It appears that the brick veneer shelf angle system would be better represented using a rotational spring at the brick veneer/shelf angle interface, so that the deflection-reducing effects of the masonry ties on the shelf angle are more accurately captured.

Design of knife plate stand-offs using the force method and virtual work

A new design approach is necessary to more accurately consider the interaction between the tied masonry veneer and the shelf angle, thereby better capturing the deflection-reducing effects of masonry ties and brick veneer on shelf angles with knife plate stand-offs that support masonry veneers. The proposed design method uses the force method in combination with virtual work to address the one-degree statically indeterminate system created by the introduction of the tie restraining force (R_{TIE}) at the first course of ties, as illustrated in the free body diagram shown in Figure 12 (page 36).

From Figure 12 (page 36), the following parameters are required to use the force method and virtual work supporting 7 m (24 ft) of brick veneer:

- b = Knife plate spacing = 813 mm (32 in.)
- P = Unfactored (service load) of masonry veneer and shelf angle (N) = 11,506 N (2,586 lb)
- P_f = Factored load of masonry veneer and shelf angle (N) = 16,108 N (3,620 lb)
- R_{TIE} = Reaction force in the brick ties at the first course of ties (kN)
- V_f = Reaction force in the brick ties at the first course of ties (kN)
- T_f = Reaction force in the brick ties at the first course of ties (kN)
- C_f = Reaction force in the brick ties at the first course of ties (kN)
- t_angle = Thickness of the horizontal leg of the angle = 7.9 mm (0.3 in.)
- L_knife = 127 mm (5 in.)
- b_knife = 19 mm (0.75 in.)
- h_knife = 102 mm (4 in.)
- t_veneer = Thickness of the masonry veneer = 92 mm (3.6 in.)
- t_airspace = 25 mm (1 in.)
- V-tie_radius = 2.4 mm (0.09 in.)

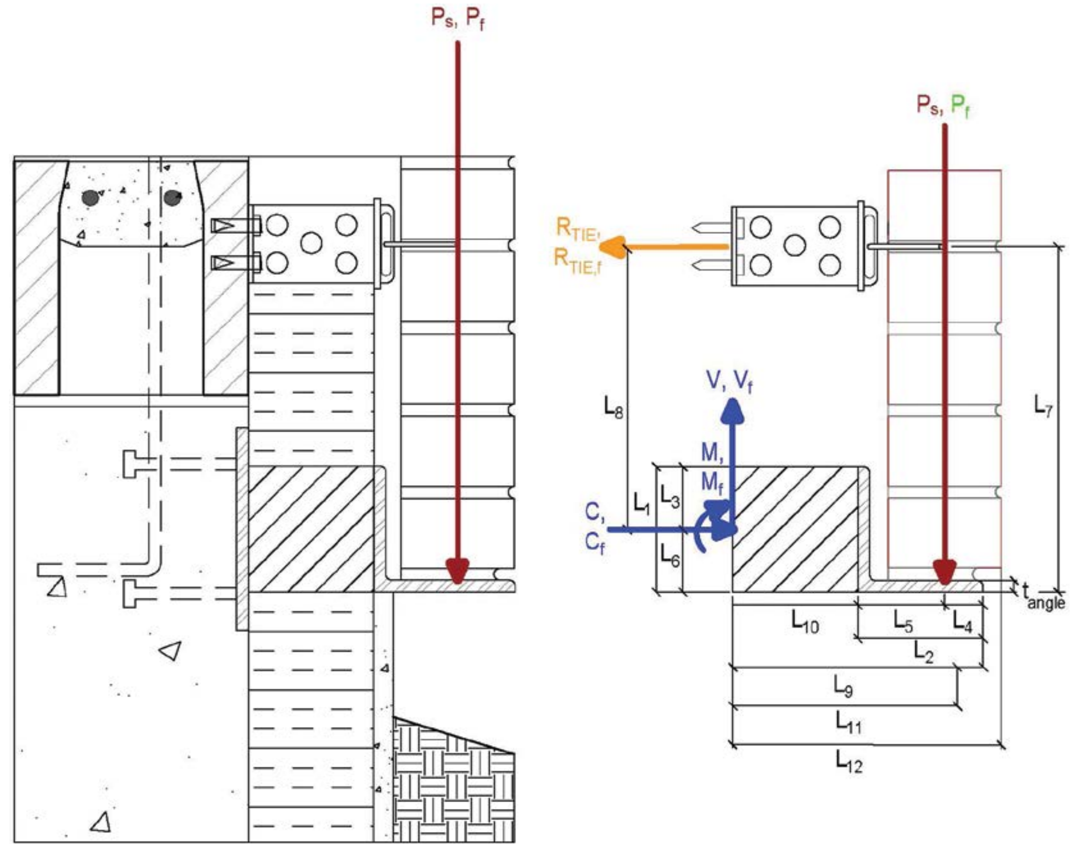
Figure 10

- L1 = Vertical leg length = 103 mm (4 in.)
- L2 = Horizontal leg length = 103 mm (4 in.)
- L3 = Vertical distance to the center of the knife plate = 51 mm (2 in.)
- L4 = L2 – L5 = 30 mm (1.19 in.) for imperial modular brick
- L5 = Eccentricity of veneer load = Air space + veneer thickness/2 = 72 mm (0.28 in.)
- L6 = L1/2 = 51 mm (2 in.)
- L7 = Max 300 mm (12 in.) from base support = 278 mm (11 in.)
- L8 = Vertical distance between the ties and the center of the knife plate = 228 mm (9 in.)
- L9 = Distance from vertical shelf angle to centroid of brick
- L10 = Length of the knife plate = 127 mm (5 in.)
- L11 = Distance from start of knife plate to centroid of brick = 199 (8 in.)
- L12 = Total horizontal distance = L_knife + t_airspace + t_veneer = 245 mm (10 in.)
- f'm = The compressive strength of the masonry veneer = 12 MPa (1,740 psi)
- Em = Modulus of elasticity of the masonry veneer = 850 f'm = 10,200 MPa (1.4 million psi)
- Es = Modulus of elasticity of structural steel = 200,000 MPa (29 million psi)

Figure 11

Figure 10 and 11: Shelf angle on knife plate stand-off specimen.

Figure 12



Free-body diagram of shelf angle at foundation—statically indeterminate.

ILLUSTRATIONS COURTESY ALBERTA MASONRY COUNCIL

$$R_{TIE} = \frac{\dfrac{\left(L_5 \cdot L_6{}^2 - 2 \cdot L_5 \cdot L_6 \cdot L_7 - L_5{}^2 \cdot L_7\right) \cdot P}{2 \cdot E_s \cdot I_{angle}} + \dfrac{\left(L_8 \cdot L_{10}{}^2 - 2 \cdot L_8 \cdot L_{10} \cdot L_{11}\right) \cdot P}{2 \cdot E_s \cdot I_{knife}}}{\dfrac{L_6{}^3 + 3 \cdot \left(L_6 \cdot L_7{}^2 - L_6{}^2 \cdot L_7 + L_5 \cdot L_7{}^2\right)}{3 \cdot E_s \cdot I_{angle}} + \dfrac{L_7{}^3}{3 \cdot E_{m,effective} \cdot I_{veneer}} + \dfrac{L_6 \cdot L_8}{E_s \cdot I_{knife}}}$$

- I_angle = b · t_angle^3 / 12 = 21,337 mm^4 (0.013 in.^{4})
- I_knife = b_knife · h_knife^3 / 12 = 1.6 million mm^4 (1.01 in.^{4})
- I_veneer = b · t_veneer^3 / 12 == 65 million mm^4 (39.74 in.^{4})
- I_tie = 4 · [ϖ·V-tie_radius^4 / 4] = 104 mm^4 (0.00064 in.^{4})

To use the force method, the statically indeterminate structure was made determinate by introducing a release. In this case, the release chosen was at the tie and labeled "Coordinate 1" in Figure 13. The service load, P, and a unit load at "Coordinate 1," were then applied to the released (determinate) structure.

A partial moment connection mimicking the introduction of a rotational spring at the brick veneer steel/shelf angle interface was simulated by reducing E_m to $E_{m,\ effective}$ to account for the reduced rotational stiffness at this interface. This partial moment connection reduces the tension load in the ties and increases the shelf angle deflection when calculated using the force method and virtual work. $E_{m,effective}$ was determined to be $^1/_{100}{}^{th}$ of E_m. This value for $E_{m,\ effective}$, was calibrated based on testing results, which provided the same deflection of 0.6872 mm (0.0271 in.) at a 17.08 kN (the weight of 7 m [24 ft] of brick veneer) on the shelf angle.

The proof of the following equations is beyond the scope of this paper, but can be determined by applying the force method and virtual work to the free-body diagram in Figure 13.

Once R_{TIE} has been determined, virtual work is applied again to obtain the deflection at the tip of the shelf angle on the knife plate stand-off at Point D in Figure 13. Without proof, the equation is as follows:

$$\Delta_C = \frac{L_5 \cdot \left[T_u \cdot \left(2 \cdot L_6^{\,2} \cdot T_s - L_6 \cdot L_7 \cdot R_{TIE}\right) + \left(2 \cdot L_7^{\,2} \cdot R_{TIE} \cdot R_{TIE_u} - L_6 \cdot L_7 \cdot R_{TIE_u} \cdot T_s\right)\right] + 2 \cdot L_6^{\,3} \cdot T_s \cdot T_u}{6 \cdot E_s \cdot I_{angle}} + \left(\frac{L_7^{\,3} \cdot R_{TIE} \cdot R_{TIE\_u}}{3 \cdot E_{m,effective} \cdot I\_veneer}\right)$$

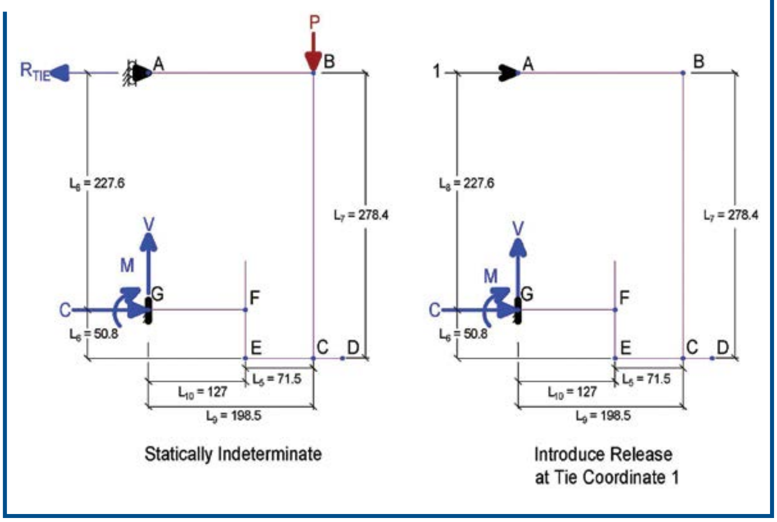
$$\Delta_D = \left(\frac{-R_{TIE} \cdot L_7}{2 \cdot E_s \cdot I\_angle}\right) \cdot L_4 + \Delta_C$$

Entering the numbers into these equations demonstrates a deflection of 0.46 mm (0.018 in.), which is less than the L/480 limit of 0.51 mm (0.02 in.).

The testing results and design method proposed results in more efficient designs for both the shelf angle and the knife plates used as stand-offs to provide c.i. for full bed brick veneer installations and in this particular case permit installations of up to 7 m (24 ft) of brick veneer using a 102 x 102 x 7.9 mm (4 x 4 x 0.31 in.) shelf angle welded to 127 x 102 x 19 (5 x 4 x 0.75 in.) steel knife plate stand-offs, which are then welded to embed plates anchored in concrete foundations or floors. Past observations of this type of construction on a school used the same size knife plates, same knife plate spacing, and same shelf angle size to support 4 m (14 ft) of masonry veneer 3 m (11 ft). Applying the new design method suggests that with the same knife plate spacing of 813 mm (32 in.) o.c., the knife plate thickness could be reduced from 19 mm (0.75 in.) to 15.9 mm (0.63 in.), and the shelf angle size thickness could be reduced from 102 x 102 x 7.9 mm (4 x 4 x 0.31 in.) to 10 2x 102 x 6.4 mm (4 x 4 x 0.25 in.) and still be sufficient to support 4 m (13 ft) of veneer.

Optimizing the shelf angle design leads to smaller shelf angles and knife plates, which not only reduce costs but also enhance thermal performance and decrease the system's carbon footprint.

Figure 13



Indeterminate structure and reactions on the released structure.

additional information

AUTHOR

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KEY TAKEAWAYS

Thermal bridging significantly reduces envelope performance; however, continuous exterior insulation and standoff shelf angle systems help mitigate these bridges compared to traditional methods of supporting the brick and integrating continuous exterior insulation. Structural performance testing modeled in the sample panels and outlined in the figures shows both HSS and proprietary standoffs safely support brick veneer, with proprietary systems offering higher capacity. Knife-plate testing reveals that masonry ties greatly reduce shelf-angle deflection. A new design method enables slimmer, more efficient shelf angles, improving performance and lowering material and carbon costs.

MASTERFORMAT NO.

04 05 19—Masonry Anchorage and Reinforcing
04 20 00—Unit Masonry
07 21 00—Thermal Insulation

UNIFORMAT NO.

B2010—Exterior Walls
B2010.20—Wall Construction

KEYWORDS

Division 04, 07
Masonry
Shelf angles
Standoffs
Thermal bridging

Bringing Acoustics to Hardware

The Science Behind Low-noise Design

By Anthony Gambrall

PHOTOS COURTESY BUILDERS HARDWARE MANUFACTURERS ASSOCIATION (BHMA)

Increasingly, building projects are not only concerned with requirements such as safety and energy efficiency, but also occupant comfort. One aspect of this is noise. Noise from HVAC units, noise from other work areas, and noise from door hardware. How many times has a person's concentration been disrupted at a meeting or conference by someone entering or exiting the room? It is essential to specify door hardware for those areas of the building that require an additional level of quiet. The Builders Hardware Manufacturers Association (BHMA) has undertaken the task of determining door hardware suitable for quiet environments with its new standard, ANSI/BHMA A156.42, *Acoustic Performance Rating for Operational Noise of Architectural Hardware*.

BHMA is the trade association for North American manufacturers of commercial builders' hardware. The organization is involved in standards, codes, life-safety regulations, and other activities that influence performance

requirements for products such as locks, closers, exit devices, and related components. BHMA is the only organization accredited by the American National Standards Institute (ANSI) to develop and maintain performance standards for locks, closers, exit devices, and other builders' hardware. BHMA currently has more than 40 ANSI/BHMA standards. The widely known ANSI/BHMA A156 series of standards sets performance criteria for an array of products, including locks, closers, exit devices, butts, hinges, power-operated doors, and access control products.

With A156.42, BHMA is once again looking to stay abreast of market needs. There are studies detailing the effects of extraneous noise in various environments. The studies show many factors contribute to the issue. The BHMA member companies have decided to address this problem and ensure that their products are part of the solution. But the concept of "quiet" is not easily quantifiable and varies considerably for different applications. In a medical environment, acceptable noise levels differ significantly from those in a conference room.

The development of the standard took a total of six years. A significant factor during this time frame was the lack of acoustical measurement expertise within the BHMA membership. So, forming a strong partnership with a sound laboratory was essential.

First on the list of developments was a test fixture. Above all, it had to be acoustically dead. Noise from external elements can be hard to remove from recordings and will impact the product's sound. Additionally, it had to be able to accommodate a wide variety of products and facilitate quick changeovers. After several iterations, a fixture was developed to meet this criterion; in testing, it did not add any extraneous noise to the recording.

Next, a testing procedure needed to be developed. The cadence established is a combination of real-world usage and limitations on recording. The real-world aspect was determined by averaging field measurements, such as the speed at which a bar is pushed and released, the rate at which a lever is turned, and the rate at which a door closes. Recording restrictions are necessary not only because of the large file sizes, but also because long recordings make it more difficult to identify specific areas of concern.

The testing cadence is broken up into three main activities:

- Door opening—Actuation of the product and opening the door (*e.g.* turning a lever or pushing a bar).
- Product release—With the door in a fixed open position, the actuation point of the product is released (*e.g.* letting go of a lever or bar).
- Door closing—A weight system pulls the door closed at a fixed speed, allowing the product to latch.

These three activities define typical door operation, allowing manufacturers to focus on areas for improvement. When aspects, such as pushbar actuation versus release, are evaluated separately and receive their own score, it helps the manufacturer determine where to allocate design effort. Further, each activity is monitored for execution speed, which includes avoiding excessive pushing or turning, as well as measuring

The first development was a test fixture designed to be acoustically dead, minimizing external noise that could affect recordings. It also needed to accommodate various products and allow for quick changeovers. After several iterations, a fixture was created that met these requirements and did not introduce any additional noise during testing.

the total time taken to complete the activity. If any of these parameters fall outside specified values, the recording is rejected, and a new one is taken. All actuations are performed by human hands. The lab has experience with this and found that non-human actuation introduces noise.

Lastly, products were needed to test. With multiple door hardware companies participating, a wide range of products was tested to achieve not only a broad application range but also a diverse sound range. Once the "what," "where," and "how" were determined, the recording process began. Testing was conducted in a semi-anechoic sound chamber, with the fixture and testing procedure in place. There were 10 recordings made for each activity, each two seconds long.

Once the recordings were finished, an analysis of the recordings began. At first, a simple analysis was considered using Peak Instantaneous Loudness. It was quick and understandable, but too general to decide what a quiet device was. Even when products deemed quiet were tested, it was not possible to distinguish them from other products. Due to the lack of clear product delineation, the BHMA team and testing laboratory personnel concluded that this analysis was inconclusive.

The subsequent phase involved evaluating the recordings by a sound jury. A sound jury is comprised of a group of impartial individuals who assess a variety of sounds, rating each based on how it might be perceived in a quiet setting. In this study, a total of 53 jurors from diverse demographics participated in sessions lasting 45 minutes. Each participant engaged in four paired comparison tests and one semantic differential test.

During the paired comparison test, jurors listened to two sample sounds and indicated which one they found to be less disruptive. Following this, participants ranked the sounds on scales that represented opposing extremes, such as "annoying" and "pleasant," during the semantic differential test. The sounds from the three activities were interspersed throughout the evaluation process, yielding valuable insights into the results of the paired comparisons.

From an analysis of the sound jury's preferences of the recorded sounds, a characteristic curve was created for each of the three activities. The curve is defined by taking sounds from an activity and ranking them from least disturbing to most. This curve, then, can be used to conduct a correlation study to compare which sound quality metrics correlate most strongly. The sound quality metrics, such as amplitude, roughness, tonality, and modulation, are the computed objective parameters for each sound. There are more than 30 metrics available for comparison. Once the top two or three best-fitting metrics have been identified, a regression equation is created. Using this equation, BHMA estimated a sound's position on the jury's original characteristic curve. This helps quantify whether a door hardware sound from a specific action is considered more or less perceptually intrusive.

The regression equations are key to answering the question, "What is quiet door hardware?" The backbone of the equations is based on end-user preferences and is further strengthened by solid sound quality metrics. This gives confidence that products meeting A156.42 are the best choice for noise-sensitive environments that need an extra level of quiet.

To come full circle, the same products that were deemed "inconclusive" in the loudness analysis were re-analyzed with the regression equations, and quiet products were discernible from their counterparts. Since then, there has been a solid division, which led to the creation of a numerical threshold in the standard. Products that score above this threshold in each of the three activities are considered appropriate for use in a quiet environment.

As with all BHMA standards, products that are certified to A156.42 are listed in the BHMA Certified Product Directory. On the landing page, select A156.42 as the standard, and a list of products with manufacturers' names and model numbers will be displayed. Additionally, each product certified to A156.42 must also pass certification for its mechanical standard; however, it does not replace mechanical requirements. The mechanical standard and grade level will be part of the A156.42 listing. It is crucial for the specified product to meet additional code criteria.

Left: A sound jury is comprised of a group of impartial individuals who assess a variety of sounds, rating each based on how it might be perceived in a quiet setting.

Below: With A156.42, Builders Hardware Manufacturers Association (BHMA) is looking to stay abreast of market needs. There are studies detailing the effects of extraneous noise in various environments.

additional **information**

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Tony Gambrall serves as the Builders Hardware Manufacturers Association (BHMA) director of standards. He coordinates the development and revision of the BHMA performance standards for building hardware products. He came to BHMA following a career in door hardware manufacturing, focusing on the areas of product testing and development. During this time, Gambrall was also a BHMA member participating in and chairing the development of standards. He can be reached at agambrall@kellencompnay.com.

KEY TAKEAWAYS

The new ANSI/BHMA A156.42 standard provides a measurable method for evaluating quiet door hardware, using specialized fixtures, human-actuated testing, and sound-jury analysis. Regression-based thresholds now define what qualifies as "quiet," and certified products must also meet their mechanical standards, giving designers clearer guidance for noise-sensitive environments.

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Let It Snow: Coatings and Permeability

Ornamental plaster ceilings are a prominent feature of many historic interior spaces, but they can present unique maintenance and repair challenges. In a recent project at a historic theater, deteriorated gypsum material was observed to filter down from the ceiling into the auditorium during performances, described on-site as "snowing." After inspection, it was found that deteriorated paint and powdery gypsum plaster can detach from the substrate and pass through cracks and other voids. Determining the source of this deterioration raised questions about how to repair and preserve the ornamental ceiling.

In the subject building, a historic theater located in a moderate climate in the United States, the coffered ceiling is composed of individual castings of fiber-reinforced gypsum plaster. The molded fiber-reinforced elements were created by pressing a mixture of plaster and plant fibers or animal hair into molds. The cast plaster elements were tied to a metal framework support system within the attic using tie wires and wadded plaster. The finish paint on the auditorium side features various colors of decorative glaze and metallic painted finishes.

Figure 1

The surface of the ceiling within the auditorium exhibited areas of loose finish and friable, powdered gypsum.

PHOTOS COURTESY WISS, JANNEY, ELSTNER ASSOCIATES (WJE)

Figure 2

In a previous repair, the attic-facing side of the ceiling had been covered with a relatively thick acrylic coating.

During a previous repair, the entire attic-facing surface of the ceiling was coated with a sprayed acrylic. This acrylic was reportedly applied to reinforce the connection between the plaster ceiling and its support system. Although intended to strengthen the plaster as a consolidant, the material did not penetrate the plaster but instead formed a thick surface coating.

The acrylic coating on the attic side was found to have low vapor permeability, and the glazed ornamental finishes on the auditorium side also have low permeability. As originally designed, the ceiling allowed moisture to escape by drying toward the attic. However, adding a low-permeability coating on the attic side severely retarded this evaporation, trapping moisture within the plaster matrix. Vapor from high interior humidity and bulk water infiltration can degrade the gypsum, causing the plaster to powder and the surface finish paint to delaminate. Additionally, as is common in older theaters, air conditioning was installed in the auditorium, which can cause a reverse vapor drive (toward the interior) during summer months, as the plaster dries toward the conditioned space.

When a historic assembly, such as the plaster ceiling in this theater, is comprehensively modified by applying a new material, such as an acrylic coating, it is important to consider all potential impacts of the change. In this project, the coating was primarily applied for structural purposes—to hold the plaster in place—but its effects on moisture management were overlooked. A more thorough review of system performance, including aspects like thermal and moisture control, fire safety, structural integrity, and material compatibility, is advisable.

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