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Massachusetts' Stretch Code sets a new benchmark as the most stringent building energy code in the United States. Rooted in the state's 2021 Next Generation Road Map Act, the code emphasizes an envelope-first strategy to reduce heating loads, address thermal bridging, and drive decarbonization through heat-pump deployment. With strict limits on vertical envelope performance and no tradeoffs allowed with shorter-lived systems, it challenges design teams to deliver durable, high-performance building solutions.

See article on page 7.

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The Envelope Challenge

Meeting *Massachusetts Stretch Code*

By Helen Sanders, PhD, and Fred Worm

PHOTO COURTESY TECHNOFORM

***Massachusetts' Stretch Code* is arguably the most stringent building energy code in the United States.** It was developed in response to Massachusetts' *2021 Next Generation Road Map Act*. According to Paul Ormond, from the Massachusetts Department of Energy Resources, the code is designed to "crush heating" loads, facilitating building decarbonization through heat-pump deployment. While heating loads are typically not the largest energy load in Massachusetts' buildings, even at an estimated 15 percent of the total energy use intensity (EUI), these loads limit the practical implementation of electric heat pumps (Figure 1, page 8).

Based on the 2021 I*nternational Energy Conservation Code* (*IECC*), Massachusetts has incorporated additional challenging thermal performance requirements for above-grade vertical building envelopes. These requirements represent a step change from any other jurisdiction in the U.S. and have caused compliance challenges across the entire design-build-material value chain. It has become especially challenging to design and effectively specify vertical above-grade building envelopes to ensure the building is stretch code-compliant. This article illustrates how to manage those challenges.

Note that the *Massachusetts Stretch Code* uses inch-pound units for all its requirements. When reviewed herein, these are converted to SI units, with the code's inch-pound units following.

Envelope-first focus

At its core, the *Massachusetts Stretch Code* is designed to preserve building envelope performance. It is the first energy code in the U.S. to fully address the impact of thermal bridging on vertical building envelope U-factor. It also has stringent air infiltration requirements based on the 2024 *IECC* and 75 percent ventilation heat recovery.

Critically, it does not permit designers to trade off reductions in vertical envelope thermal

figure 1

figure 2

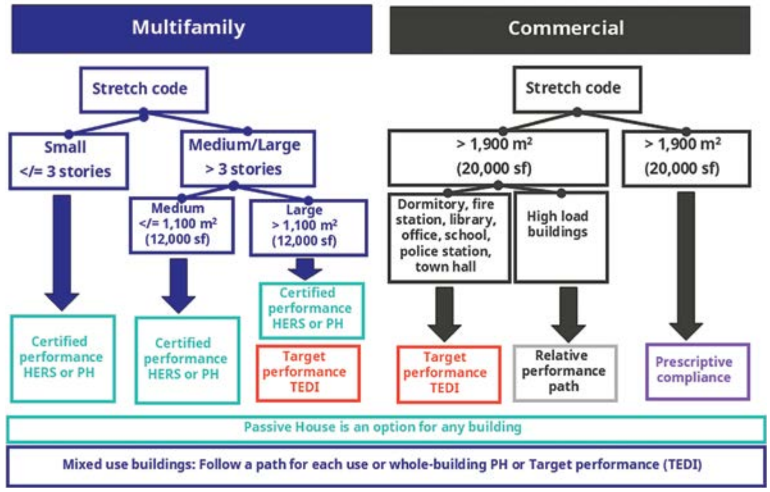

figure 3

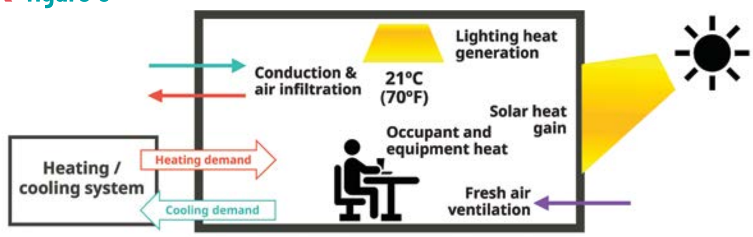

FIGURE 1: Challenges of heat pump deployment when heating loads are too high.
PHOTO BY ENRICO BONILAURI, EMU PASSIVE

FIGURE 2: The compliance pathways (Prescriptive, Relative Performance, Thermal Energy Demand Intensity [TEDI], Passive House [PH], and Home Energy Rating System [HERS]) in the *Massachusetts Stretch Code* and where they can be used.
DIAGRAMS COURTESY TECHNOFORM

FIGURE 3: Thermal Energy Demand Intensity (TEDI) for heating and cooling. TEDI for heating or cooling is the annual heating or cooling demand required to maintain the desired indoor temperature and ventilation per unit floor area, respectively.

performance with increasing roof performance. This often-used strategy would lead to increases in the insulation of the already high-performance roof and degradation of the vertical envelope. Roofs, below-grade walls, floors, slab-on-grade floors, and opaque doors with minor exceptions must comply with the values in Table C402.1.4 of the base 2021-*IECC* code. The performance of the vertical envelope also cannot be traded off for increases in performance of systems such as HVAC and lighting. These systems typically have much shorter service lives than the envelope and are more easily upgraded to the newest technology on a shorter lifecycle than the building envelope. In contrast, the performance choices made for the building envelope are baked in for many decades. There is a maximum vertical envelope thermal transmittance (U-factor) limit (also known as a backstop) in all compliance paths.

Additional thermal performance requirements apply when glazed walls—curtain walls, storefronts, or window walls accompanied by spandrel—are used. The requirements were designed to make it difficult, but not impossible, to design with glazed walls, which have higher transmittance than other wall types.

For designs where glazed walls (vision plus spandrel area) cover less than or equal to 50 percent of the wall area, the area-weighted U-factor must not exceed 0.73 W/m²K (0.1285 BTU/hr·sf·F). Where glazed walls comprise more than 50 percent of the wall area, the U-factor maximum is raised to 0.91 W/m²K (0.16 BTU/hr·sf·F). Note that "glazed wall area" should not be confused with "window-to-wall" ratio. The latter is the transparent area divided by the total wall area.

To prevent the tradeoff of the often-overestimated spandrel performance with transparent performance in glazed walls, the Massachusetts code also mandates a maximum glazed wall vision U-factor of 1.4 W/m²K (0.25 BTU/hr·sf·F). [Note: this is not the center-of-glass U-factor.] As described later, this maximum is

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figure 4

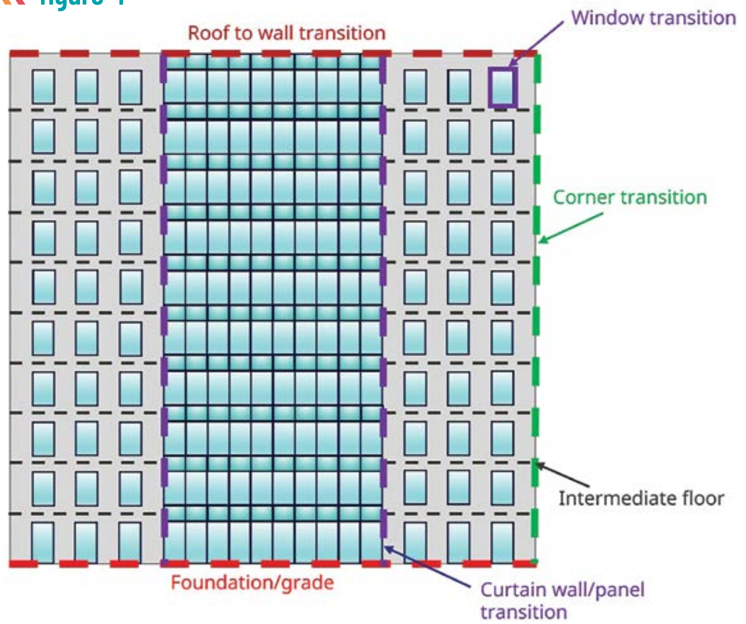


figure 5

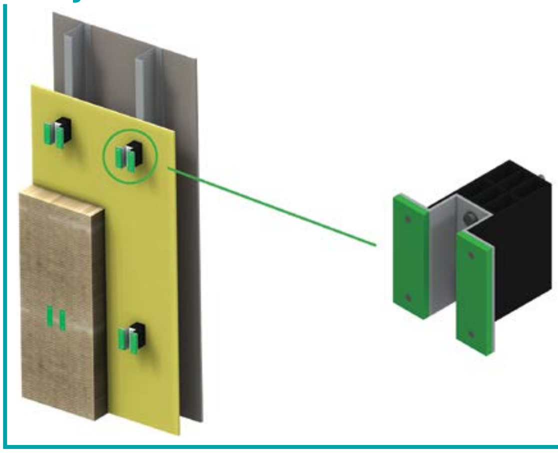


FIGURE 4: Facade example #1 with punched opening windows and a curtain wall covering less than 50 percent of the wall area. Thermal bridges that must be accounted for are identified with dotted lines.

DIAGRAM COURTESY TECHNOFORM

FIGURE 5: Thermal bridge mitigated rainscreen wall using cladding attachments and continuous insulation (c.i.), assumed in facade example #1. Detail 5.1.95 in the Thermal Bridging Guide (TBG).

DIAGRAM COURTESY STANTEC

moot in practice because much higher performance from the vision areas is typically needed.

Multiple compliance paths

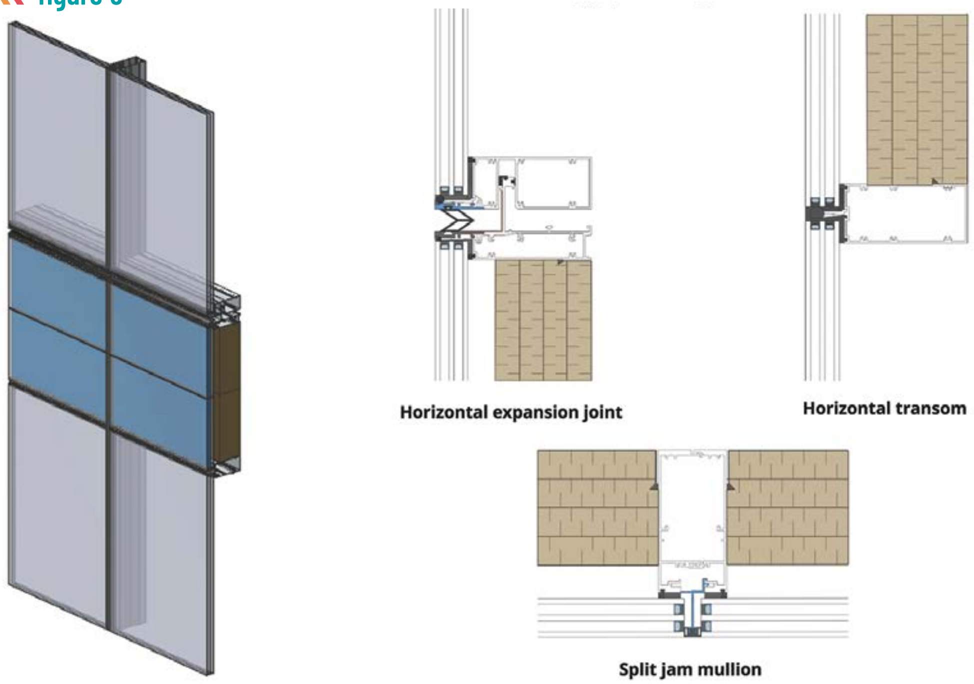
The *Massachusetts Stretch Code* allows five different compliance paths with limitations to their applications (Figure 2, page 8):

- Prescriptive path: Limited to buildings with a floor area less than 1,860 m^2 (20,000 sf), each building component must meet a prescribed performance. There is a component performance alternative within this path that allows for a tradeoff between envelope components, with some limits as described above. This sets the maximum envelope thermal performance (backstop) for the relative and target compliance paths.
- Relative performance path: Limited to use in high-load buildings, such as laboratories and hospitals. Based on Section 407 of the *IECC*, building simulation must show that the energy performance of the proposed building is better than that of a comparable building based on the code's prescriptive requirements. However, building envelopes must comply with the prescriptive path's envelope component alternative and limits.
- Target performance path: Must be used for commercial buildings more than 1,900 m^2 (20,000 sf) that are not high-load buildings. It is one of three choices for multifamily buildings over three stories and more than 1,100 m^2 (12,000 sf). It requires compliance through building simulation. The simulation must show that it meets an annual building EUI target and a performance target based on the thermal energy transfer across the building envelope called Thermal Energy Demand Intensity (TEDI). Figure 3 (page 8) illustrates the concept. There is a TEDI requirement to limit both heating and cooling demands, ensuring that overheating is also controlled. An envelope backstop based on the prescriptive requirement also applies.
- Home Energy Rating System (HERS): One of the compliance paths for multifamily buildings of any size with additional prescriptive requirements.
- Passive House Certification: Can be used for any building type and is one of the compliance choices for any multifamily building. Compliance is certified on as-built performance. Additional prescriptive requirements exist for roof reflectance, electrical power, documentation, maintenance, and commissioning.

Thermal bridge mitigation requirements

Fenestration assembly U-factors account for reductions in thermal performance in windows due to thermal effects at the edge of glass and the frame. Only recently have thermal bridges within opaque walls—including curtain wall spandrels and rainscreen panels (known as clear field thermal bridging)—been considered for *Massachusetts' Stretch Code* compliance. Thermal bridges at transitions between envelope systems and at penetrations have also been ignored. Estimates in BC Hydro's Thermal Bridging Guide (TBG), created by Morrison Hershfield (now Stantec), and referenced by the *British Columbia Step Code* and *Massachusetts Stretch Code*, suggest thermal bridging degrades the performance of opaque building envelopes by 20 to 70 percent.

figure 6



Structurally glazed curtain wall assumed in facade example #1 comprises triple-glazed infill with a center-of-glass U-factor of 0.67 W/m²K (0.118 BTU/hr•sf•F). Spandrel uses 130 mm (5 in.) of insulation. Detail 4.1.3 in the Thermal Bridging Guide (TBG) V1.8.

DIAGRAM COURTESY EVOKE

The stretch code requires thermal bridging in 11 different facade assemblies and linear interfaces to be accounted for, including:

- Cavity insulation between wall framing
- Brick ties holding brick panel sections to framing
- Fasteners for attaching wall panels to framing
- Balcony-to-wall interfaces
- Fenestration-to-wall transitions
- Wall-to-roof transitions (parapets)
- Wall-to-grade transitions
- Corner intersections
- Interior floor-to-exterior wall transitions
- Interior wall-to-exterior wall transitions
- Brick shelves

Thermal bridging is accounted for by applying thermal derating values to clear field U-factors, assigning thermal transmission values to linear transitions (psi-factors), and point thermal bridges (chi-factors) in the opaque wall areas of the vertical building envelope. The overall thermal performance of the vertical building envelope is an area-weighted average of the thermal transmittance of the derated opaque elements and the vision glazing.

The *Massachusetts Stretch Code* provides three alternative approaches to assigning thermal bridge derating values:

- Using prescriptive thermal conductance values that are defined for each type of thermal bridge. These values assume a very high thermal conductance. Adopting this compliance path causes many challenges in meeting the envelope thermal performance requirements.
- Reference thermal conductance values from the TBG when using assemblies listed in this guide. This path provides a way for design teams to more easily mitigate thermal bridging to ease compliance, while minimizing cost and complexity.
- 2D or 3D thermal simulation of the proposed clear field, and linear and/or point thermal

figure 7

A high-performance fenestration system reaching a system U-factor of 0.91 W/m²K (0.16 BTU/hr•sf•F) using 44-mm (1.7-in.) wide polyamide (PA) thermal barriers with foam-filled cavities to reduce conduction and convection.

PHOTO COURTESY WAUSAU WINDOW, APOGEE ARCHITECTURAL METALS

figure 8

Clear Field thermal transmission	Panel wall	Curtain wall spandrel	Punched window	Curtain wall vision	Total
Area, m² (sf)	565 (6,080)	186 (2,000)	229 (2,460)	381 (4,100)	1360 (14,640)
% of total area	41.5%	13.7%	16.8%	28.0%	100%
Clear field derated U-factor, W/m²K (BTU/°F.hr.sf)	0.33 (0.058)	0.65 (0.114)	0.91 (0.16)	0.94 (0.165)	0.64 (0.113)
Thermal transmission U-factor x area, W/K (BTU/°F.hr)	186 (353)	121 (228)	208 (394)	358 (677)	873 (1652)

Total thermal transmittance of the clear fields (spandrel and vision area) of the prototypical facade of example #1. Total U-factor is calculated as the total thermal transmission divided by the total facade area. This calculation does not include linear thermal bridging at transitions.

TABLES COURTESY TECHNOFORM

figure 9

Facade #1 Linear thermal bridge type	Design	Prescriptive linear derating (minimal mitigation)		Reference linear derating from TBG (mitigated thermal bridging)		
	Interface length m (f)	Psi-value W/m.K (BTU/hr.ft.°F)	Thermal transmittance **psi-value x length,** W/K (BTU/hr.°F)	Psi-value W/m.K (BTU/hr.ft.°F)	Detail reference	Thermal transmittance **psi-value x length** W/K (BTU/hr.°F)
Panel to window transition	474 (1554)	0.55 (0.32)	260.5 (497.3)	0.062 (0.036)	5.3.12	29.4 (55.9)
Curtain wall to wall transition	74 (244)	0.55 (0.32)	40.9 (78.1)	0.062 (0.036)	5.3.12	4.6 (8.8)
Panel to grade transition	21 (70)	0.90 (0.52)	19.2 (36.4)	0.505 (0.292)	5.8.2	10.8 (20.4)
Curtain wall to grade transition	15 (50)	0.90 (0.52)	13.7 (26.0)	0.856 (0.495)	2.5.1	13.0 (24.8)
Panel to roof/parapet transition	21 (70)	1.04 (0.60)	22.2 (42.0)	0.702 (0.406)	5.5.12	15.0 (28.4)
Curtain wall to roof/parapet transition	15 (50)	1.04 (0.60)	15.8 (30.0)	0.759 (0.439)	2.2.4	11.6 (22.0)
Intermediate floor to exterior vertical wall	192 (630)	1.04 (0.60)	199.7 (378.0)	0.026 (0.015)	5.2.34	5.0 (9.5)
Corner transition	37 (122)	0.43 (0.25)	16.1 (30.5)	0.149 (0.086)	5.6.4	5.5 (10.5)
Total thermal conductance through linear thermal bridges			**588 (1,118)**			**95 (180)**

Total thermal transmittance through the linear thermal bridges for the facade in example #1 using the prescriptive derating option and reference derating using the Thermal Bridging Guide (TBG). The thermal transmittance of each thermal bridge condition is the product of the interface length and its psi-value.

bridge mitigation details. A 3D analysis is required for assemblies with lateral heat flow or thermal bridging in multiple planes.

For assemblies not listed in TBG, simulations must be done or the prescriptive values used.

Stretch code impacts on glazed facades

The following examples illustrate the impact of thermal bridge mitigation and area-weighted U-factor requirements in facades containing glazed walls. The first has a mix of curtain wall (<50 percent of the wall area) and punched opening windows. The second is covered entirely by a curtain wall.

Facade example one: Mixed fenestration, low-glazed wall

An example elevation including a center strip of curtain wall (glazed wall system) flanked by punched windows in a steel-framed rainscreen wall is shown in Figure 4 (page 10). The rainscreen wall and curtain wall spandrel are considered clear fields for thermal derating purposes. Linear thermal bridging at transitions is shown as dashed lines. In this example, the window-to-wall ratio is 45 percent (total transparent area divided by total wall area), and the percentage of glazed wall area (total area covered by a glazed wall, which includes spandrel area, divided by total wall area) is 42 percent. As noted above, the *Massachusetts Stretch Code* requires the area-weighted U-factor of the vertical wall to not exceed 0.730 W/m²K (0.1285 BTU/hr·sf·F) for glazed wall areas up to 50 percent.

Rainscreen wall

In this example, the rainscreen wall is thermally mitigated by incorporating RSI 2.96 (R16.8) continuous exterior insulation and using thermally broken cladding attachment clips with 610 mm (24 in.) vertical spacing. This assembly's derated clear field U-value is 0.33 W/m²K (0.058 BTU/hr·sf·F) as reported in the TBG V1.6 or higher for Detail 5.1.95. See detail in Figure 5 (page 10).

Curtain wall spandrel

The example curtain wall spandrel is also thermally efficient, utilizing structurally glazed, high-performance, triple-pane, insulating glass (IG) with two low-e coatings; argon gas fill and warm edge spacer [the center of glass U-factor is 0.67 W/m²K (0.118 BTU/hr·sf·F)]; and 130 mm (5 in.) of insulation. A resultant clear field U-factor, derated for thermal bridging, of 0.65 W/m²K (0.114 BTU/hr·sf·F) for a 1.5 x 1.2 m (5 x 4 ft) spandrel

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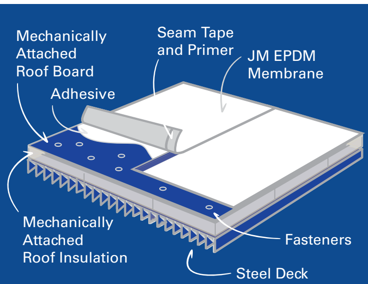

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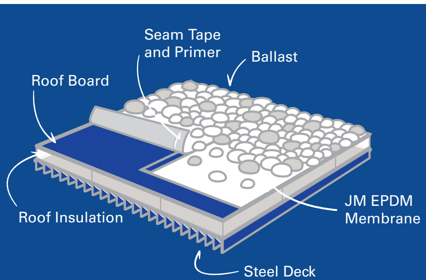

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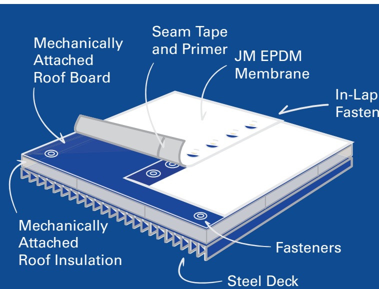

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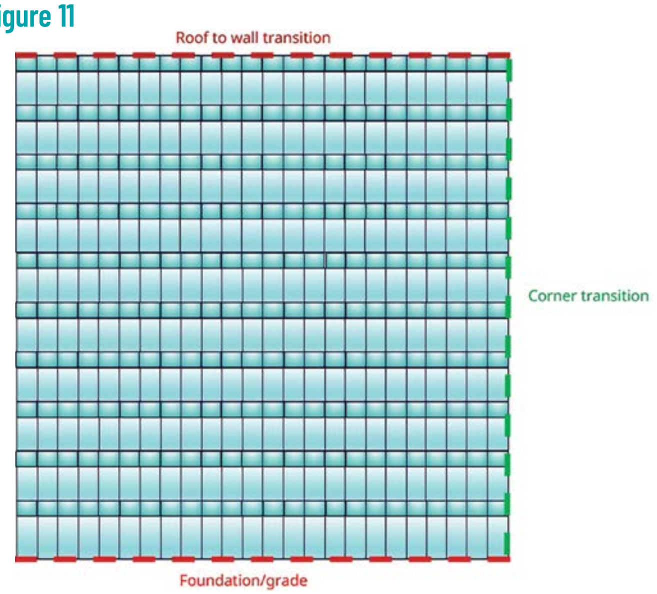
figure 10

Area-weighted U-factor of the facade in example #1 using prescriptive derating and mitigated thermal bridging through the reference method using the Thermal Bridging Guide (TBG) compared to the *Massachusetts Stretch Code* requirement.

Thermal bridges	Clear field heat transmission W/K (BTU/°F.hr)	Linear transmission W/K (BTU/°F.hr)	Total thermal transmission W/K (BTU/°F.hr)	Area-weighted U-factor W/m².K (BTU/°F.hr.sf)	Meets stretch code maximum U=0.73 W/m².K / 0.1285 BTU/°F.hr.sf?
With prescriptive derating	873 (1652)	588 (1118)	1461 (2770)	**1.07 (0.189)**	✗
With mitigated derating with TBG	873 (1652)	95 (180)	968 (1832)	**0.71 (0.125)**	✓

figure 11



Facade example #2, fully glazed with a curtain wall with a window-to-wall ratio of 67 percent. Linear thermal bridges are indicated with dotted lines.

DIAGRAM COURTESY TECHNOFORM

panel is reported by the TBG V1.6 or higher for Detail 4.1.3 for this system. See Figure 6 (page 11).

Curtain wall transparent glazing

In this example, the curtain wall's transparent glazing similarly includes structurally glazed, high-performance, triple-pane IG with two low-e coatings, argon gas fill, and warm-edge spacer [center of glass U-factor of 0.67 W/m²K (0.118 BTU/hr·sf·F)]. This provides a vision fenestration assembly U-factor of 0.94 W/m²K (0.165 BTU/hr·sf·F). See Figure 6 (page 11).

Punched opening windows

The high-performance, triple-glazed, fixed windows in this example deliver a fenestration U-value of 0.91 W/m²K (0.16 BTU/hr·sf·F). To achieve this performance, this commercial window example (Figure 7, page 11) uses wide 44-mm (1.7 in.) polyamide (PA) thermal barriers to reduce conduction, with foam to reduce convection.

Area-weighted U-factor calculation: Example facade one

Figure 8 (page 12) summarizes the area-weighted U-factor and total thermal transmission of the clear field areas—opaque rainscreen and spandrel panels derated to account for thermal bridging—and the total transparent fenestration U-factor.

The area-weighted clear field U-factor of 0.64 W/m²K (0.113 BTU/hr·sf·F) must be derated yet further to account for thermal bridging at the linear interfaces. Thermal bridging will add to the clear field thermal transmission of 873 W/K (1,652 BTU/hr·F).

Figure 9 (page 12) summarizes the increase in thermal transmittance of the wall due to all identified linear thermal bridges in the example facade, when using:

1. The *Massachusetts Stretch Code*'s conservative prescriptive linear derating values (prescriptive linear derating).
2. The reference derating method, using details from the TBG that better mitigate thermal bridging than the prescriptive assumptions (reference linear derating).

Figure 9 (page 12) demonstrates the benefit of designing with TBG-referenced transition details, which reduce thermal transmission from 588 to 95 W/K (from 1,118 to 180 BTU/hr·F). In this example, the prescriptive thermal bridging transmittance is 68 percent of the clear field transmittance. Even with mitigated thermal bridging, the thermal transmittance at the interfaces is more than 10 percent of the clear field transmission.

Due to the many small punched opening windows, thermal bridging at the window-to-wall transitions dominates the linear transmittance, indicating that (i) special attention should be paid


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figure 12

Total thermal transmittance of the clear fields (spandrel and vision area) of the fully glazed facade, example #2. Total U-factor is calculated as the total thermal transmission divided by the total facade area. This calculation does not include the impacts of thermal bridging at transitions.

TABLES COURTESY TECHNOFORM

Clear field thermal transmission	Curtain wall spandrel	Curtain wall vision	Total
Area, ft²	446 (4800)	914 (9840)	**1360 (14,640)**
% of Total Area	33%	67%	**100%**
Clear field derated U-factor, BTU/°f.hr.sf	0.65 (0.114)	0.94 (0.165)	**0.84 (0.148)**
Thermal transmission U-factor x area (BTU/°f.hr)	290 (547)	859 (1624)	**1149 (2171)**

figure 13

Total thermal transmittance through the linear thermal bridges for the fully glazed facade in example #2. The thermal transmittance of each thermal bridge condition is the product of the interface length and its psi-value.

Façade #2 Linear thermal bridge type	Design	Reference linear derating from TBG (mitigated thermal bridging)		
	Interface length, m (ft)	Psi-value, W/m.K (BTU/hr.ft.°F)	Detail reference	Thermal transmittance (ps-value x length) W/K (BTU/hr.°F)
Curtain wall to grade transition	36.6 (120)	0.856 (0.495)	2.5.1	31.3 (59.4)
Curtain wall to roof/parapet transition	36.6 (120)	0.759 (0.439)	2.2.4	27.8 (52.7)
Curtain wall corner transition	36.6 (120)	0.432 (0.25)	Prescriptive	15.8 (30.5)
Total thermal conductance through linear thermal bridges, W/K (BTU/°F.hr)				**74.9 (143)**

to those areas to mitigate the heat loss and (ii) designs which minimize those transitions—such as using long strip windows to wrap the building, large windows, or expanses of curtain wall rather than small punched opening windows—can minimize such losses.

Further, it is clear from the area-weighted U-factor calculations summarized in the table in Figure 10 that it is not possible to meet the *Massachusetts Stretch Code* area-weighted U-factor requirement without mitigating thermal bridging. Even then, it is only possible to meet the requirements by using very high-performance, triple-pane windows and curtain wall with assembly U-factors of 0.94 W/m²K (0.165 BTU/hr·sf·F) or less, not including spandrel. This performance is significantly higher than the prescriptive U-factors of 1.7 and 1.8 W/m²K (0.30 and 0.32 BTU/hr·sf·F) for fixed and operable fenestration, respectively. It is also much more stringent than the minimum vision curtain wall U-factor of 1.4 W/m²K (0.25 BTU/hr·sf·F).

Facade example two: Highly glazed wall

It is instructive to evaluate the impact of a fully glazed (100 percent) wall, since this minimizes wall-window transitions, and for glazed wall areas greater than 50 percent. For these, the required U-factor is relaxed to 0.91 W/m²K (0.16 BTU/hr·sf·F). The model facade is shown in Figure 11 (page 14) and has the same dimensions as in the first example with a facade area of 1,360 m² (14,600 sf), a 67 percent window-to-wall ratio.

For calculating the thermal transmittance, the TBG reference mitigated linear derating values listed in Figure 9 (page 12) for the first example were applied to the curtain wall-to-roof, to-grade, and corner transitions. The same curtain wall system was used as in the first example for comparability.

Figure 12 shows the clear field thermal transmission of the curtain wall vision and spandrel areas. As described in the first example, the spandrel U-factor has been derated for thermal bridging.

Figure 13 illustrates the thermal transmittance of the linear thermal bridging interfaces. There are no reference derating details in the TBG for curtain wall corner transitions, so the prescriptive value was used. In practice, a 3D simulation of the corner may be appropriate, especially in buildings with a lot of reticulation. Note that in this case,

figure 14

Overall performance, facade #2	Clear field heat transmission W/K (BTU/°F.hr)	Linear transmission W/K (BTU/°F.hr)	Total thermal transmission W/K (BTU/°F.hr)	Area-weighted U-factor W/m^2.K (BTU/°F.hr.ft^2)	Meets stretch code maximum U = 0.91 W/m^2K / 0.16 BTU/°F.hr.sf?
With mitigated derating with TBG	1149 (2171)	75 (143)	1224 (2314)	**0.90 (0.158)**	✓

Area-weighted U-factor of the fully curtain wall glazed facade in example #2 with mitigated thermal bridging through the reference method using the Thermal Bridging Guide (TBG), compared to the *Massachusetts' Stretch Code* requirement.

the linear thermal transmittance is five percent of the total heat flow through the facade. However, the total thermal transmittance of the wall is 31 percent higher than in the first example. The largest contribution to thermal bridging is in the spandrel clear field, which is accounted for in the spandrel U-factor derating.

Figure 14 summarizes the total facade thermal transmittance (clear field plus linear thermal bridging) and the total area-weighted U-factor (total thermal transmission divided by the total area). The result demonstrates that the 100 percent curtain wall can comply (just) with the higher U-factor = 0.91 W/m^2K (0.16 BTU/hr·sf·F) Massachusetts code requirement. However, it requires the vision curtain wall to have a U-factor below 0.97 W/m^2K (0.17 BTU/hr·sf·F) and highly insulating spandrel—neither of which represents business-as-usual installed performance in the U.S.

Takeaways from facade examples

To comply with *Massachusetts' Stretch Code* target and relative performance paths, especially when using glazed wall systems, designs must:

- Minimize thermal bridging at interfaces, avoiding prescriptive derating
- Use highly insulating fenestration with U-factors less than 0.97 W/m^2K (0.17 BTU/hr·sf·F)
- Use highly insulating spandrel assemblies
- Use thermally broken cladding attachment systems

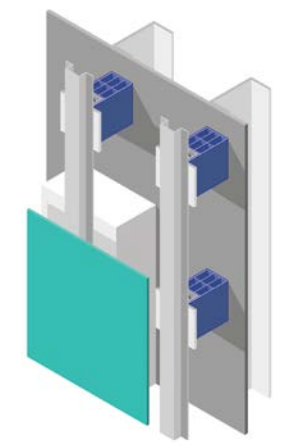
Solutions that support achieving this level of performance are illustrated below.

Solutions

Rainscreen wall systems

Opaque wall systems should be detailed with thick continuous insulation (c.i.) with mitigation of linear and/or point thermal bridges. Attachments should be thermally broken by using thermally broken clip point supports instead of continuous aluminum z-girts, and the frequency of attachment points should be minimized (Figure 15).

figure 15



Example of a thermally broken clip rainscreen attachment system.

DIAGRAMS COURTESY TECHNOFORM

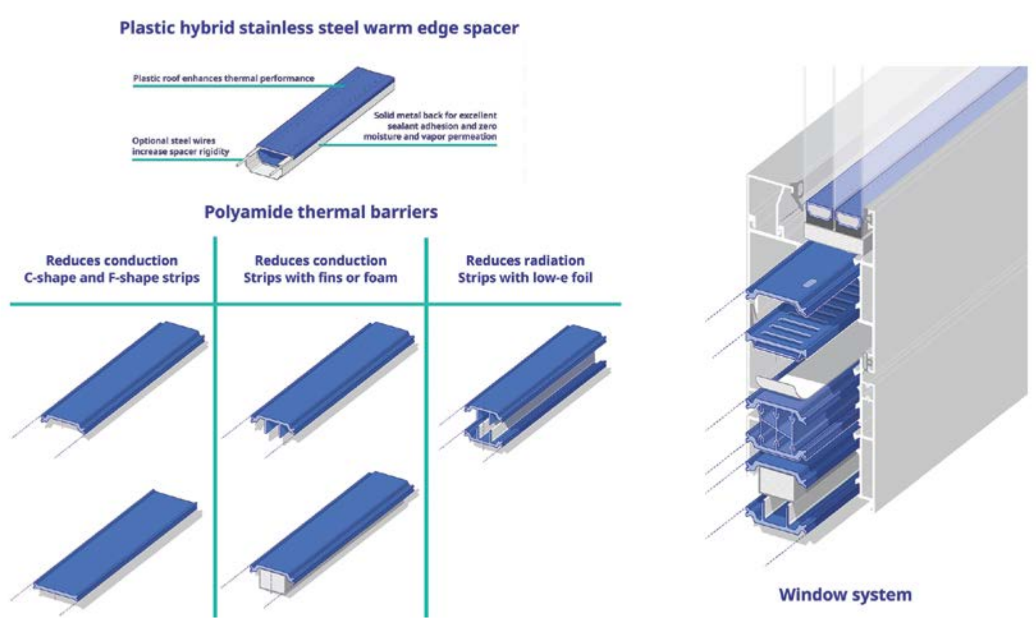
Fenestration

The prescriptive fenestration U-factors of 1.7 W/m^2K (0.30 BTU/hr·sf·F) for fixed windows and 1.8 W/m^2K (0.32 BTU/hr·sf·F) for operating windows, and the minimum U-factor of 1.4 W/m^2K (0.25 BTU/hr·sf·F) for glazed wall vison areas will generally not be sufficient to meet the overall vertical wall U-value requirements when complying through the target or relative performance paths.

As indicated by the examples, vision fenestration U-values will likely need to approach 0.91 W/m^2K (0.16 BTU/hr·sf·F) to meet the requirement and will require the following strategies:

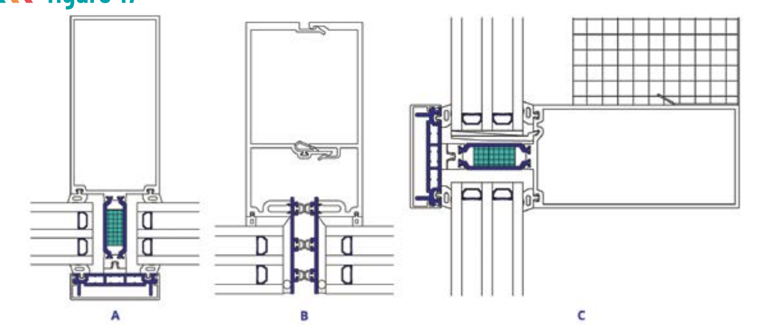
1. High-performance aluminum frames with wide, complex thermal barriers that significantly reduce heat conduction and convection (Figures 7 [page 11] and 16 [page 18]). Deep thermal breaks centered on the glazing to align the thermal insulation plane and provide an optimal solution in terms of conduction. Additional performance improvements can be realized with the addition of foam in the thermal break cavities to reduce convection and radiation heat loss. In addition, these

figure 16



Strategies to increase the thermal performance of aluminum fenestration using complex polyamide (PA) thermal barriers and plastic hybrid stainless steel (PHSS) warm-edge spacer.

figure 17



Strategies for high thermal performance curtain wall: (a) Captured curtain wall with plastic hybrid stainless steel (PHSS) warm-edge spacer, wide polyamide (PA) dual thermal barriers and foam, and a 40 percent glass filled PA pressure plate; (b) Structurally glazed curtain wall with PHSS warm-edge spacer and PA thermal barrier strategies to reduce the conduction and convection at the glass edges; (c) Highly insulated, captured spandrel assembly with strategies as in (a) plus deep insulation behind the insulating glass (IG).

improvements also reduce condensation risk and improve thermal comfort.

2. Warm-edge spacer, such as a plastic hybrid stainless steel (PHSS) spacer (Figure 16), in the IG unit to reduce conduction at the edge of glass.
3. Argon-filled, triple-pane IG unit with optimized cavity dimensions of approximately 13 mm (~0.5 in.) and two low-e coatings, one in each cavity, delivering a center-of-glass U-value of approximately 0.68 W/m^{2}K (0.12 BTU/hr·sf·F). Incorporating vacuum insulated glazing (VIG) as the room-side lite of an IG unit (hybrid VIG) is another potential solution. Hybrid VIG must incorporate a warm edge spacer to address VIG's high-edge conduction and allow for a deeper thermal break in the framing system.

Captured curtain wall

The thermal efficiency of captured curtain wall systems can be improved using deep PA dual thermal barriers to reduce conduction, foam to fill the cavities to reduce convection, and a 40 percent glass-filled PA pressure plate in place of aluminum (Figure 17a).

Structurally glazed curtain wall

For structurally glazed curtain walls, PA glass edge adapters can be used to reduce conduction and can carry gaskets, compartmentalizing cavities to reduce convective heat transfer (Figure 17b). A warm-edge spacer, such as the PHSS spacer incorporated into the detail in Figure 17b, is critical in such systems since the edge of glass is the weakest conduction link. Warm-edge spacers can reduce structurally glazed system U-factors by up to 0.28 W/m^{2}K (0.05 BTU/hr·sf·F).

Spandrel assemblies

Special attention must be given to spandrel assemblies to mitigate thermal bridging. The most efficient use triple-pane glazing with warm-edge spacer, maximize the insulation behind the IG. Deep thermal barriers, foam filling, and PA pressure plates are critical tools for captured systems, as illustrated in Figure 17c.

Conclusions

To meet the aggressive envelope thermal performance targets required by the *Massachusetts Stretch Code*, high-performance windows, and window wall or curtain wall vision area details are required. Fenestration system U-values of 0.91 W/m^{2}K (0.16 BTU/hr·sf·F) will be needed for most buildings where prescriptive compliance is not permitted, especially if glazed walls are incorporated. For these buildings, at a minimum, compliance will require high-performance triple glazing, warm-edge spacers, and well-thermally broken aluminum framing.

Curtain wall spandrel thermal performance must be maximized through optimum insulation thickness and framing details to mitigate thermal bridges.

Architectural design must mitigate thermal bridges in opaque walls and at assembly transitions. Envelope transitions, penetrations, and reticulation should be minimized to the extent possible.

Larger continuous strip windows and larger curtain wall vision modules can improve performance due to reduced fenestration-to-wall interfaces (thermal bridging) and increased glass-to-frame ratio (lower U-factor). U-factors for project-specific fenestration sizes can be used where they exceed the National Fenestration Rating Council's (NFRC) model sizes.

Compliance on projects with glazed wall systems may be easier to achieve at glazed wall areas exceeding 50 percent as the overall vertical wall U-value required relaxes to 0.91 W/m^{2}K (0.16 BTU/hr·sf·F).

Due to the increased compliance complexity, envelope system experts must be brought to the design table early—much earlier than they have historically been consulted. To achieve success, a holistic envelope design approach and early coordination across trades to manage thermal bridges at system interfaces is essential. Engaging with envelope consultants familiar with *Massachusetts' Stretch Code*, and with fenestration system fabricators and installers will support creative high-performance design and solution development.

additional information

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KEY TAKEAWAYS

Massachusetts' Stretch Code sets a new national standard for energy efficiency by enforcing stringent requirements on building envelope performance, particularly in minimizing heating loads and thermal bridging. The code prohibits envelope trade-offs, mandates low U-factors for vertical walls and fenestration, and introduces complex compliance paths. Success requires early coordination among design, envelope, and fenestration experts. High-performance solutions—such as triple-glazed windows, thermally broken framing, and advanced spandrel assemblies—are essential for compliance, especially in glazed facades. The code emphasizes holistic thermal design and early integration of envelope strategies to meet decarbonization and energy efficiency goals through sustainable, high-performance construction.

MASTERFORMAT NO.

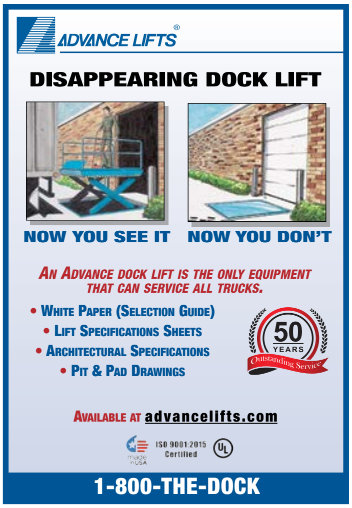
07 21 00–Thermal Insulation
07 42 00–Wall Panels
08 44 13–Glazed Aluminum Curtain Walls

UNIFORMAT NO.

B2010–Exterior Walls
B2020–Exterior Windows

KEYWORDS

Division 07, 08	Stretch Code
Curtain wall	Thermal bridging
Glazing	U-factor



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Water, Water Everywhere

Low-carbon Concrete's Water Dilemma and What Can Be Done About It

By Chris Bennett, CSC, iSCS, CDT, Melody Fontenot, AIA, CSI, CCCA, CCS, iSCS, SCIP, Maria McCain, MSc, LEED GA, TRUE Advisor, Fitwel Ambassador, Alliance for Water Stewardship PC, Kyle Picket, USGBC, Keith Robinson, RSW, FCSC, FCSI, Ryan Stoltz, P.E., iSCS, LEED AP, and Rae Taylor, PhD

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Water scarcity is no longer a distant concern but a rapidly escalating global crisis. Around the world, water availability is declining while water demands are rising. Regions that were once water-secure are now struggling to meet even basic needs, threatening the foundations of food security and public health. Agricultural systems are under mounting pressure as irrigation sources dry up, and millions face the risk of losing access to clean, safe drinking water.

Amid this crisis, a surprising contributor emerges: the construction industry. Water is essential for life and critical for mixing, placing, and curing concrete. Water is the most widely consumed material in the world and is also one of the four primary ingredients in concrete, the second most consumed resource globally, after water itself.

Outside of highly water-stressed regions, the prevailing focus on cement's carbon footprint has led to the vital conversation around water-wise construction being overlooked. Many new mix designs paradoxically demand more water as the industry races to adopt low-carbon alternatives to traditional Portland cement. Like the mariner adrift on a sea of undrinkable water, the construction industry now finds itself surrounded by solutions that promise lower carbon—but demand more of the very resource we are running out of.

Climate change, population growth, and shifting precipitation patterns tremendously stress global water systems. Within 25 years, growing water scarcity could threaten more than half of the world's food production. Meanwhile, architects, engineers, contractors, and specifiers—key players in reshaping the built environment—are being encouraged to use low-carbon concrete alternatives that have more variability than traditional cement mixes. Beneath low-carbon concrete's green promise lies a less understood risk: many of these mixes require more water in the mix to remain workable, which can compromise strength, amplify volumetric instabilities, promote shrinkage cracks and crazing, and shorten the concrete's service life.

PHOTO COURTESY O'CONNELL ROBERTSON

Efforts to reduce carbon emissions, including environmental product declarations (EPDs) that do not consider long-term durability, may unintentionally result in more fragile structures with a shorter service life and increased repairs. This outcome can undermine environmental benefits, stress ecosystems more, and increase construction and facility maintenance costs.

CONCRETE'S PERMANENT WATER FOOTPRINT

Water used to make concrete becomes permanently unavailable. Once it reacts with cement, it cannot be extracted. Although concrete can absorb and release moisture, the water involved in the chemical reaction is permanently bound. This creates a lasting "water footprint," unlike the "carbon footprint," which can eventually be offset over hundreds of years as the environment reabsorbs carbon from cement production.

Why?

Irreversible hydration
The hydration of cement is a chemical reaction that creates new compounds. These compounds are stable and do not revert to their original components (cement and water) under typical conditions.

Water of convenience
Concrete contains "water of convenience," excess water not used in the hydration process. This water can evaporate or be removed, but it is not the same as the water that has chemically reacted with the cement.

Porosity
Concrete is porous, meaning it has tiny spaces that can absorb and retain water. This absorbed water can evaporate, but it does not mean it is extracted from the hardened concrete matrix.

Curing versus drying
Curing is the process of maintaining moisture for the chemical reaction to complete. Drying is the process of water evaporating from the concrete after the reaction is finished. While drying can remove excess water, it does not reverse the hydration process.

Recycling concrete
While water cannot be extracted from concrete, the material can be recycled by crushing it and reusing the aggregate in new concrete or other construction applications.

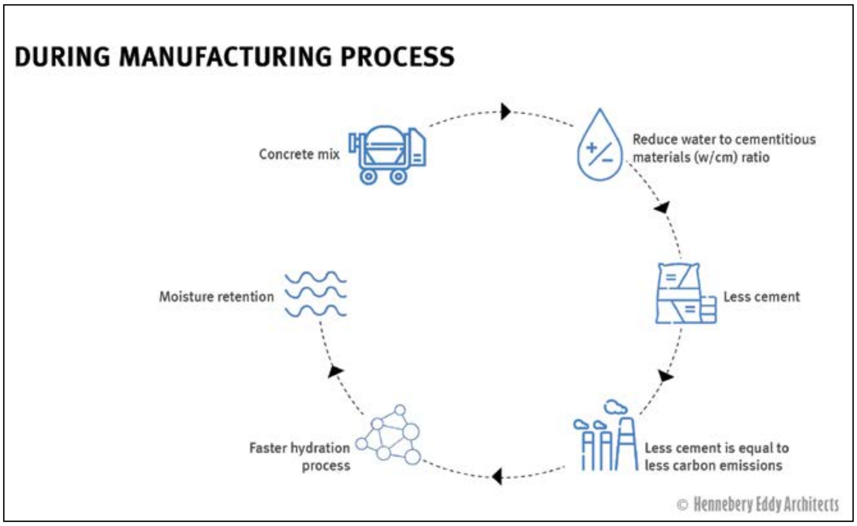
Lifting the albatross

The good news? The problem is well understood, making it possible to address. Elevating water resource management as a key design and construction objective offers a pathway to resolving the tension between carbon reduction and water conservation. Projects such as Kendrick Elementary School in Waco, Texas—an area facing real water shortages—provide valuable insight and leadership to inform approaches elsewhere. The following sections examine the underlying challenges and outline key strategies to help balance these competing demands.

Water demand in traditional low-carbon concrete

The shift toward using record volumes of Portland Limestone Cement (Type 1L or PLC) and supplementary cementitious materials (SCMs)—such as fly ash, slag, calcined clays, and injected CO2-based additives—has fundamentally changed how concrete behaves. These materials do not react like cement, often increasing water demand for hydration and flowability, or reducing particle packing efficiency—requiring more water to fill voids and maintain workability.

Unfortunately, many in the architecture, engineering, and construction (AEC) community have not updated their approaches to design, documentation, training, or on-site execution. As a result, there is a tendency to treat new low-carbon concrete as if it were traditional concrete. The consequences include unnecessarily extended schedules due to delayed strength gain, reduced durability, additional mitigation measures, contractor dissatisfaction with workability, low compressive breaks, increased



Concrete is unique in that it is manufactured on-site. Using nano-modified concrete (NMC) with locally sourced materials offers an opportunity to conserve water through lower water-to-cementitious materials (w/cm) ratios, while simultaneously improving strength, reducing porosity, and extending the material's lifecycle.

DIAGRAMS ©HENNEBERY EDDY, ORIGINALLY FROM THE ARTICLE "NANO-MODIFIED CONCRETE: ENHANCING DURABILITY & SUSTAINABILITY IN MODERN CONSTRUCTION" BY SANSKRUTI BHAGAT

risk for all stakeholders, and—perhaps most ironically—the potential for higher global warming potential (GWP) due to shorter life cycles.

At the same time, the call from many ready-mixed concrete suppliers and trade organizations are encouraging the removal of water-to-cementitious material (w/cm) ratios from specifications, allowing more water to be consumed in efforts to improve workability for their contractor customers—despite understanding that too much water lowers strength, increases porosity, and can cause immediate durability issues (*e.g.* cracking, deflection, freeze-thaw failure).

As a result, hundreds of thousands of cubic meters (millions of cubic feet) of permeable, low-durability concrete are placed every year—material that often requires immediate or early-life repair. Such remedial work is costly, time-consuming, and environmentally detrimental, undermining the very sustainability goals that low-carbon concrete is intended to achieve. While higher water content is often justified as a means to improve workability and meet the water demand of SCMs, it is worth noting that water can be a high-margin component for ready-mixed concrete suppliers. Since concrete is sold by weight, this dynamic can create potential conflicts of interest when advocating for the removal of contractual w/cm ratio limits.

Understanding SCMs and their water demands

Each SCM affects concrete differently. Fly ash, for example, may reduce early strength gain and require more water for workability. Slag cement may delay set times. Other additives, including glass pozzolan or carbon-injected solutions, can increase complexity in early hydration stages.

These differences matter. A lack of understanding often leads to adding excess water in the field—at the batching plant, in transit, or during placement. This additional water raises the w/cm ratio, often weakening the concrete matrix and increasing permeability, shrinkage, and surface cracking.

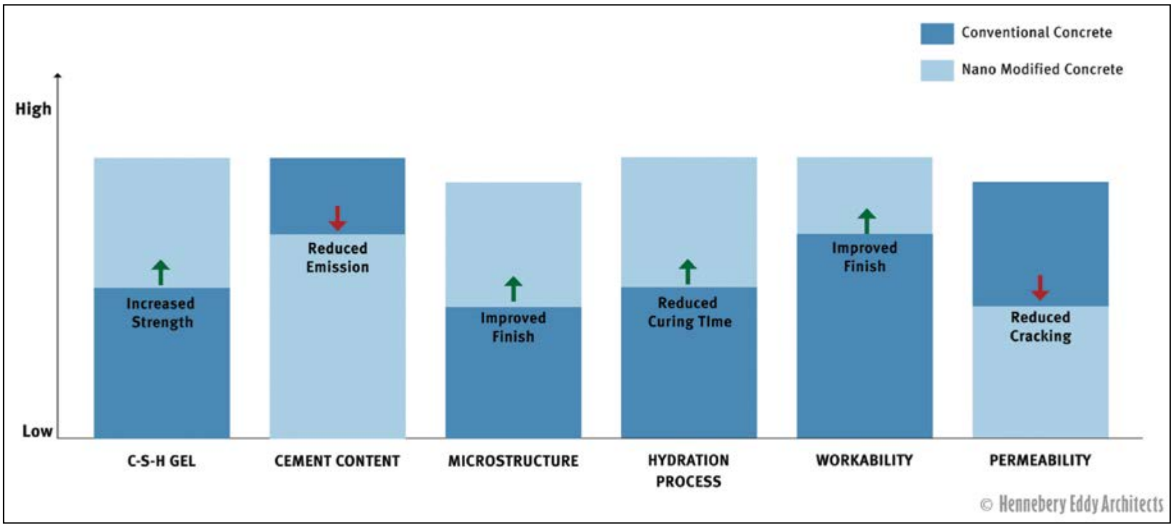
Eric Traffie, a certified contractor and member of Bomanite New England, the American Concrete Institute (ACI), and the National Concrete Refinement Institute (NCRI), states:

"Sure, adding water is easy—but if you're not careful with how much, it can come back to bite you. Too much water might make the pour go smoother, but it can weaken the concrete long-term and lead to expensive fixes before the building even opens."

Sidonie Immler, a partner at Foster + Partners, says: "Sustainable developments need to be looked at holistically. Solutions do not exist in isolation. Whole-systems thinking must include water management, particularly in the concrete industry."

Case Study: PLC in practice

Portland Limestone Cement (Type 1L or PLC), now the leading type of cement available in the U.S. and Canada, contains five to 15 percent limestone—compared to a maximum of five percent in Type I and Type I/II cements. If substituted pound for pound, this can reduce CO2 emissions by 10 to 15 percent. While some industry participants have claimed minimal performance differences, the reality on job sites has proven more complicated. Contractor complaints regarding reduced finishability ("stickier mixes"), shorter set times, and batch variability persist,



and all too often, the short-term solution is simply adding more water.

Concrete is sensitive to small changes. While properly deployed PLC can improve particle packing, it can also alter hydration rates, reduce early strength, and increase surface porosity. Concrete suppliers frequently increase PLC content within their mixes by five to 10 percent to achieve comparable cement content to that experienced with Type I and Type I/II cement mixes. While avoiding the risk of low-strength breaks, they are negating the carbon reduction benefits promised by advocates of Type 1L cement. The question remains whether the industry is truly reducing its carbon footprint while maintaining concrete quality, or merely trading one performance challenge for another.

Water management: The critical factor

Water management remains one of the most overlooked—and most critical—elements of sustainable concrete production. On many projects, water is introduced at multiple stages of the process, often without submittals and oversight. Whether added to improve slump, offset delays in placement, or adjust mix temperature, each unmeasured addition has the potential to radically alter the concrete's fresh and hardened properties. Even seemingly minor increases can change setting time, reduce strength, and compromise durability.

Addressing this challenge requires more than just better procedures—it requires education. Everyone involved in the process, from mix designers and quality control (QC) technicians to pump operators and finishing crews, must understand the role water plays in modern concrete, particularly in mixtures that incorporate SCMs. These materials can be more sensitive to water content, making proper management essential for achieving the desired performance. Without this shared understanding, even the most carefully engineered mix can yield inconsistent, disappointing results in the field.

The Goldilocks zone: Optimal hydration for superior concrete

Concrete needs water to hydrate cement, but too much water weakens performance. Getting the w/cm ratio "just right" is essential for strong, durable concrete. The American Concrete Institute (ACI) and Canadian Standards Association (CSA A23.1) recommend keeping w/cm ratios below 0.50–0.55 for most applications. For dense or high-performance concrete—such as industrial slabs, watertight structures, or exterior paving exposed to freeze-thaw cycles and deicing salts—the ratio is often limited to 0.40 or less. According to Abram's Law, higher w/cm ratios reduce strength and increase porosity, shortening service life. In aggressive environments like seawater or sulfate exposure, a w/cm ratio of 0.40–0.45 is commonly specified. Excessive water leads to:

- Reduced strength (ACI 211.1)
- Increased cracking and shrinkage (ACI 224R)
- Segregation and bleeding (ACI 302.1R)
- Lower freeze-thaw and chemical resistance (ACI 318)

Forces shaping water use in concrete

Finding the "Goldilocks zone" for water content is crucial for concrete performance, and achieving the right economic balance in water valuation is equally

ENHANCING HYDRATION WITH NANO-MODIFIED CONCRETE

Cement hydration is the reaction between cement and water that forms hardened concrete. It dissolves cement particles, creating compounds like calcium silicate hydrate (CSH) and calcium hydroxide ($Ca(OH)_2$) that bind the concrete. This process is crucial for concrete's strength and durability.

SCMs replace a portion of the cement in concrete mix designs to reduce concrete production's overall "carbon footprint" while maintaining or improving desirable performance characteristics. The inclusion of SCMs in concrete mix designs must account for the water content balanced against the design attributes of concrete performance.

The past 20 years of sustainable design have focused mainly on reducing the carbon emissions associated with cement production using the easiest solution to reducing cement content: maximizing the use of SCMs and, more recently, using Portland Limestone Cement (PLC). There has been minimal consideration for alternative solutions for cement reduction in concrete and water reduction using materials that improve contact between the cement particles and the available water for hydration.

Nano-modified concrete uses tiny particles like nano-alumina, nano-clay, nano-platelets, nano-silica, and carbon nanotubes. These particles improve cement hydration by increasing the surface area for reactions, enhancing hydrolysis throughout the matrix, reducing the number of pores created, and reducing mix friction between particles. This leads to increased workability, reduced water demand, and stronger, more durable concrete. NMCs can be deployed in conjunction with or without traditional low-carbon mix designs.

essential for sustainable construction practices. According to the World Resources Institute (WRI), water prices in most regions significantly undervalue this vital resource, typically covering less than half the true cost of water infrastructure and environmental externalities.

Building standards have established more stringent water-to-cement ratio limitations to counter these economic systems that artificially favor water-intensive concrete solutions. These technical requirements function as regulatory safeguards against excessive water use while incentivizing concrete formulations with superior durability.

International standards support lower w/cm ratios

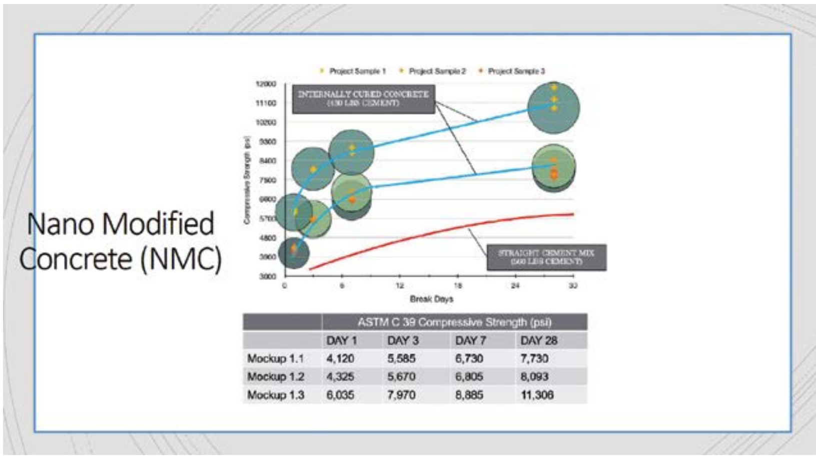
Across the globe, major codes and standards consistently emphasize the need to limit water-to-cement ratios to improve strength, durability, and sustainability:

- ASTM C94 / ACI 318 (USA)—Requires low w/cm ratio for strength and long-term durability.
- EN 206 (Europe)—Sets maximum w/cm ratios for various exposure classes, including carbonation and chloride resistance.
- BS 8500 (UK)—Supports EN 206, reinforcing low w/cm ratios for durability.
- IS 456 (India)—Recommends maximum w/cm ≤0.50 in aggressive environments.

- AS 1379 / AS 3600 (Australia)—Prescribe w/cm ratio limits for sulfate, marine, and freeze-thaw exposures.
- NZS 3101 (New Zealand)—Provides durability targets similar to Australia's, with clear w/cm ratio limits.
- DIN 1045-2 (Germany)—Emphasizes impermeability by specifying low w/cm ratios.
- PN-EN 12390-8:2019-08 (Poland/EU)—Supports findings that lower w/cm ratios reduce permeability.
- JIS A 5308 (Japan)—Specifies limits on w/cm ratios according to exposure and durability requirements.

Water-wise solutions in Waco, Texas

Waco, Tex., is quickly becoming a model for sustainable, water-wise concrete. After seasonal fly ash shortages forced the district to use all-cement concrete mixes at the recently completed high school, Gloria Barrera, chief of facilities and operations for the Waco Independent School District, and their designer, O'Connell Robertson, were determined to find a better solution for the next new build, Kendrick Elementary School. Engaging a concrete consultant, the design team explored new options and gravitated toward nano-modified concrete (NMC) technologies as a solution to their challenges. Following extensive research and early design-phase planning, the team implemented a single NMC mix design for all site and building concrete, updated specifications, provided for additional testing to ensure accountability and peace of mind, offered training for the local subcontractor and supplier communities, and established an economical, sustainable maintenance plan that included a path for the district to eliminate future needs for stripping and reinstallation of high GWP clear coats and sealers on their interior concrete floors.



	ASTM C 39 Compressive Strength (psi)			
	DAY 1	DAY 3	DAY 7	DAY 28
Mockup 1.1	4,120	5,585	6,730	7,730
Mockup 1.2	4,325	5,670	6,805	8,093
Mockup 1.3	6,035	7,970	8,885	11,306

Kendrick Elementary lowered embodied carbon and conserved water with a single mix design for all site and building concrete. Water-to-cementious material (w/cm) ratios were kept between .36 and .38 while the pounds of cement dropped from the regional baseline of 255-plus kg (56 lb) of cement reduced to 195 kg (430 lb).

PHOTOS AND DIAGRAM COURTESY STRUCTURES PE, LLP AND TAO GROUP SOLUTIONS

- 24 percent cement reduction without the use of SCMs
- 32 percent reduction in water use
- One mix design for all site and building concrete
- High early strength in days, not months
- Avoided fly ash dependency
- Fewer subcontractor mobilizations
- Accelerated schedule and early building occupancy
- Use of NMC concrete systems for a more stable mix
- Reduce shrinkage, crazing, and surface cracking
- Safer floors through testing and concrete refinement
- Elimination of resinous materials on the walking surfaces
- Reduce overall install and facility maintenance costs to the owner

Water savings was a surprising metric—not originally on the team's priority list. Traditional 20,684 kPa (3,000 psi) and 27,579 kPa (4,000 psi) concrete mixtures typically use w/cm ratios between 0.45 and 0.55. This is significantly higher than the w/cm ratios targeted by ACI Committee 211 for durable high-performance concrete (HPC). It could be argued that the excess water in traditional mixes, while aiding workability, is the root cause of nearly all common concrete issues, including surface cracking, curling, crazing, shrinkage, and high permeability.

The core principle is simple: less water equals better concrete—as long as the cement particles are properly hydrated. Reducing water content to HPC levels has historically presented challenges with workability and finishability. This is where NMC admixtures and additional training again added value to the project. The chemical admixture alters the hydration process, allowing cement particles to hydrate efficiently. The result is a water-wise concrete mix with strength and durability comparable to high-performance blends—but with improved workability and shorter schedules.

Fortunately, the curing properties of the NMC admixture also greatly reduce water evaporation at the surface, locking moisture into the mix so cement particles have a readily available water source throughout the curing process. The nano-modified concrete reduced the w/cm ratio from 0.45 to between 0.36 and 0.40. As a result, the Kendrick Elementary project saved approximately 310,400 L (82,000 gal) of water and prevented an estimated 422 tonnes (465 tons) of CO_2e emissions.

"The Kendrick project was an adventure worth the effort," says Gloria Barrera. "Waco ISD was ready to step up to the challenge to control costs, improve quality, and reduce embodied carbon and water use. Our concrete is beautiful and far surpasses previous traditional approaches."

A call to action

Concrete is not only the world's most versatile construction material; it also serves as the bedrock of the built environment, both literally and figuratively. When

Teams at Kendrick Elementary in Waco, Tex., are being trained to conserve water and reduce embodied carbon in concrete and produce refined finishes.

PHOTOS COURTESY STRUCTURES PE, LLP, TAO GROUP SOLUTIONS, AND O'CONNELL ROBERTSON

comparing materials used in construction worldwide, concrete dwarfs all other building materials with a mass of 10 times greater than any other. From skyscrapers to bridges, dams to driveways, concrete is the undisputed titan of construction. When designed, specified, and placed properly, it offers significant sustainability benefits, as long as durability is not compromised.

Increasing water content—a growing trend when introducing new mix designs aimed at carbon reduction—is compromising durability and shortening the lifespan of concrete. This needless waste of water, stemming from treating a new material as if it were still traditional concrete, also squanders a valuable resource that many regions can no longer afford. It is crucial to challenge the misconception that "low-carbon" automatically equates to "durable performance."

Education and training within the AEC industry will be more important than ever to navigate the complexities of emerging concrete solutions. Innovative approaches, like the nano-modified concrete used at Kendrick Elementary, offer a path to durable concrete with impressive sustainability achievements and water savings. Success stories like Kendrick will continue to move the industry forward.

Historically, cement reduction has been the main driver of sustainable concrete solutions. Yet, with escalating populations, ever-increasing concrete production, and failing concrete, water savings will emerge as a dominant sustainability concern in water-stressed regions of the world.

In the quest for sustainable concrete—where durability and resource conservation must align—the Ancient Mariner's lament rings true: "Water, water, everywhere, nor any drop to spare." It serves as a reminder to craft resilient structures that honor our planet's need for lower greenhouse gas (GHG) emissions, long-lasting facilities, and the preservation of precious water resources.

Jarrod Sterzinger of O'Connell Robertson emphasizes: "Partnering with Waco ISD gave us the opportunity to explore sustainable strategies that support both construction goals and long-term stewardship. Through this collaboration, we identified the value of preconstruction education, and internal curing with nano-modified concrete as a solution that not only enhances performance and durability, but also significantly reduces embodied carbon and water use. It's the kind of innovation that reflects a shared commitment to smarter, more responsible building."

With every drop of water saved, the strength is set to last.

Resources

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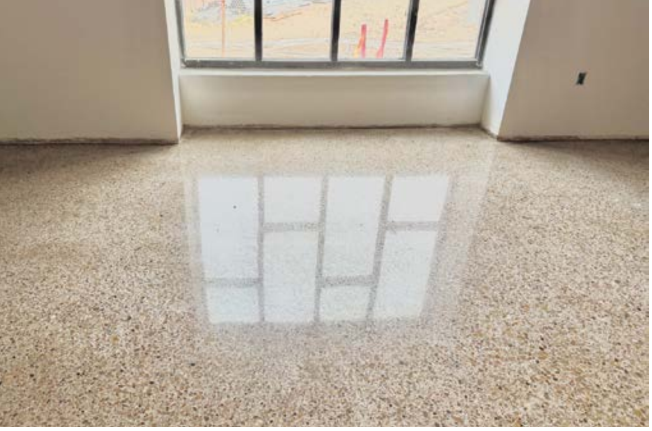
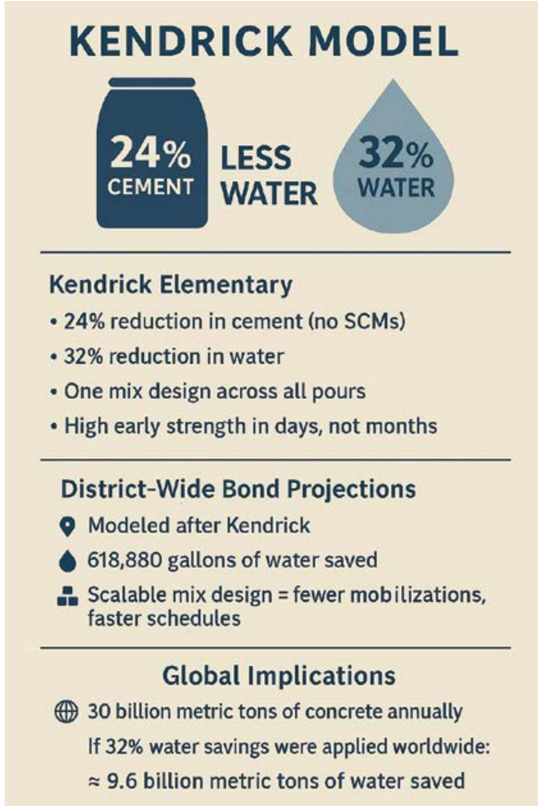
- For ongoing research in nano-modified concrete (NMC), see "Recent advances in nano-modified concrete: Enhancing durability, strength, and sustainability through nano silica (nS) and nano titanium (nT) incorporation.
- For further reading on nano-additives in concrete, read Wei Tian et al., "Nano-Additives



Together, Waco ISD, Bennett Build, Built Wright, BWC Education, Langmerman Engineering, Miller Sierra, One Source, O'Connell Robertson, Structures PE, LLP, and Tao Group Solutions reduced cement, schedule, and water—a collaborative commitment to sustainable, beautiful concrete construction.



Even small changes can make a big impact. The global appetite for concrete is approximately 30 billion metric tonnes (33 billion tons)—which means a massive demand for both cement and water. If the same approach used at Kendrick Elementary were applied globally, immediate water savings could reach 9.6 billion metric tonnes (10.6 billion tons). The Kendrick Model can be deployed anywhere using local materials. Further reductions in cement and water—with or without SCMs—can help achieve even higher benchmarks for embodied carbon reduction and water stewardship.

DATA FROM WACO ISD, O'CONNELL ROBERTSON, STRUCTURES PE, LLP, AND LANGERMAN ENGINEERING. AI-GENERATED IMAGE VIA CHATGPT WITH DALL·E

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additional information

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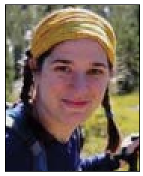


Rae Taylor, Ph.D., holds a doctorate in civil engineering and materials science from the University of Leeds, along with a postgraduate certificate in technology management from the Open University. Her research focuses on improving the environmental impact of construction materials, particularly through cement replacement materials and additives that influence cement microstructure. She can be reached at raemorristaylor@gmail.com.

KEY TAKEAWAYS

Water scarcity is an urgent global crisis, and the construction industry is a major contributor due to its heavy reliance on water in concrete production. While low-carbon concrete alternatives like Portland Limestone Cement (PLC) and supplementary cementitious materials (SCMs) aim to reduce greenhouse gas (GHG) emissions, many of these mixes require more water, risking durability and increasing long-term costs. The lack of updated specifications and oversight often results in weaker concrete and early-life repairs. Case studies like Kendrick Elementary in Waco, Tex., show that innovative solutions—such as nano-modified concrete—can lower water and carbon usage while maintaining strength and workability. Managing water content and educating the architecture, engineering, and construction (AEC) industry on water-wise design is now essential. Sustainable concrete must balance durability with resource conservation to avoid trading one crisis for another.

MASTERFORMAT NO.

01 35 91–Sustainability Assessment
03 30 00–Cast-in-Place Concrete
03 05 00–Common Work Results for Concrete
03 35 49–Refined Concrete Finishes

UNIFORMAT NO.

A1010–Standard Foundations	A1030–Slab on Grade
A1020–Special Foundations	B1010–Floor Construction

KEYWORDS

Division 01, 03	Portland Limestone Cement
Concrete	Supplementary cementitious materials
Embodied concrete	Sustainability
Greenhouse gases	Water conservation
Nano-modified concrete	Water-to-cementitious material

Beyond Color

Coatings that Protect and Perform

By Gary Edgar

PHOTOS COURTESY PPG

From high-profile to high-rise, monumental architectural buildings and top-tier commercial structures require the right protective coatings to ensure long-term performance and lasting curb appeal. Today's high-performance protective coatings from leading manufacturers—including fluoropolymer-based powder and liquid formulations—are engineered to withstand the effects of UV exposure, heat, moisture, salt spray, and freezing temperatures. Providing a formidable barrier against these environmental elements is critical, as the stakes and expectations are high.

One of the most important jobs of architectural-grade metal coatings is to prevent the development of corrosion. According to the Association for Materials Protection and Performance (AMPP), corrosion alone costs the global economy more than $2.5 trillion annually. AMPP cites studies showing that implementing proven corrosion control practices could save up to 35 percent of these costs.

When it comes to a building's long-term performance against corrosion, world-class protective coatings make a true difference. Plus, they offer longevity and cost efficiency while reducing energy consumption and maintenance needs. It is critical to specify coatings engineered for the specific substrate material, performance requirements and environmental exposure of a building. Careful consideration must be given to a coating's resistance to corrosion, overall durability, color and gloss retention, and performance standards such as FGIA/AAMA 2605.

Protective performance is paramount, but architects and designers are also seeking modern innovations such as color-shifting pigments that change appearance based on light and angle. This empowers them to deliver dynamic designs with a single color formulation. These innovations allow for dynamic designs with a single color formulation and highlights a key role for paint manufacturers: collaborating with architects to meet precise aesthetic requirements, including the creation of custom colors, in the most efficient way possible.

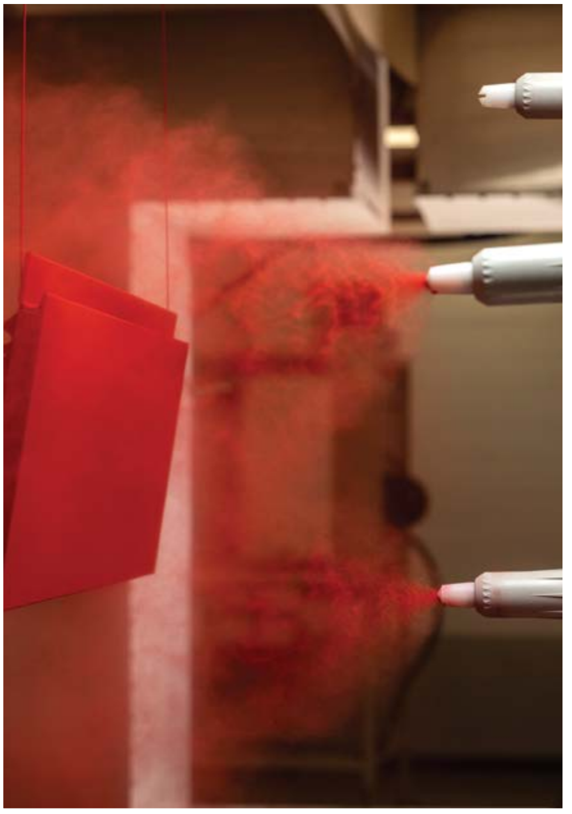
Leading coatings manufacturers are delivering on all fronts. With advanced material science, their formulations permit architects to realize their design visions with coatings that offer increased durability, energy efficiency, and performance. These, in turn, satisfying the demands of building owners and developers. By understanding how these contemporary coating technologies differ from previous generations and reflect today's architectural demands, specifiers can unleash more design freedom while meeting sustainability and building performance requirements.

A new era of paints and coatings

Architects are becoming more ambitious with their designs, committed to creating stunning structures that win awards and make a statement. Yet they must also adhere to 21st-century performance standards, meeting a host of environmental and building code demands.

Today's architectural metal coatings must do more than create striking visuals. They play a fundamental role in structural integrity, energy efficiency, and environmental impact. Among the most advanced solutions available today are fluoropolymer-based powders and liquid

Lyrik Back Bay in Boston used a two-coat powder coating system, formulated with fluoroethylene vinyl ether (FEVE) resins.



Powder coating being spray-applied onto a part.

Metal extrusion coated with powder coatings.

coatings, recognized for their outstanding durability, weatherability, and design flexibility.

Fluoropolymer-based powders

For architects designing modern facades and high-performance building envelopes, fluoroethylene vinyl ether (FEVE-based) powder coatings offer a balance of long-term durability and color retention with sustainability advantages. These fluoropolymer solutions meet stringent standards such as FGIA/AAMA 2605 for applicability for architectural extrusions and aluminum components such as window frames, panels, and curtain walls.

To meet the FGIA/AAMA 2605 performance requirements, coatings must pass demanding laboratory testing that replicates years of exposure to challenging environmental conditions:

- Humidity resistance—Coatings are subjected to 4,000 hours of continuous humidity with minimal blistering.
- Cyclic corrosion testing—Coatings must endure 2,000 hours of cyclic wet and fog/dry testing with minimal evidence of corrosion.
- Chemical resistance—Coatings must resist degradation when exposed to harsh substances, including muriatic acid, nitric acid, mortar, detergents and window cleaners.

One of the most stringent requirements of the FGIA/AAMA 2605 standard is its real-world weathering performance. Coatings must demonstrate exceptional durability in the field after 10 years of continuous outdoor exposure in South Florida, a subtropical region known for its intense UV radiation and humidity. To comply, the coating must meet the following benchmarks:

- Color retention—Limited to a color shift of no more than five Delta E units.
- Chalk resistance—A minimum rating of eight for dark colors and six for white finishes.
- Gloss retention—At least 50 percent of the original gloss must be maintained.
- Erosion resistance—Less than 10 percent loss of coating thickness.

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Liquid coatings offer the perfect blend of aesthetic appeal and long-term protection, making them an ideal choice for metal roofing, wall panels, building exteriors, and monumental architectural applications.

Next-generation fluoropolymer powders maintain color and gloss stability well beyond the typical five- to 10-year benchmark. In fact, third-party testing of these coatings from leading manufacturers has shown minimal degradation even after 12 years of high-UV exposure in South Florida. This superior performance makes them ideal for high-visibility architectural creations or signature structures that demand exceptional and long-lasting aesthetics.

Advanced fluoropolymer formulations permit architects to specify with more design freedom. Premier exterior grade FEVE powder coatings offer extended gloss ranges of five to 85 units, which allows for more versatility compared to standard FEVE powder coatings, which typically only offer gloss ranges of 25 to 75. These powders can also replicate anodized metal or natural materials and are applied with high-transfer efficiency that exceeds traditional FEVE powder coatings by more than 20 percent. The result is better material utilization and reduced waste for applicators.

From a sustainability perspective, architects can specify the most advanced FEVE powders because they are specifically formulated without chemicals that can present environmental and health concerns, including:

- Triglycidyl isocyanurate (TGIC)
- Perfluorooctanoic acid (PFOA)
- Fluorosurfactants
- Volatile organic compounds (VOCs)
- Hazardous air pollutants (HAPs)
- Living Building Challenge (LBC) Red List substances
- Substances of Very High Concern (SVHCs)

Case study: Lyrik Back Bay

The new Lyrik Back Bay development in Boston is a case study in the effectiveness of such coatings. This mixed-use development set a new benchmark for logistical complexity because it required building over the eight-lane Massachusetts Turnpike (I-90) and two Massachusetts Bay Transportation Authority (MBTA)/Amtrak rail lines. The location added intricacies for the coatings manufacturer and the metal finishing contractor.

The development includes CitizenM Boston Back Bay Hotel, tracking LEED certification, an underground parking facility, retail and restaurant spaces, and a European-style public plaza. Crews finished each building with a two-coat powder coating system formulated with high-performance FEVE resins. This was a crucial choice for the long-term performance of the buildings' exteriors, which must endure weather extremes that range from harsh, snowy winters to hot, humid summers and temperature fluctuations in between.

Powder coatings are often the finish of choice for architectural applications due to an array of attractive features for specifiers and building owners. In fact, FEVE-based exterior-grade coatings have been used on architectural applications such as curtain walls, building facades, and extrusions for monumental buildings and commercial storefronts for more than 30 years.

Powder coatings were specified for Lyrik Back Bay because of their:

- Excellent mechanical properties, including hardness, scratch, and abrasion resistance
- Resistance to dirt pickup
- More uniform appearance regardless of orientation
- Thicker film build compared to most standard liquid coatings

High-performance liquid coatings

In addition to powder coating technologies, architects and builders are choosing liquid coil- and extrusion-applied polyvinylidene fluoride (PVDF) fluoropolymer coatings for architectural metal finishing. Like powders, today's PVDF liquid coatings offer a proven combination of aesthetics, durability, and environmental resilience.

Top-tier liquid coatings for architectural applications combine proprietary resins and pigment technologies with 70 percent fluoropolymer-based resins. These coatings offer a wide palette of special effects, glosses, and colors while meeting FGIA/AAMA 2605 specifications. They excel at combating the effects of weathering with optimal UV resistance and long-term color stability.

Used on metal substrates such as aluminum panels, curtain walls, roofs, and cladding systems, fluoropolymer liquid coatings also provide exceptional resistance to chalking, fading, corrosion, and chemical attack. This is true even in seacoast environments with high humidity and salty air.

Advancements have expanded the design potential for architects. Modern systems offer a vast palette of colors, gloss levels, and special effect finishes, including mica, metallic, and low-sheen variants.

With average temperatures climbing worldwide, it is more important than ever to consider the most up-to-date coating systems available. For example, cool coatings formulated with infrared (IR) reflective pigments are being specified with increasing frequency. These energy-efficient coatings lower energy demands for cooling by reducing heat absorption. They are especially critical in hot, sunny regions but are rising in popularity in all climate zones for their performance benefits.

Case study: Allegiant Stadium

Cool coating technology was critical for Allegiant Stadium in Las Vegas, a state-of-the-art facility with a construction price tag of $1.9 billion. Construction of the 10-level fully domed venue posed significant challenges, including its sheer size at 167,225 m^2 (1.8 million sf) and 25,401 tonnes (28,000 tons) of structural steel, plus its setting in the searing sun and heat of the Mojave Desert. The project required high-performance coatings technologies that could withstand the extreme weather and also match the signature colors of the home team. An added challenge was that one of their two main colors is black, which absorbs the most solar radiation from the sun.

Architects worked with a global leader in paints and coatings on advanced custom-color coatings infused with IR-reflective pigments that help cool the climate-controlled building using less energy. The coatings are formulated to achieve a higher degree of total solar reflective (TSR) value than standard protection exterior paints. This was critical to endure decades of heat and UV exposure while preserving the structural integrity of the stadium by reducing corrosion, warping, thermal expansion, and polymer degradation.

Ultimately, both fluoropolymer liquid and powder coatings support long-term building exterior performance with minimal maintenance. Their durability enables extended lifecycles for architectural metal surfaces, helping to reduce the frequency of recoating.

Design with confidence

Today's architectural creations are becoming more daring, dynamic, and performance-driven than ever before.

By specifying advanced fluoropolymer powder and liquid coating systems that meet the highest performance standards, architects can meet the demands of modern architecture while balancing durability, sustainability, design freedom, and adherence to industry standards such as FGIA/AAMA 2605.

Leading building product manufacturers, architects, and specifiers have shifted the conversation around coatings. High-performance coatings are no longer an aesthetic afterthought but a critical design decision that plays a vital role in a structure's performance across its lifetime. As chemistries such as fluoropolymer powder and liquid coatings deliver desired performance and aesthetics on an escalating scale, so does the opportunity to design more boldly than ever before.

additional information

AUTHOR

Gary Edgar is the national architectural specification manager for PPG's building products in North America, which includes factory applied PPG DURANAR liquid coatings and PPG CORAFLON PLATINUM powder coating. He has been with PPG for 27 years, with 18 years devoted exclusively to Air-Dry Fluoropolymer coating systems. Edgar is an active member of industry associations including, AEC, FGIA, AAMP, and MCA. His responsibilities include product and specification recommendations, application recommendations, along with product training to the specification community. He is also responsible for PPG's coil, extrusion (powder/liquid) and ADS warranty approval and is an AAMP/NACE certified coating inspector.

KEY TAKEAWAYS

High-profile architectural structures require effective protective coatings for long-term performance and curb appeal. High-performance options such as fluoropolymer-based powders and liquid coatings are designed to withstand UV exposure, heat, moisture, and freezing temperatures. Technologies such as cool coatings are essential for managing energy demands in hot, arid regions. Key considerations for architects include corrosion resistance, UV durability, color retention, and adherence to standards such as FGIA/AAMA 2605. Innovations like color-shifting pigments enable multifaceted designs with single formulations. Understanding these technologies allows specifiers to achieve design freedom while aligning with sustainability and performance needs.

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KEYWORDS

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Composite Roofing

Strength Meets Sustainability

By Brian Davis
AIA, LEED AP, GRP

PHOTOS COURTESY BRAVA ROOF TILE

Composite roofing, also known as synthetic roofing, has a long history dating back to the mid-1800s. Early synthetic tiles were made of materials such as asphalt, rubber, and early forms of plastic. They were known for their ability to withstand moisture and heat, making them a durable roofing solution. However, today's composite roofing materials are a far cry from their predecessors.

Thanks to innovations in polymer chemistry, advanced manufacturing techniques, and growing demand for environmentally responsible products, composite roofing now offers performance, beauty, and sustainability unmatched by traditional steep-slope roofing systems.

Environmental impact

Although roof replacement is a relatively infrequent event for most homeowners, the environmental impact is anything but small. The Environmental Protection Agency (EPA) estimates that construction and demolition activities in the United States generate more than 544 million tonnes (600 million tons) of waste annually. Approximately 9.9 million tonnes (11 million tons) of waste come from asphalt roofing shingles, accounting for about eight percent of the nation's total waste related to building activities.

Asphalt roofing has long been the standard in the United States. Its manufacturing process involves covering a fiberglass sheet with an asphalt coating and granules to make it water-resistant. While widely used, asphalt shingles are prone to damage from heavy winds and occupy landfill space when disposed of. Compared to today's composite alternatives, asphalt shingles lack the same durability and environmental considerations. Although there has been an emergence of new technology to recycle shingles, there is still far too much that ends up in landfills.

Using recycled materials in roofing helps reduce waste in landfills, promoting a more sustainable lifecycle for building materials. Composite roofing is recognized for its environmental benefits, far surpassing traditional materials. Synthetic roofing is more durable than its natural counterparts and has a longer lifespan. This means the work will hold up over time, lowering the impact on the environment. They have been manufactured to reduce environmental impact, save energy, and provide higher resistance than their conventional counterparts for things such as rot, pests, algae growth, and UV damage, offering a long-lasting roofing solution that benefits both the home and the environment. The lifecycle of the product also depends on how it is produced. Full recycled tiles are manufactured with sustainable materials from their inception, unlike mixtures made with partially non-sustainable materials.

According to the U.S. Green Building Council (USGBC), buildings account for 39 percent of carbon dioxide emissions in the United States, making the shift to sustainable materials crucial for reducing environmental impact. By 2021, a survey by the National Association of Home Builders (NAHB) found that nearly one-third of builders reported an increase in the use of green materials, reflecting a significant rise in consumer demand for eco-friendly construction options. Using these materials has the advantage of earning points towards LEED certification, a recognized standard for measuring building sustainability, thereby enhancing the marketability and credibility of building projects. Certain composite tiles also meet California's Title 24, *Building Energy Efficiency Standards* and Cool Roof Rating Council (CRRC) requirements, especially beneficial in hot climates where heat reflection is critical to energy efficiency. The growing regulatory support and consumer demand for sustainable building practices drive the trend toward composite roofing.

Design versatility and visual appeal

As technology advanced, the formulations of composite materials also evolved, leading to the development of advanced plastics and rubbers that brought the reality of composite roofing to the forefront, making it a true competitor for traditional tiles. Beyond just serving as a roof, these advancements have enabled sustainable roof alternatives to compete in their function and aesthetics. Composite roof tiles have evolved into a range of aesthetic styles, where they now mimic the look and feel of traditional roof materials such as wood, slate, and clay, with the added benefits of longevity, durability, and a lightweight design.

Today's composite roofing materials replicate the appearance of traditional roofing, while offering a sustainable and highly durable alternative.

Some companies use a unique multi-coloring process where mineral pigments are blended throughout the entire tile, not just applied to the surface. This ensures authentic color variation and long-lasting vibrancy. UV inhibitors are also added during manufacturing to prevent fading, helping the roof maintain its appearance for decades.

Advantages over traditional roofing

Composite roofing offers significant advantages, particularly in durability and resistance. These products resist common issues such as cracking, warping, and insect damage, further enhancing their longevity and reducing the need for repairs and replacements.

Three key factors influence a roof's energy performance: solar reflectivity, thermal emittance, and insulation (R-value). Solar reflectivity measures how much sunlight a material reflects away rather than absorbing as heat. Thermal emittance refers to how efficiently a material releases absorbed heat, rather than transferring it into the building below. These two properties are combined in the Solar Reflectance Index (SRI), which gives a comprehensive view of how well a material performs in sunny conditions. R-value, meanwhile, gauges the material's ability to resist heat flow—higher values indicate better insulation. Roofing materials that score well across all three help reduce cooling loads, improve indoor comfort, and lower energy bills. Cool roofs are characterized by a high Solar

Composite roofing materials use a unique multi-coloring process, ensuring pigments are blended throughout the entire tile, not just applied to the surface, for long-lasting vibrancy.

Local climate greatly affects a roof's lifespan. Composite materials are engineered to handle thermal expansion and contraction, allowing them to withstand wide temperature swings and harsh weather conditions.

PHOTO BY JONATHAN HEAD

Reflectance Index (SRI), typically above 70, which indicates their ability to reflect solar heat and release absorbed heat. Higher SRI values signify a cooler roof surface, helping to reduce heat transfer into a building.

Composite materials are engineered to accommodate thermal expansion and contraction, enabling them to perform reliably across various temperatures without compromising structural integrity. In addition to these properties, synthetic roof tiles can enhance a roof's insulation performance. Some profiles feature structural ribbing on the underside, which creates an air gap that contributes to the overall thermal resistance of the roofing assembly. When combined with a thermal underlayment, this design can help increase the roof's total R-value. The result is improved energy efficiency, long-term cost savings, and a reduced environmental impact over the product's lifecycle.

When selecting roofing materials, it is essential to consider the local climate and environment, as these factors significantly impact the roof's lifespan. Different weather conditions can impact the performance of roofing systems. For example, some materials perform well in dry climates but may deteriorate in humid or wet environments due to their tendency to absorb moisture. Conversely, materials that can handle moisture may not perform well in areas prone to hail or high winds. In this space, composite materials offer advantages over traditional roofing, as they are designed with specific needs in mind, including hail resistance in the Midwest, high winds in coastal regions, fire resistance in the CA region, and UV resistance in higher elevation areas.

Traditional cedar shake roofs, for example, lack fire resistance and may pose greater risks, leading to higher premiums. Asphalt shingles are susceptible to damage from heavy winds, whereas synthetic roofing offers superior durability against wind uplift, hail, and fire resistance.

Choosing cool roof-certified materials is essential for homeowners in hot, sunny climates. Solar reflectivity refers to a roof's ability to reflect a portion of the sun's energy, reducing heat transfer into the building. This property is measured by the SRI. Light-colored roofs generally have higher SRI values, making them more energy-efficient in hot climates. Cool roofs further benefit by utilizing materials with high solar reflectance to lower roof temperatures. This minimizes heat absorption and reduces air conditioning demands compared to standard composite roofs.

Homeowners in these areas should look for tiles tested and certified by the CRRC for solar reflectance and thermal emittance, and meet Title 24 requirements for Californians. These tiles help reflect sunlight and reduce interior temperatures, decreasing air conditioning demands and utility bills.

Weight restrictions are another critical consideration for roofing projects. Roofers must ensure the installed structures can support the necessary weight without compromising safety. Many building codes require roofs to support 0.96 kPa (20 psf), but this can vary. It is essential to verify the weight ratings of roofing products to ensure they can withstand conventional weathering and natural disasters. Additionally, the lightweight nature of the tiles makes them easy to move, carry, and load on the roof compared to traditional heavier materials.

Building regulations typically require commercial flat roofs to support more weight than residential sloped roofs. This standard is necessary because flat roofs need to support heavier live loads in concentrated areas, such as snow. In contrast, sloped roofs help reduce the duration and buildup of live loads by allowing snow and other materials to slide off more easily, which lowers the structural demands over time—but does not eliminate them entirely.

Many buildings also rely on heavy exterior appliances, such as HVAC systems and water tanks. As a result, these structures must provide enough strength to support equipment and workers throughout the year. Synthetic roof tile can be an ideal solution, offering a combination of lightweight construction and high durability. These materials provide impact resistance against snow and hail while minimizing the need for additional roof framing due to their lower weight, which helps reduce structural load without compromising performance.

Insurance savings through roof resilience

The performance benefits of synthetic roofing materials can also lead to financial savings beyond just reduced maintenance or energy costs. One less obvious but increasingly important factor is the changing landscape of insurance policies. Insurers are beginning to recognize the value of durable, weather-resistant roofs, such as composite tiles, in reducing the risk of damage from severe weather events. As a result, homeowners with resilient roofing systems may qualify for lower premiums or other insurance incentives. One example is the Fortified Roofing Program, developed and administered by the Insurance Institute for Business & Home Safety (IBHS), a nonprofit research organization. The program establishes "Fortified" standards to strengthen homes and buildings against severe weather, including high winds, hail, hurricanes, and tornadoes. It offers homeowners substantial financial incentives, including grants and significant insurance discounts, for installing roofs that meet these rigorous criteria. Most, if not all, synthetic roofing manufacturers' products are FORTIFIED Certified and are eligible to be used as a roofing system in their program. This means they have met all of the performance requirements.

These programs enhance property protection and contribute to long-term cost savings through reduced insurance premiums. The program offers a network of specialized contractors trained to implement the necessary upgrades tailored to the specific weather challenges a given location faces. Participants gain access to a resilient construction standard developed from extensive scientific research conducted by IBHS. Additionally, homeowners receive third-party verification to ensure the construction materials and installation methods used on their properties meet the rigorous standards required for a Fortified designation certificate, ensuring a high standard of protection against severe weather events. The program can earn up to $10,000 in grant money towards roofing projects (dependent on the state) and savings of up to 80 percent on property insurance. Some insurance carriers,

Cool-certified materials and light-colored roofs generally have higher Solar Reflectance Index (SRI) values, making them more energy-efficient in hot climates.

PHOTOS COURTESY BRAVA ROOF TILE

Insurers increasingly acknowledge that durable, weather-resistant roofing materials can help mitigate storm-related risks, which may influence homeowners' decisions to select composite tiles.

such as State Farm, offer national benefits for homeowners' insurance policies. Homeowners can refer to the IBHS site for specific terms, conditions, and requirements.

Roofing maintenance

Regular maintenance can extend the lifespan of any roof, including composite systems, which typically have lower roof maintenance compared to that of a traditional roof. Still, professional inspection should be conducted at least once a year and after any major storm. Key tasks during these inspections include clearing gutters, checking for damaged tiles, sealing flashing, trimming nearby vegetation, and inspecting attics for signs of leaks. A proactive approach helps identify minor issues before they escalate into major repairs, helping protect the roof system's long-term integrity.

Conclusion

As one of a home's most enduring components, the roof should be built with materials that align with environmental and performance priorities. Composite roofing products stand out for their many benefits: They are long-lasting, durable, and aesthetically pleasing. These materials are favored for longevity, optimal wind resistance, waterproof qualities, and diverse styling options.

Composite roofs can mimic the appearance of various organic materials, such as slate, cedar shake, and clay/concrete tiles, without their associated drawbacks. Unlike the latter, composite roofing is more lightweight, molded for an authentic look and feel, offers a larger range of color options, and has much more ease of installation. These materials also have impressive performance, such as Class A fire ratings, Class 4 impact resistance, Miami-Dade approval, and high wind resistance.

In a changing climate, selecting a composite roofing system that offers sustainability, durability, aesthetic versatility, and energy efficiency can be a practical and forward-looking choice.

additional information

AUTHOR

Brian Davis AIA, LEED AP, GRP, is the director of technical support at Brava Roof Tile, a manufacturer of synthetic shake, slate, and barrel tile roofing. Davis started his career in the roofing industry with GAF, where he worked for 17 years, assisting with both residential and commercial roofing applications. He is an associate American Institute of Architects (AIA) member, LEED AP, and Green Roof Professional (GRP). Davis holds a bachelor's degree in architectural engineering from Alfred State University.

KEY TAKEAWAYS

Composite roofing has evolved into a high-performance, sustainable alternative to traditional materials. Made from advanced polymers and often incorporating recycled content, synthetic tiles resist rot, pests, UV damage, and extreme weather. Their lightweight design eases installation and structural demands while mimicking the appearance of slate, wood, and clay. These roofs offer notable energy efficiency through improved solar reflectivity, thermal emittance, and insulation (R-value), helping reduce cooling loads and utility bills. Tested products can meet California's Title 24, *Building Energy Efficiency Standards*, and Cool Roof Rating Council (CRRC) standards, earning LEED credits and insurance discounts. Composite roofing's long lifespan and lower maintenance requirements further support environmental and financial goals, making it a durable, adaptable solution for changing climates and evolving building codes.

MASTERFORMAT NO.

07 31 00—Shingles and Shakes
07 32 00—Roof Tiles
07 01 50—Maintenance of Membrane Roofing

UNIFORMAT NO.

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B2010—Exterior Walls

KEYWORDS

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Cool roof
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Synthetic materials

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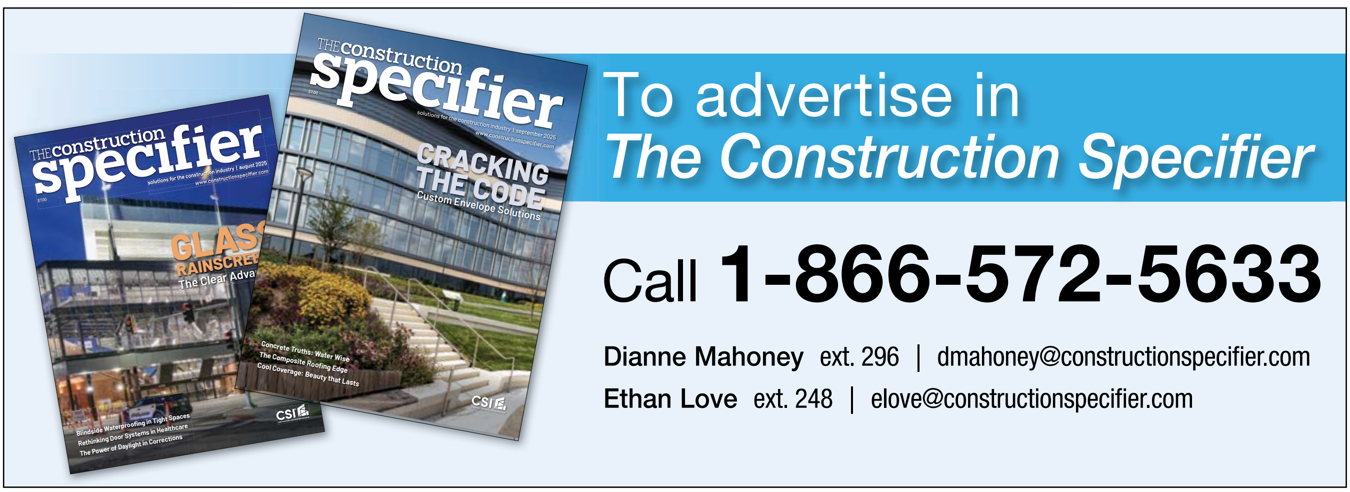

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Balconies on the brink: Weatherproofing fails

In residential construction, exterior balconies are often supported in whole or in part by structural elements that cantilever from the interior framing. While this detail can be a structurally efficient way to support a balcony, the elements that penetrate the building envelope must be protected. Two recent examples show the damage that can result if weatherproofing systems are neglected in this type of balcony configuration.

The first example is at a multi-building student housing complex in the southern United States. Plate-connected wood trusses spanned from the interior to the exterior to support second and third-floor balconies. The exterior balcony deck was finished with wood sheathing, sheet waterproofing, and a concrete topping slab. The designers assumed the waterproofing would protect the trusses; therefore, untreated wood and mild steel connectors and fasteners were used even at the exterior trusses. Deficiencies in the installation and ineffective perimeter detailing in the waterproofing led to water infiltration and deterioration of the trusses. Since the balcony structure was concealed between the concrete topping slab above and the plywood soffit below, water infiltration and subsequent deterioration of the trusses progressed undetected for an extended period (Figure 1).

The second example is a condominium development in the Midwest. The four-story building consists of two tiers of duplex units, with balconies cantilevered from the facade at the third floor. The original design called for cantilevered framing at the side edge of each balcony, with intermediate balcony framing spanning between these elements, parallel to the facade. This design was changed during construction to cantilever the 2x10 wood floor joists from interior to exterior. Treated wood was used for the cantilevered joists, but the joist penetration detail through the building envelope was not addressed. In particular, an unsealed gap between the doubled 2x10 joists at either side of the balcony created a direct path for air and water leakage to the interior. Although the brick veneer was sealed to each joist, the primary air-water barrier layer was unsealed at the penetrations (Figure 2). Leakage around the joist penetrations led to water infiltration and severe wood framing and window header decay below the balconies (Figure 3).

figure 1

figure 2

figure 3

Figure 1: The plate-connected wood trusses were insufficiently protected by the balcony waterproofing, leading to extreme wood decay within just a few years.

PHOTOS COURTESY WISS, JANNEY, ELSTNER ASSOCIATES (WJE)

Figure 2: The wood joists penetrating the building envelope were sealed to the brick, while the air-water barrier behind the veneer was unsealed.

Figure 3: The window header below the balcony experienced rapid wood decay due to the inadequately sealed joist penetrations above.

While cantilevered balcony framing may be structurally efficient, careful detailing for weather protection is necessary. Structural elements penetrating the envelope must be selected for exterior exposure, such as treated wood, stainless steel fasteners, or galvanized steel. Each structural element penetrating the envelope requires perimeter flashing and sealing at the primary and secondary layers of the exterior assembly. During construction, mock-up review and water testing help ensure that these often complex details are installed correctly.

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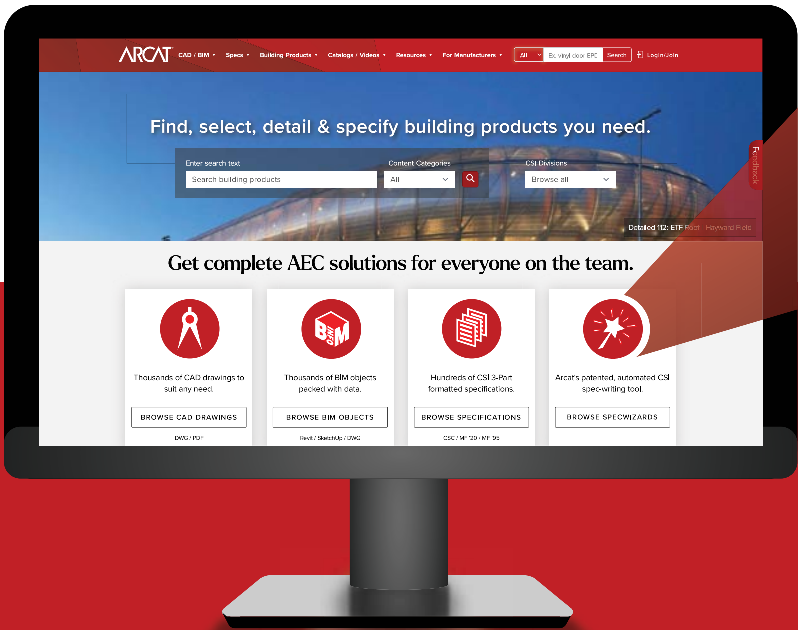

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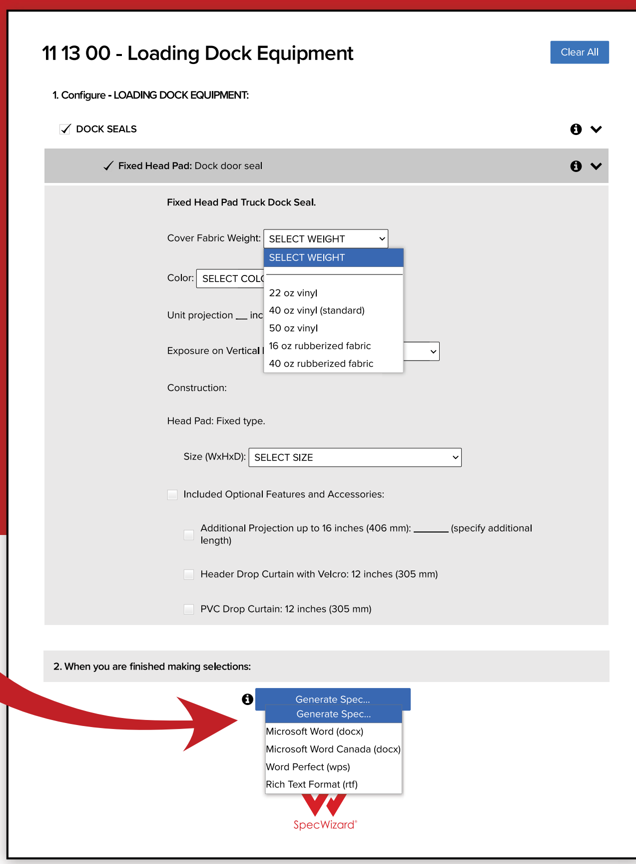

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