FRP ROOF DECK:

A Solution for Challenging Conditions

By Tom Toler

A SPECIALIZED NEED

A roof deck serves as the structural substrate for roofing materials while providing protection for equipment, products, and personnel located below. These basic functions require materials that provide long-term, reliable performance.

However, many facilities have chemical exposures or continuous moist conditions that can result in a short service life for metal or wood roof decks and produce costly maintenance and premature replacement of the entire system.

Corrosive elements can attack uncoated edges of a steel deck and its fastening points. Moisture will eventually cause wood planking to rot and deteriorate. Concrete plank decking is sometimes used for harsh conditions; however, chemical vapors can penetrate the porous material, attack its reinforcing bars, and cause the decking to flake or spall. This can be a concern for personnel safety and can damage equipment or contaminate finished goods located below. In addition, aged concrete deck planks can sag and, in extreme cases, experience catastrophic failure and collapse.

Facilities that can have these conditions include natatoriums, food and chemical processors, pulp and paper mills, power plants, mining and metal treatment facilities, and others.

A PROVEN SOLUTION

Offering long and reliable service life, a properly fiberglass-reinforced plastic (FRP) roof deck can provide performance exceeding that of metal, wood, or concrete decking for these types of applications.

For corrosive conditions, an FRP roof deck is a lower-cost alternative than stainless steel. In addition, when compared to concrete planks, an FRP roof deck can provide an 11-pound-per-square-foot reduction in dead load on the building structure. As support for either single-ply or built-up roofing, structural FRP decks have delivered significant life cycle cost savings and outstanding performance for many end users. To achieve this level of performance and acceptance, an FRP deck must effectively address all of these issues:

- Chemical and moisture resistance
- Long-term support for dead and wind-uplift loads
- Installation
- FM and UL requirements

CHEMICAL AND MOISTURE RESISTANCE

To ensure appropriate selection of materials, the potential effects of chemical or high-moisture exposure should be considered in the design and specification stage. Many factors must be evaluated, including chemical type, concentration, duration of exposure, and operating temperature.

FRP materials made with an appropriate polymer resin system can easily resist chemical exposures that are deleterious to metal components. A well-designed FRP roof deck does not rust, rot, peel, or flake, thus eliminating the threat of falling particles that can damage equipment or contam-

CHEMICAL RESISTANCE: PREMIUM-GRADE VINYL ESTER

Chemical	Concentration	Operating Temp (˚F)
Chlorine dioxide	Fumes	210
Chlorine wet gas	All	210
Copper sulfate	All	210
Hydrochloric acid	15%	210
Hydrogen sulfide	All	210
Magnesium chloride	100%	210
Phosphoric acid	85%	210
Sodium chloride	All	210
Sodium hydroxide	Vapor	180
Sodium hypochlorite	5%	180
Sulfuric acid	50%	210

Table 1

Photo 1 – A corrosion-resistant FRP roof deck can deliver long, maintenance-free service life in chemical or high-moisture exposures.

inate product. FRP roof decks have an extensive history of successful use in continuous wet conditions such as those found in papermaking operations.

The type of resin used in the FRP material will affect its long-term capability to resist chemical attack. Both vinyl ester and isophthalic polyester resin systems offer outstanding corrosion resistance. Vinyl ester materials have better strength retention at elevated temperatures and capacity for support of long-term dead loads. In consideration of these factors, premium-grade vinyl ester resin should be the required resin system for an FRP roof deck. The chemical resistance table (*Table 1*) provides guidelines for vinyl ester materials in a sampling of chemical exposures. See *Photo 1*.

STRUCTURAL PERFORMANCE

In an FRP material, the primary source of strength and stiffness is its glass fiber reinforcement. As structural properties are controlled by the content and alignment of the fibers, glass-reinforcing content must be maximized.

For a roof deck, it is recommended that FRP material contain a minimum reinforcing content of 50% of its weight, which should be a minimum of 1 lb. per sq. ft. (psf). This is virtually twice the amount of glass-fiber reinforcing that is found in light-duty, chopped strand FRP panels and results in much higher strength and stiffness properties. As translucent roofing and siding, chopped-strand-reinforced FRP panels may be suitable for some applications with low structural requirements but not as a structural roof deck.

For effective reaction and transfer of loads within a structural FRP panel, the glass fiber reinforcements should be straight and continuous and aligned in both

longitudinal and transverse directions. The reinforcing alignment and glass content provide the structural capability necessary to support the dead load of roofing materials and wind uplift loads with minimal deflection.

The reinforcing content of 50% by weight in straight, continuous, bidirectional alignment is the basis of design for Tuff Span, the first FRP building panel used as a structural roof deck. This is also a typical requirement for other FRP materials used for demanding structural applications such as pultruded FRP beams and grating.

As a key part in developing the first FRP material used as a roof deck, engineers conducted repetitive, large-scale tests to accurately determine material capacity to support long-term, dead, and uplift loads at deflection levels typical for structural roof decks. The large-scale tests are the basis for load/span data developed for the FRP decks in *Figures 1* and *2* and their accompanying tables (*Tables 2* and *3*).

For metal deck panels, moment capacity is typically the limiting factor for determining maximum spans. However, for an FRP profile such as the 6.5 deck, deflection and stiffness (EI) can be the controlling design limits. These can result in longer allowable spans for a two-span condition when compared with a multiple span. To increase stiffness and maximum spans, these FRP decks are designed with greater panel depth than metal deck units. The 6.5 x 2 deck is 2 in. deep versus the 1.5-in. depth of conventional steel B Deck. The 8.0 deck is manufactured in 3.5-in. depth as compared to 3-in.-deep, steel N Deck.

6.5 x 2 VFR 500

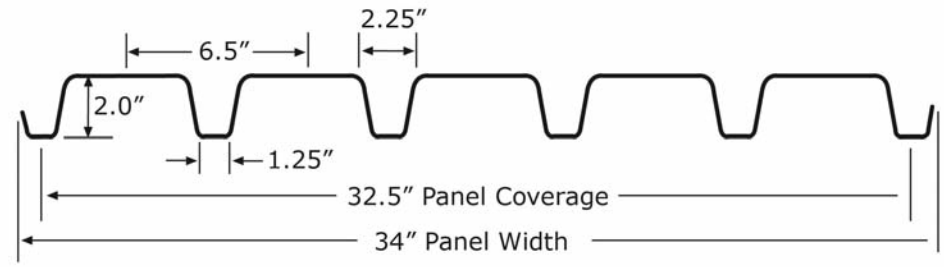

Figure 1

DEAD + LIVE / UPLIFT LOADING: L/D=180, FOS=2.5							
Uniform load, psf	**20**	**30**	**40**	**50**	**60**	**70**	**80**
Single span	7'0"	6'1"	5'6"	5'1"	4'10"	4'7"	4'4"
Two span	9'4"	8'2"	7'5"	6'11"	6'6"	6'2"	5'10"
Three or more spans	8'7"	7'6"	6'10"	6'4"	6'0"	5'8"	5'5"

Table 2

8.0 x 3.5 VFR 700

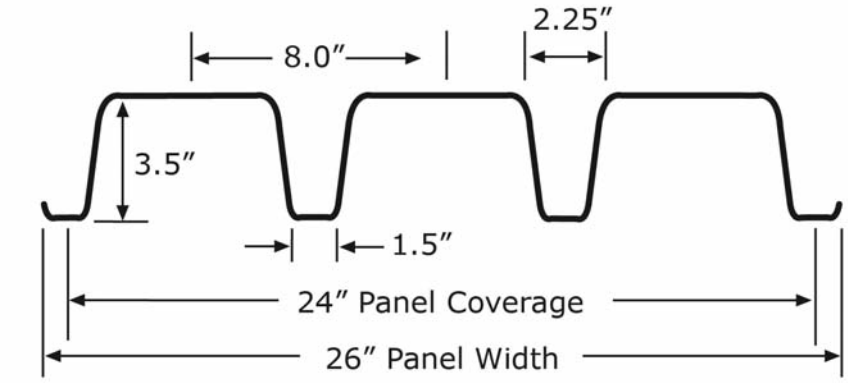

Figure 2

DEAD + LIVE / UPLIFT LOADING: L/D=180, FOS=2.5							
Uniform load, psf	**20**	**30**	**40**	**50**	**60**	**70**	**80**
Single span	9'6"	8'3"	7'6"	7'0"	6'7"	6'3"	6'0"
Two span	12'9"	10'6"	9'1"	8'1"	7'5"	6'10"	6'5"
Three or more spans	11'9"	10'3"	9'4"	8'8"	8'2"	7'8"	7'2"

Table 3

Photo 2 – Fastening of FRP roof deck to supports is similar to a metal deck. Layout of the lighter FRP sheets is faster.

Photo 3 – Mechanical fasteners or cold adhesives are commonly used to attach roofing membrane and insulation to FRP deck.

FM GLOBAL LISTINGS

Roof Deck Section	6.5 x 2 VFR 500	8.0 x 3.5 VFR 700
Maximum span	6 ft. 3 in.	8 ft.
Fastener - washer diameter	1-60 = .729 in. 1-90 = 1.125 in.	1.125 in.
Side-lap fastener spacing	18" o.c.	24" o.c.
NC insulation fasteners	16 / 4 x 8 board	16 / 4 x 8 board
Polyiso insulation board	1.3 in.-thick minimum	1.3 in.-thick minimum
BUR glass felt	3 ply minimum	3 ply minimum
Wind uplift rating	1-90	1-90
Deflection limit	L/240	L/240

Table 4

Photo 4 – A corrosion-resistant, FRP roof deck can deliver long, maintenance-free service life in chemical or high-moisture exposures.

INSTALLATION

Offered in rib profiles similar to conventional steel deck, installation time and procedures for fastening FRP roof deck to supports are similar to those for a metal deck. With lighter weights, the layout of FRP deck panels is typically quicker and costs less than metal units. Compared to concrete decking, installation cost for a much lighter FRP roof deck is significantly lower.

Attachment of roofing insulation or membrane to FRP roof deck can be achieved by the following:

- Mechanical (positive lock) fasteners such as Enduro NC plastic, SFS-TPR peel rivet, or Rawl speed-lock toggle
- Cold adhesives such as Olybond 500, Duro-Grip, or an equal. Uplift data are available for Olybond 500 and Duro-Grip materials used with FRP roof deck.
- Hot bituminous adhesive (if allowed) with temperature not exceeding maximum value set by the *NRCA Handbook of Accepted Roofing Knowledge*

See *Photos 2* and *3*.

FM AND UL LISTINGS

FRP roof decks with vinyl ester and a fire-retardant resin system have a UL Class 1 flame spread rating of 25 or less in accordance with ASTM E84 testing. FRP roof deck sections are also UL listed for Class 90 uplift, including construction #NM523 for 6.5 x 2 VFR 500 and construction #NM524 for 8.0 x 3.5 VFR 700.

A roofing assembly with FRP 6.5 x 2 roof deck has FM Global approval for Class 1 fire and Class 1-90 windstorm classification. Other assemblies with FRP roof decks are listed as Class 2 per *FM Report J.I. OTOA9* (*Table 4*).

SUMMARY

Conventional metal, wood, or concrete roof decks may not be the best materials for chemical or continuous wet conditions. Structural FRP roof decks constructed with 50% reinforcing content, premium-grade vinyl ester, and fire-retardant resin have proven that they can provide longer service life and significant life cycle cost savings for these challenging structural and environmental conditions. The following two case histories are provided as examples.

CASE HISTORY: WEYERHAEUSER PAPER

Prior to June 1987, Weyerhaeuser Paper had tongue-and-groove wood roof deck installed on its Longview, Washington, paper mill. According to roof consultant Gus Siegrist of A.N.G. Consulting Services, Inc., the roof was leaking, and the deck was rotting and deteriorating.

Expecting that an FRP roof deck would stand up to the demanding conditions, Siegrist and Weyerhaeuser selected Tuff Span 6.5 VFR 500 roof deck to replace the 44,000-sq.-ft. wood roof deck. The FRP roof deck is still in service after 24 years and has delivered huge life cycle cost savings for Weyerhaeuser. See *Photo 4*.

CASE HISTORY: UNIVERSITY OF WEST FLORIDA NATATORIUM

As the result of exposure to moist, chlorinated conditions, the coated steel roof deck at the University of West Florida natatorium had been weakened by corrosion and seriously damaged during Hurricane Ivan. In its search for a replacement material, STOA Architects included the following requirements for the new roof:

- Resistance to chlorine vapors
- Resistance to hurricane-force, wind uplift loading due to its coastal location
- Compatibility with cold adhesives for attachment of roofing materials

STOA identified an FRP roof deck as the material that would provide performance superior to metal for the environmental conditions in the natatorium. Installed in 2005, the FRP roof deck has met expectations and provided outstanding service. See *Photo 5*.

Photo 5 – FRP roof decks are a suitable substrate for either single-ply or built-up roofing.

Tom Toler

Tom Toler has held senior management positions for both steel and FRP building panel manufacturers. During his career, Toler has contributed to the development of several FRP products, including FRP roof and form deck, FRP roofing panels supporting foot traffic, the first FRP exterior cladding to achieve FM approval, long-span FRP structural shapes, and FRP louvers and ridge vents. He served on the committee for the Society of Plastics Institute that developed ASTM 3841, the standard for fiberglass-reinforced plastic building panels. Tom is currently product manager for building and environmental products for Enduro Composites, Inc., located in Houston, Texas.

LIGHTWEIGHT INSULATING CONCRETE (LWIC), A JOBSITE-PRODUCED ROOF DECK SYSTEM

By Mark J. Bates

Lightweight insulating concrete (LWIC) is one of the most efficient, accommodating roof deck systems available. Its versatility allows for a fast and easy solution for custom drainage designs, working over various substrates in the most difficult slope-to-drain projects. Consultants, however, seem to become frustrated when comparing one LWIC contractor with another due to differences in production, methods of application, and material quality. Certainly, the right contractor can greatly benefit the outcome of a project, favorably affecting its budget, schedule, and quality. Specialized on-site batch plant equipment is required to produce LWIC, and the condition of the equipment will determine the production rate and quality of LWIC materials.

LWIC BATCH PLANT EQUIPMENT

LWIC batch plant equipment (*Figure 2*) is designed to mix and batch LWIC at a constant, consistent mix, while continuously pumping material to the roof substrate. The batch plant may be small and simple or it may be large and complex; depending on the

Figure 2 – LWIC batch plant equipment is designed to mix and batch LWIC at a constant, consistent mix.

type, the batch capacities vary from 0.75 to 2 cubic yards. Well-maintained, properly functioning equipment is vital to providing productivity and quality LWIC product. The accuracy of measuring devices, sealed mixer doors, mixer paddles, and pumping units is important in producing a quality LWIC.

- **Load cells** are used to determine the weight of the Portland cement that is used in each batch of concrete. Faulty load-cell readings can provide inconsistent densities at the point of placement, leaving the LWIC with inconsistent compressive strengths.
- **Water metering devices** are used to determine the amount of water that is used in each batch of concrete. A defective water meter can cause concrete mix designs to be too fluid and/or too tight, creating an inconsistent mix and making it difficult for the finisher to provide a smooth, consistent surface. The National Roof Deck Contractors Association's (NRDCA) 300-page document titled *Procedures to Determine the Accuracy of Measuring Equipment for LWIC* is a great source to determine the accuracy of load cells and water meter devices.
- **Mixer doors.** After producing each concrete batch, a mixer door opens and dispenses the concrete into a hopper; once emptied, the door is returned to the closed position, allowing the operator to produce another batch of concrete. A proper functioning mixer door should be leak-free; when mixer doors leak, diluted concrete escapes, falling into the holding hopper and providing a product of inconsistency at point of placement.
- **Mixer paddles** accurately distribute material throughout the concrete mix and properly wet the cement and aggregate particles. Broken or missing paddles can prevent materials from being thoroughly mixed, providing a material that falls short of project requirements.
- **Pumping Unit.** The pumping unit is a progressive, cavity-type pump made of two main parts: a rotor and stator. From the hopper, the LWIC is driven into the cavities created between the rotor and stator. As the rotor turns and advances forward, the LWIC is pumped through the concrete hose to the point of placement, delivering a smooth, pulse-free material at a high flow rate of application. The rotor and stator are wear items that require replacement several times a year; worn rotors and stators can cause loss of viscosity, reduced concrete discharge, loss of pressure, and erratic density changes.

For best performance and reliability, the following application guidelines are based on evaluations from successful tested assemblies, experience, and research.

SLURRY COATS

Slurry coats are commonly the weak link in these systems. The slurry coat is a layer of LWIC placed between the receiving substrate and the EPS holey board insulation. Proper application of slurry coat is essential for optimum performance of any LWIC system. Insulation boards should be placed in such a manner as to cause full contact of the board surface with the freshly placed slurry. The concrete should enter into the keying holes of the holey board, and the boards should be placed in a running bond pattern of staggered joints butted tightly together. After placement, the insulation boards should be walked in to firmly set the board in slurry coat. Once complete, all foot traffic (including the consultant, building inspectors, and all other trades) should be eliminated from the freshly placed insulation board surface until the following day. It is of the greatest importance that this slurry coat set is not disturbed until the concrete hardens to provide an adequate bond between the slurry coat and the board surface, a bond that typically develops overnight.

The following day, field inspections are performed. An indication of inadequate slurry coats or incomplete insulation board contact with the slurry is that the boards will freely move when walked on, or one can lift the board from the slurry with ease. The consultant may discover that boards had contact with only the top of the flutes in the metal decking. If these are left in place, the LWIC topcoat application will not flow into these empty voids (*Figures 3A* and *3B*).

Empty voids that are left are cause for concern. After the completion of the roof deck and prior to the installation of the roof membrane system, these systems can sometimes contain intruded water when

Figures 3A and 3B – Slurry coats with contact at top flutes only.

exposed to heavy rains. The amount of water intrusion will vary from manufacturer to manufacturer. Water intrusion collects in low areas under the system; for reroof or concrete substrates, it is strongly suggested that prior to the start of the LWIC system, all points are noted on project drawings (*Figure 4*). This water also collects in voids left from inadequate slurry coats. Water that remains in these voids will vent out at a slow pace and can cause water droplets to form on the underside of the metal deck. The use of slotted or perforated metal decking may or may not be helpful in addressing this problem (*Figure 5*).

Prevention is key to averting these voids; provide a suitable slurry coat, and, if in question, more is better. Remember that when the insulation boards are walked in to the slurry coat, any excess material will come up through the holes of the insulation, leaving a uniform slurry coat thickness. When applying the slurry coat, it is important to not allow it to set before the insulation boards are installed. Contractors should never get too far ahead of themselves. A good rule of thumb is to discontinue placement of the slurry coat after 2 to 3 cubic yards are placed, then proceed with installation of the insulation until all boards are set in the fresh concrete. Then walk the boards down, and repeat the process.

For best performance, slurry coats are required to set overnight before applying the topcoat. Often, contractors feel compelled to begin the top pour within hours after the slurry coat placement; when contractors are questioned, a common reply is that "it might rain." The thought is, if the topcoat is placed and rained on, there will be less remedial work to do the following day. When adverse weather conditions are threatening, normally the last two hours of placement are most vulnerable to rain damage. The best defense against adverse weather conditions is proper slurry coat application.

When exposed insulation boards are subjected to rain, the insulation board must be inspected to confirm adhesion to the substrate. Any loose insulation boards should be removed, and standing water should be removed by vacuuming. Apply a new slurry coat over the substrate and reinstall the insulation boards in such a manner as to

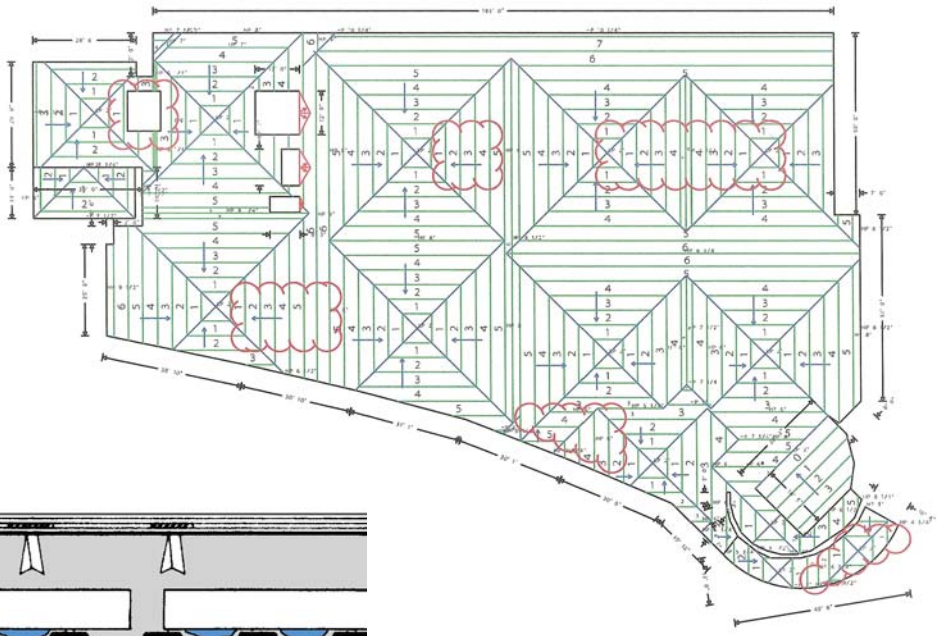

Figure 4 – Note existing low points on project drawings.

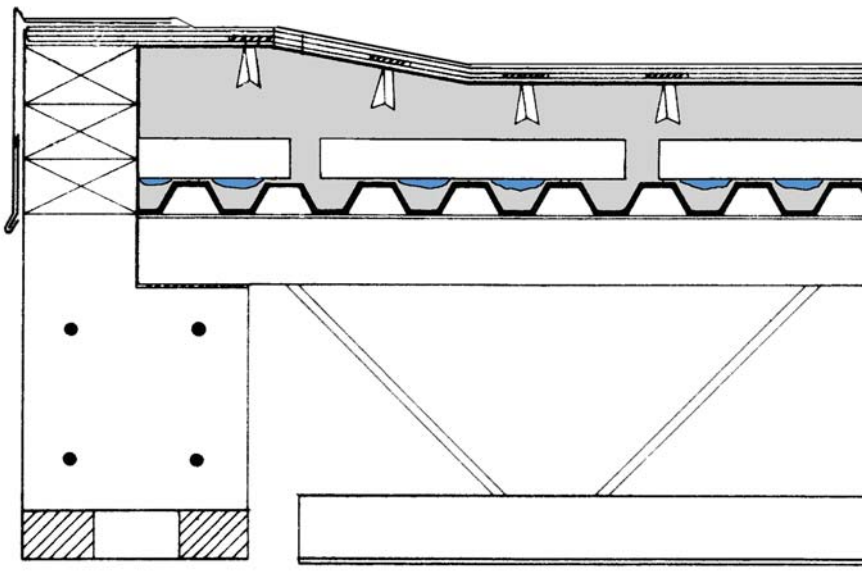

Figure 5 – Rainwater collects at empty voids.

cause full contact of the board surface with the plasticized concrete (*Figure 6*).

Same-day topcoat applications have proven to be problematic if the slurry is not allowed to set before the topcoat application. Insulation boards have a tendency to float toward the top surface, leaving the insulation board with questionable bond to the substrate. Another problem is insignificant topcoat thickness for base ply fasteners to properly set. There are no cost advantages to allowing the slurry to set overnight versus placing the topcoat the same day, unless the project is so small that the contractor is able to complete the project in one workday instead of having to return the following day to complete the topcoat. When approached with guidelines stating the topcoat may be placed later the same day as the slurry coat, any claims should be accompanied with documentation of successful testing.

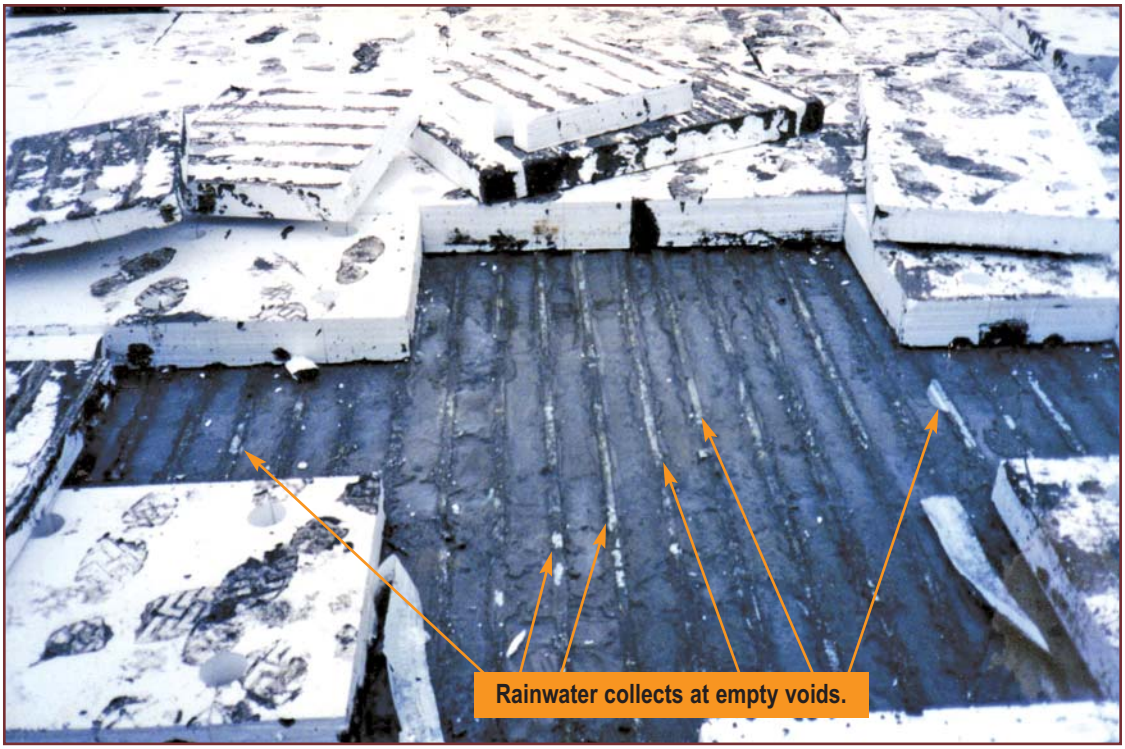

Figure 6 – Inadequate slurry coat. The only contact of the EPS boards with the slurry coat is at the metal deck's top flute.

Figure 8 – End-of-the-day cold joint for following day tie-in.

Figure 7 – Cold joint formed using a square aluminum screed.

FINISHING TOOLS

LWIC finishing tools and screeds are used to establish the grade for the topcoat placement. Square tube screeds are used to support a straight edge, and when pulled, the straight edge will create a finished surface. Screeds are set to ensure the LWIC is applied to the required depth. When removed, the area is then finished to a smooth trowel finish. The finish should be smooth enough to receive the roof membrane cover. Screeds are made of aluminum square tubing and should be used in place of heavy, round steel pipe. Steel pipes are difficult to handle and maintain, having a tendency to roll away when the concrete is placed. Screed should be used whenever possible. String lines should be considered only when screeds could not be used and/or over irregular surfaces or intricate, sloped sections. Screeds and straight-edged floats ensure proper minimum coverage.

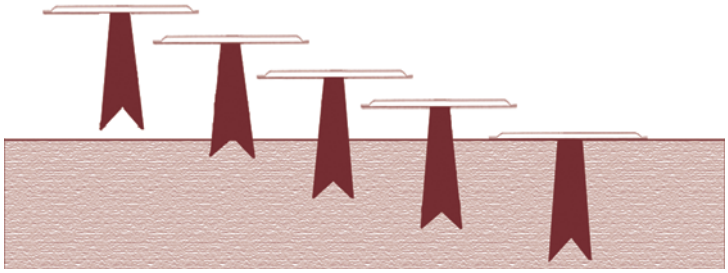

Figure 9 – Low compressive strength decreases fastener resistance.

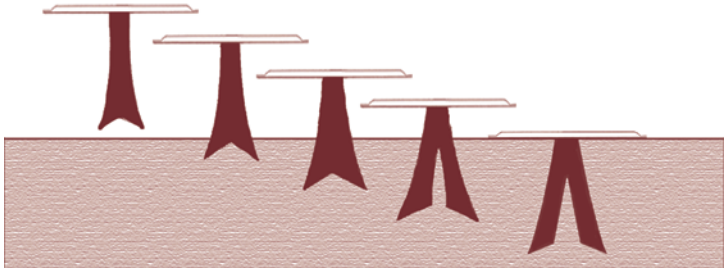

Figure 10 – High compressive strength increases fastener resistance values.

Finishing tools should be the type used to finish the LWIC to smooth-troweled finish in order to receive the roof membrane cover. Cold joints should be formed at the end of the day by using a square aluminum screed bar; after a short set time, they are removed, leaving a nice, clean tie-in for the following workday. *Figures 7* and *8* provide excellent examples of how to form a cold joint using a square aluminum screed.

COLD JOINTS

Cold joints and/or pour lines are intersections between two LWIC pours, one old and one new. When improper techniques are used or when equipment mechanical breakdowns occur, cold joints become a common point of concern. Some are noncritical and are considered as surface imperfections unacceptable to receive roof membrane covers due to the surface roughness. Typically, scraping and a thin layer of patch material minimizes the concerns. Others will require the removal of unsound material consisting of flaking, soft, powdery, unbounded materials, which should be replaced in accordance with manufacturer-approved materials and guidelines.

INDUSTRY STANDARDS FOR FASTENERS

Industry standards state the lightweight

insulating concrete fastener withdrawal shall have a minimum resistance of 40 pounds at the time of roofing. This is also a Florida Building Code requirement. Does this longstanding standard make any sense when faced with wind speed designs of 150 mph? In a word, "no." Long before 12-ft. x 24-ft. wind uplift tables came into being and long before ASCE 7 was authored, it was generally believed that monolithic roof decks (including LWIC decks) were airtight and therefore not subject to the positive pressures generated on the underside of roof membranes. Accordingly, the industry discounted applicable uplift requirements by one-third for monolithic structures, the thought being that two-thirds of the forces on the roof membrane were generated from above, and the one-third that was thought to be exerted from below was negated by the impervious monolithic deck. With Class I-60 being the most frequently encountered "standard" for wind uplift performance, and a typical fastening pattern of one fastener per sq. ft. (100 fasteners per square), an average fastener withdrawal of 40 lbs. was necessary to achieve compliance.

Today's product approval listings fail to mention the minimum fastener resistance requirements, only stating the number of days before roofing begins; others simply state "after several days." Depending on ambient temperatures, roof deck manufacturers may wait several days before roofing begins, in anticipation of fastener resistance values. As the LWIC cures, it gains compressive strength and, as such, increases fasteners' resistance values. When base ply fasteners are installed, the fastener's dual legs diverge as they wedge and anchor into the LWIC (*Figures 9* and *10*). Compressive strengths and fastener spacing will vary, depending on applicable uplift requirements. Individual roof deck manufacturers have specific requirements that need to be addressed before roofing begins. Prior to roofing, field withdrawal testing should always be performed to evaluate the ability of the LWIC to retain the base ply fasteners. When test results fall below project requirements, a modified fastener spacing pattern should be considered.

A basic understanding of the LWIC substrate, common sense, flexibility, and simple, rudimentary math skills are necessary to fine-tune fastening patterns based on the level of performance actually encountered on each specific LWIC roof deck. New dual-legged fasteners address today's higher wind uplift requirements. These fasteners often make marginal assemblies viable and viable assemblies safer and more secure.

Taking the time to understand the characteristics of the material will lead to better installations and more satisfied customers.

Mark J. Bates

Mark J. Bates is the director of product development for Quantum Roof Deck Systems. He has over 27 years of experience in all aspects of the LWIC industry and personally designed and built one of the country's largest LWIC batch plants. Bates is a past president of Celcore, Inc. and served as president of the Florida Roof Deck Association (FRDA) from 2008-2010.