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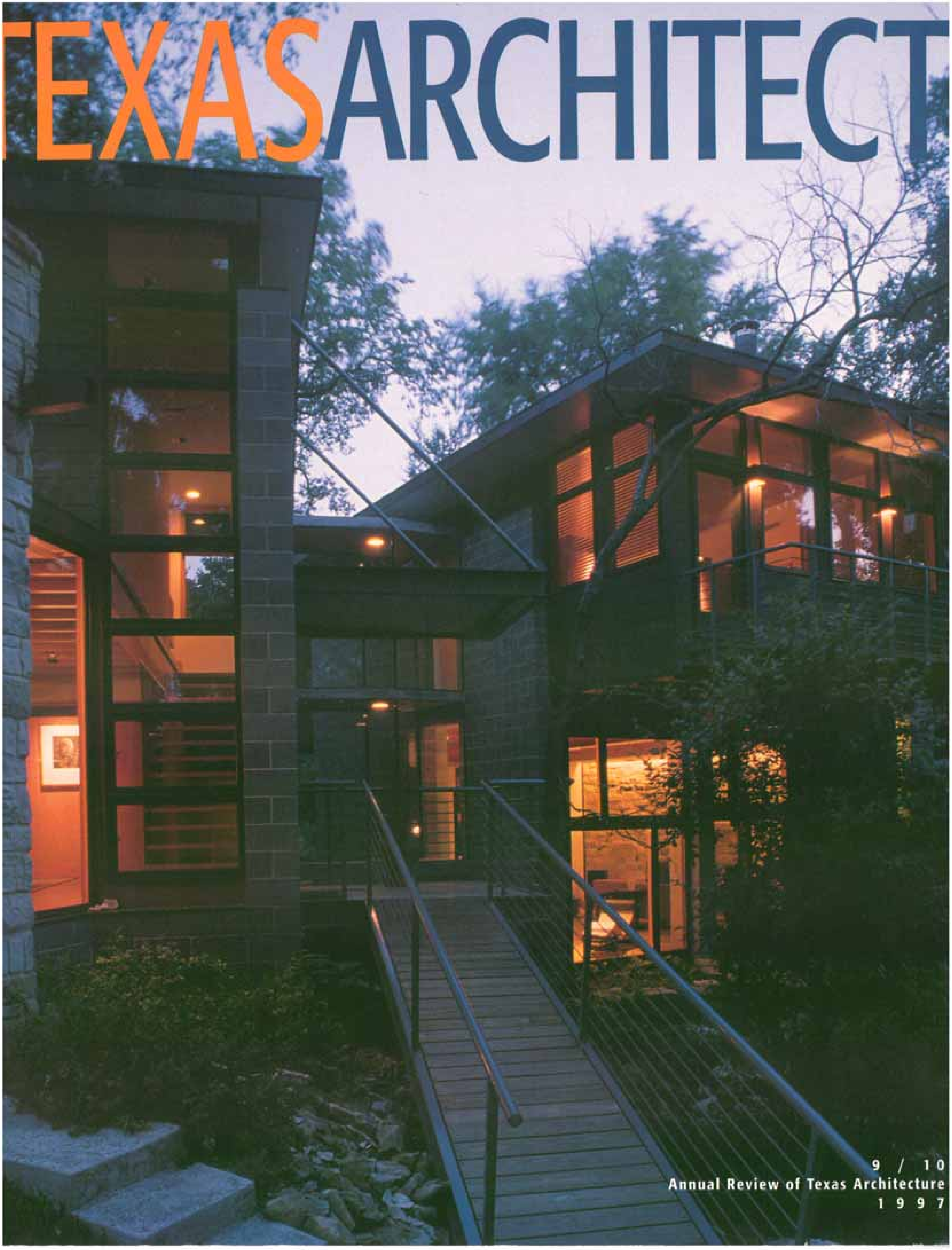

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Annual Review of Texas Architecture
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A Roofing Alternative

A ROOF SUBSTRATE THAT IS commonly utiized, both in existing and new construction, n the southern and southwestern regions of he United States, is lightweight-insulating concrete. This article provides ideas and general information regarding material options, application methods, testing procedures, system-construction sequencing, and constructibility options that can be used during installation of new lightweight-insulating concrete or roof-replacement activities over existing lightweight-nsulating concrete fill substrates.

General Information

LIGHTWEIGHT-INSULATING CONCRETE has been used in the construction of roof decks since he late 1930s. It consists of Portland cement ASTM C 150, Types I, II, and III), water, and either a lightweight aggregate or an air entraining agent. There are two basic types: 1) aggregate lightweight-insulating concrete, or 2) cellular lightweight-insulating concrete.

The aggregate type of lightweight concrete has been used since the late 1930's. Two predominant aggregates have been utilized: vermiculite or perlite. Both are naturally occurring minerals that are mined. The aggregate that is used in the concrete is formed by aking the mined ore and heating it at elevated temperatures (1600 degrees Fahrenheit), causing the mineral to expand many times 4 to 20 times) its original size and volume. Consequently, the resulting "expanded" particle occupies a larger volume at a lower weight.

These "lightweight" aggregates are incorporated into the concrete mixture (Portland cement and water) in lieu of sand and gravel typically used in traditional structural concrete), in order to create the lightweight-insulating concrete while providing some level of insulating value. These aggregates, when used in lightweight-insulating concrete, should conform to ASTM C 332, "Lightweight Aggregates for Insulating Concrete" Group 1 designation (aggregates prepared by expanding products such as perlite or vermiculite).

W.R. Grace was the predominant supplier of vermiculite-based lightweight-insulating concrete for many years. In 1995, Siplast purchased the rights from Grace to the lightweight-insulating concrete business and is the current predominant supplier of the vermiculite=fill material. Siplast markets their products under the previous names used by Grace, which are Zonolight Insulating Concrete (ZIC) and NVS (Non-venting substrate) Insulating Concrete. The perlite-based material is generally provided by regionally located deck applicators rather than one particular manufacturer. The Perlite Institute has published guidelines and standards for perlite-aggregate-based lightweight-insulating concrete.

The cellular or "foam" lightweight concrete has been used since the 1960s. Cellular concrete utilizes a pre-generated foam ("detergent") that is introduced into the cement and water mixture. The foam creates tiny air bubbles within the concrete mixture during the batching process. The control of the density of the fill is achieved by substituting macroscopic air cells for all or a portion of the fine aggregate. After placement and during the curing process, the foam dissolves, creating a network of open air cells throughout the concrete mixture, thus creating the lightweight characteristic and, in addition, providing some level of insulating value.

The use of the foam creates a "slickness" characteristic that allows for ease of use during the placement of the concrete. Consequently, less water is necessary with cellular concrete because the addition of the foam concentrate makes the concrete more workable. The foam concentrate should comply with the standard specifications as established by ASTM C 869, "Specification for Foaming Agents Used in Making Pre-formed Foam for Cellular Concrete," when tested in accordance with ASTM C 796, "Test Method for Foaming Agents for Use in Producing Cellular Concrete Using Pre-formed Foam." At this time, several manufacturers provide the cellular type of lightweight-insulating concrete, including Elastizell Corporation of America (Elastizell Cellular Concrete), Celcore, Inc. (Celcore Cellular Concrete), Cellufoam Concrete Systems (Ultra-Lite), Mearl Corporation (Mearlcrete), Lite-Crete, Inc. (Lite-Crete Cellular Concrete), and Siplast (Insucel.)

Common properties of the two variations of lightweight insulating concretes

Property	Aggregate	Cellular
Cement: Aggregate Ratio	1:3.5–1:6 1:3	(cement:foam)
Cement Content	4–5 sacks/cubic yd	6 sacks/cubic yd
Water:Cement Ratio	1.25–1.6	0.5–0.6
"Wet" Density	35–60 pcf	30–45 pcf
"Dry" Density	20–40 pcf	20–40 pcf
Compressive Strength	130–300 psi	120–200 psi

Other elements can and have been substituted for the aggregate to achieve alternative lightweight mixtures. One is expanded polystyrene (EPS) beads. Combinations of the lightweight aggregates, EPS beads, and/or foam have also been used to achieve a desired formulation by various manufacturers. One manufacturer, Siplast, currently provides a hybrid mixture of both aggregate (vermiculite) and foam which is called Zonocel.

If you are a registered architect and an AIA member, reading this regular feature in *Texas Architect* can help you accumulated valuable learning units. After reading *"TA* Specifier," complete the questions on page 48 and check your answers on page 87 for two learning units.

CONTINUING EDUCATION AIA

Learning Objectives

After reading this article and completing the exercises, you will be able to:

1. understand the material qualities of lightweight concrete;
2. understand the advantages and disadvantages of lightweight concrete;
3. realize the implications for its applications and installation.

The typical R-value of lightweight concrete ranges from approximately 1.1–1.5 per inch, depending upon the added element (aggregate versus foam). The R-value of the lightweight-concrete system can be increased significantly with the inclusion of EPS board. EPS board has a typical R-value of approximately 4.15 per inch based on a minimum density of 1 pcf. The R-value is determined by independent testing of materials in accordance with ASTM C 177 "Standard Test Method for Steady State Heat Flux Measurement and Thermal Transmission Properties by Means of the Guarded Hot Plate Apparatus."

Advantages of Lightweight-insulating Concrete

The advantages of lightweight-insulating concrete are as follows:

- Provides one-hour to two-hour fire-rated deck assemblies without the addition of thermal barriers or the application of fireproofing on the underside of the metal deck.
- The insulating concrete is attached to the structural deck without the use of mechanical fasteners.
- The insulating concrete provides a smooth monolithic substrate without joints or surface irregularities for application of the new roof.
- Provides excellent resistance to wind uplift since the lightweight concrete provides a monolithic substrate that prevents air infiltration occurring below the roof assembly.
- Provides a relatively dense substrate for attachment of the roof assembly that reduces thermal fluctuations and/or thermal stresses incurred by the roof membrane.
- The lightweight concrete can be considered a permanent part of the structure or a "recyclable" insulation.
- The insulating concrete typically remains in place during roof replacement activities, unlike rigid board insulations, which are commonly discarded.
- Lightweight-insulating concrete can provide a substrate with a relatively high compressive strength (minimum 125 pounds per square inch) compared to 10–30 psi for common rigid board insulations.
- Lightweight-insulating concrete is inert and will not rot or decay and remains dimensionally stable under variable climatic conditions.
- Provides a positive slope that can be created for any building configuration.

Batching

The lightweight-insulating concrete is batched on-site to the desired proportions, pumped to the desired location, deposited, and screeded to the desired thickness. The elements of the lightweight mixture are batched in a mobile mixer and pumping machine. The Portland cement (Type I, II, or III, ASTM C 150), water (potable), and either the aggregate or the foam are all stored adjacent to the machine. The aggregate is commonly retained in a typical storage trailer adjacent to the batching machine and supplied in 100 pound paper or cloth bags. The foaming agent is supplied by the manufacturer in either 55-gallon drums or five-gallon pails. The foam is then mixed by the deck applicator (typically 40 parts water to 1 part foam) and stored in plastic storage/dispensing tanks mounted on a trailer. The trailer is then positioned in adjacent to the batching equipment.

The Portland cement is typically stored adjacent to the batching machine in what is commonly referred to as a "bulker" or a container trailer with bulk storage and self-discharging capacity. The water can be obtained from either a source at the subject building, public facilities (i.e. fire hydrant), or a mobile-storage tanker. The entire set-up can be considered to be an on-site mini-batch plant. Strong Manufacturing Company is the predominant manufacturer of the type of equipment currently utilized for the batching/placement of the lightweight-insulating concrete. Approximately 90 percent of the lightweight-insulating concrete fill for roofing is mixed and placed using the "DeckMate" mobile insulating-concrete mixer and pump manufactured by Strong.

The cement and water are supplied to the batching machine via measured mechanical methods utilizing spring-tension or platform scales. The aggregate is typically removed from the bags manually and placed in a holding device until the desired proportion (determined by weight) is reached, whereupon it is introduced into the batching machine by mechanical methods. The foaming agent is introduced into the mix via a hose that is attached to the source. The operator adds the foam to the mix by activating a manually triggered apparatus on the hose until the desired quantity is achieved. The technician can determine the foam output of the apparatus by

ROOFING INDUSTRY

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filling a container of known volume with the foam and timing this process. The ASTM suggested ratio of water to foaming agent is 40 parts water to 1 part agent, by volume.

Several factors can arise during the batching process that could impact the physical characteristics of the final product.

1) The type of Portland cement selected can have an effect on the proportioning of the components. Most mix designs are based on Type I cement. However, using Types II or III, which have a finer cement particle size, will require a higher water/cement ratio to achieve the same product workability.
2) It has been estimated that the compressive strength of the lightweight-insulating concrete can be reduced 5 to 10 pounds per square inch (psi) for every one percent increase in the water/cement ratio.
3) An increase in the water/cement ratio can result in an increase in occurrence and/or concentration of dry shrinkage cracks in the lightweight concrete during the curing process.
4) The compressive strength may decrease 5 to 10 psi for every one percent increase in the foam volume.
5) Proper dispersion of the cement particles throughout the mix is important in maintaining the physical characteristics of the specified product. The compressive strength can be reduced if proper cement dispersion is not achieved. Some common characteristics of improperly dispersed cement are lumps, clots, and pellet-size balls of cement.

Placement

AFTER OBTAINING the desired mixture, the material is transported (pumped from the hopper) utilizing conventional concrete-pumping equipment. A two-inch diameter flexible hose is typically used with common pumping capabilities of 15 to 35 cubic yards/hour at maximum distances of 1,000 feet horizontally or 200 to 300 feet vertically. The material is placed on the substrate with a typical minimum thickness of one to two inches, depending on the type of lightweight-insulating concrete utilized. Wood nailers or blocking are commonly used at low points and perimeters to provide a stop and thickness guide for the lightweight concrete.

After placement, the lightweight concrete is screeded and finished utilizing the conventional techniques and tools used with traditional concrete placement. Fill boards, matching the desired thickness of the lightweight-insulating concrete, and/or string lines are often used during the placement to maintain proper slopes and/or thicknesses during the screeding process.

Typical batching equipment and cement bulker

All photos courtesy of Karl Schaack.

When the thickness of the lightweight concrete is anticipated to exceed the minimum-required thickness (typically two inches), an expanded polystyrene (EPS) board is commonly used as a "filler" board. The EPS board provides several functions when incorporated into the lightweight-insulating concrete: It reduces the overall weight of the lightweight concrete, reduces total material costs, and increases the insulating value of lightweight-insulating concrete. The thickness of the EPS board can range from 1 to 16 inches, depending on the capacity of the manufacturer's equipment. When the desired insulation-board thickness exceeds the maximum thickness of the available insulation board, two or more boards typically have to be laminated together to achieve the desired thickness.

Roof assemblies incorporating lightweight-insulating concrete that are published in the Underwriters Laboratory (UL) Directory have a maximum thickness of eight inches for the EPS board. UL limits the thickness based on structural and heat transfer issues. The thickness is also limited due to manufacturing equipment that cannot produce boards of a greater thickness. The size of the board is typically two-feet-by-four-feet. Boards four-feet-by-eight-feet can also be made.

As outlined by Underwriters Laboratory, the polystyrene-foamed plastic insulation board should have a density of 1.0 +/-0.1 pcf. Other criteria for the EPS board as outlined by UL include the following: 1)The EPS board should have a hole or a hole/slot configuration constructed into the board; 2)The holes should be a nominal three inches in diameter spaced approximately twelve inches on-center per row or three holes in a row (across the width of the board); 3)The rows should be spaced approximately 16 inches on-center longitudinally or lengthwise along the board; and 4) The holes should equal approximately three percent of the gross surface area of the board. One manufacturer, Siplast, provides a polystyrene board that has the designated holes together with slots or a hole/slot combination that are also incorporated into the board.

The holes and/or slots in the EPS board provide two functions: 1) they allow the board to become "keyed" into the lightweight concrete "tieing" together the lightweight concrete located below and above the board, and 2) they provide an avenue for outward moisture migration during the curing process for the newly placed lightweight concrete ("slurry coat") below the EPS board.

Underwriters Laboratories classifies the polystyrene board for surface-burning characteristics (Classification BRYX) and for wind-uplift characteristics (UL Construction No. 110 and No. 155—Class 90: Roof Deck Construction TGKY). If the foamed-plastic board is designated to be used in a roof deck construction with a UL "P" design number, it means that the polystyrene board bearing the UL mark under category BRYX or CCVW (category of Foamed Plastic in the UL Fire Resistance Directory) may be used in the construction of UL Fire Resistance Designs (BXUV). The EPS board should meet the requirements established by ASTM C 578 "Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation," Type I.

The lightweight concrete is initially placed either in the flutes of the steel deck (filling

Roofing warranties: A liability trap?

Most architects know of the risks of implied warranties with strict liability as the measure of professional performance. For an unfortunate few, the lesson has been a painful trip through a legal system clouded by the *White Budd* case (*TA*, March/April 1993). For others, it has been through confrontation with an onerous architect/owner agreement like that promulgated by the National Construction Law Center (*Architecture*, February 1997). For almost all architects involved in public work, it has been evident in the attitude that an architect's job is to somehow protect the bureaucracy from any responsibility for building ownership. Some roofing cases provide an example of how that works.

Case in Point

In the early days of built-up roofing, manufacturers controlled the entire process. After World War II, the nationwide building boom and new competitive forces made that system increasingly impractical, so the manufacturers began establishing networks of approved roofers. To control quality and protect their ability to warrant their product, they established standards for field practices and inspections. To provide financial substance to their warranties, they offered performance bonds for roofs meeting those standards.

These bonds were backed by a surety and typically cost around 10 percent of the financial exposure, which was limited in several ways and usually capped by a dollar amount. The bond offered no coverage to repair structures or finishes that might have been damaged by leaks. It excluded coverage of accessory items like insulation and metal flashing. It was voided by "unusual" use of the roof such as heavy traffic or by alterations or repairs not approved by the manufacturer. It was also limited to the normal life expectancy of the system—usually 15 years for three-ply roofs and 20 for four- or five-ply systems. Hence the term "bondable roof" entered the lexicon of the trade and architects began referring to a "15- (or 20-) year roof" as a shorthand way to describe the underlying technical requirements, whether or not a bond was actually specified.

Then, in the late '80s, several Texas school districts with large, built-up roofs ranging from 5 to 15 years old that leaked were advised by attorneys that the term "20-year bondable roof" in the 1970s specifications or project correspondence constituted an implied warranty by the architect that the roof would not leak for 20 years. Although the school district had not purchased the manufacturer's bond, this was actually far better. It covered damages to finishes, prior repairs, and all accessories. School districts are not bound by the three-year statute of limitations on claims of negligence or breach of contract, so they could claim entitlement to a whole new roof up to 10 years into the life of the old one. Best of all, it was free. All they had to do was hire the attorney on a contingency fee and sue. Faced with a trial in which the jury would be taxpayers from the district and with defending an architect who had not inspected and tested the roof to the extent required by the manufacturer if they had warranted it, the architect's liability carrier capitulated. They, along with the contractor, (if still solvent), bought the district a new roof.

Avoiding the Trap

Although roofing bonds are a thing of the past, major manufacturers still advertise extended warranties with similar costs and limitations. One company, for instance, offers, for $15 per square (about 10 percent of the initial roof cost), their 20-year "classic" warranty, which covers repairs to both roof and insulation. They also offer a "standard" warranty at $8 per square for the roof alone. Both exclude collateral damage and both are voidable by misuse or unauthorized repair.

Whether or not either is economical depends on project-specific factors. Warranties make more sense for buildings planned for stable, long-term owner occupancy than for buildings where frequent additions or alterations or a quick turnover are expected. Most roofing problems appear in the first two or three years of a building's life, when still covered by the contractor's warranty, so the money might be better invested in a higher-quality roof or a specialized consultant to oversee the installation.

The architect should help the owner make an informed decision. If a manufacturer's warranty is purchased, advise the owner of requirements for maintenance and inspection. Make sure the warranty is delivered prior to closeout and that the small print conforms to the terms specified. If an explicit warranty is not purchased, architects can avoid creating an implied one by accurately documenting their advice throughout and by knowledgeable use of both the technology and the language of roofing. ***John McGinty, FAIA***

John McGinty, FAIA, of Houston, is managing principal of American Construction Investigations, a forensic consulting firm.

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the flutes completely) or on top of a solid substrate (i.e. structural concrete, secondary roof, etc.) to provide a slurry coat approximately 1/8-inch-thick (measured from top flange of deck rib or top of substrate). The EPS board should be placed within approximately 30 to 60 minutes after the slurry coat is applied. The EPS board should be placed or embedded into the slurry coat so that the bottom of the board comes in full contact with the slurry coat and the slurry coat enters the keying holes. The board should be installed with the long dimension of the board parallel to the flute direction of the steel form deck, where applicable. The transverse joints (joints at the ends of the boards) should be staggered and all joints should be butted snugly. The board should also be held back from the roof edge approximately three inches. The EPS boards are placed in a stair step configuration to achieve the desired slope. A maximum differential of one inch should be maintained for adjacent stair-stepped boards.

Once the EPS board is installed, the overlying lightweight concrete should be placed within one to four hours into the holes and over the board to reach the desired thickness. It is possible that the EPS board, particularly the boards with thickness greater than two inches, can "float" in the lightweight concrete if a proper slurry coat is not initially applied and the EPS board is not properly embedded into the slurry coat. If this occurs, it is advised that the EPS board and affected lightweight concrete be removed and replaced.

If during the placement process and the following 24 hours, the ambient air temperature is expected to be 40 degrees Fahrenheit or lower, then installation of the lightweight concrete should be delayed until warmer temperatures will prevail. However, if installation must proceed during cold weather, certain precautions, such as using warm water during the batching process, should be followed. If proper precautions are not implemented, freezing of the concrete can occur and jeopardize the quality.

Prior to the installation of the new roof assembly, the adequacy of the slope created by the newly placed lightweight-insulating concrete substrate can be verified via water testing. By conducting water testing, potential areas of inadequate drainage (i.e. bird baths)

can be identified. If these areas are identified, the low-profile lightweight can be leveled to match the surrounding substrate. A "rich" mixture (1:3–1:4 cement to water ratio) can be hand-troweled onto the substrate to fill in the low area. Prior to applying the trowelable mixture, the existing lightweight concrete should be removed to a depth of approximately 1/2-inch within the subject area. Then the subject area should be well wetted (visible surface moisture) just prior to the application of the rich mixture. Wetting of the existing surface prevents the underlying dry substrate from drawing moisture out of the repair mixture, which would cause rapid curing. The rapid curing would result in embrittlement of the repair mixture and subsequent cracking. Feathering the edges of lightweight concrete in a repair area should be avoided, as the thin lightweight-insulating concrete will have a tendency to crack and become disbonded.

For lightweight concrete with perlite aggregate, control joints are required at roof perimeters and penetrations. These control joints should be typically one inch wide and should extend down through the full depth of the concrete. A compressible-fill insulation, typically fiberglass insulation, is installed at the control joint location and the lightweight concrete is placed up against the insulation. These joints are required because the perlite-based concretes can experience expansion after placement due to the expansive nature of perlite.

After placement, lightweight concrete (like traditional concrete) requires time for curing and hydration of the Portland cement. As with traditional concrete, the 28-day curing time frame also applies to lightweight-insulating concrete in order to achieve the maximum physical characteristics and properties. However, roof application can and should occur prior to the 28-day cure time. A cure time of five to seven days is normally required for aggregate lightweight-insulating concrete prior to roof insulation. For cellular lightweight concrete, 48 to 72 hours is a typical cure time allowance prior to installing the new roof. Actual cure time will depend on the climate and weather during the placement and curing process. A common rule of thumb used in the industry states: If foot traffic upon the lightweight concrete does not result in depressions in the surface of the lightweight concrete, then the concrete is suitable to receive the new roof.

Current typical industry practice involves placement of the lightweight concrete over a corrugated-metal form deck. Other possible substrates that have been utilized in the past, and to some extent continue to be used today, include structural and/or precast concrete, cementitious wood-fiber panels, fibrous form boards over bulb Tee's, gypsum form boards over bar joists, reinforced kraft paper/wire mesh over bulb Tee's, wood, and existing roof membranes.

The steel deck should be coated with either G60 or G90 hot dipped galvanized zinc coating. A G60 galvanized coating results in a zinc coating applied at a rate of approximately 0.6 ounces per square foot to both sides of the sheet. The G90 coating results in a zinc coating applied at a rate of approximately 0.9 ounces per square foot. Both of these coating weights conform to ASTM A 525. Neither bare metal nor painted metal decking is acceptable to be used as a form deck for lightweight-insulating concrete. Steel decking with the G60 coating is acceptable for use with lightweight concrete. However, in higher moisture/humidity exposure conditions, the G90 coating may be more appropriate.

The steel decking should have uniformly distributed slots located on either the bottom or the sides of the flutes. Common available slotted steel decks are manufactured with 0.75- to 1.5-percent net free area venting. The amount of bottom venting required will depend upon the local exterior climatic conditions, the quantity of water used in the mix, and the interior temperature and humidity conditions. The steel used in manufacturing decking conforms to either ASTM A 611 or A 446 having a minimum yield strength of 33 ksi. Some typical manufacturers that provide steel decks for lightweight-insulating concrete substrates include, but are not limited to, Wheeling and Vulcraft.

If cellular concrete is used, the metal form deck should not have bottom side venting. Cellular concrete or other non-venting types of lightweight concrete should be installed over a "non-venting" substrate. If cellular concrete is placed over a venting substrate, accelerated curing can occur possibly resulting in shrinkage cracks and decreased physical properties.

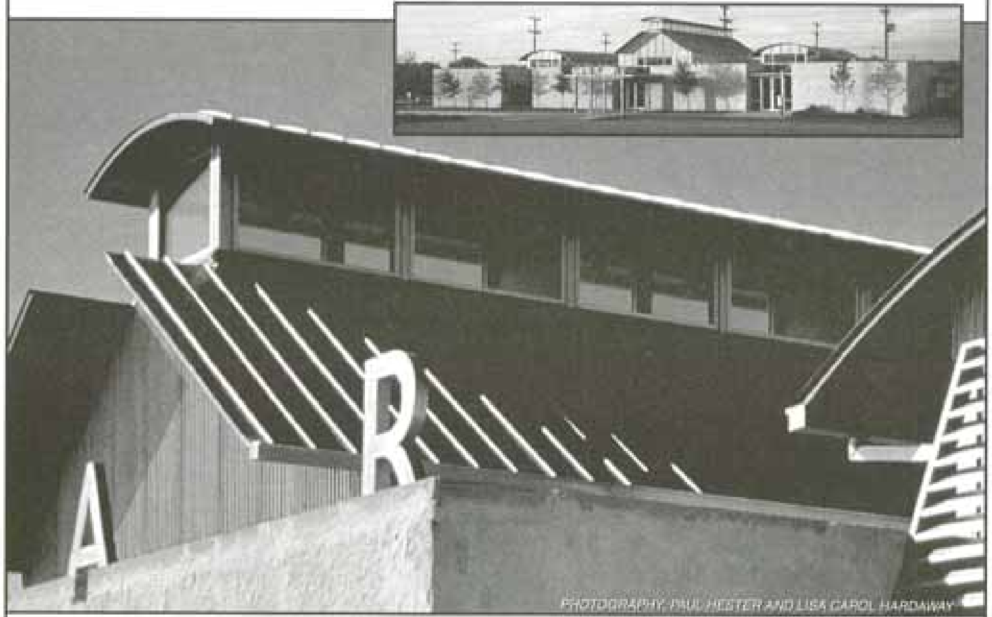
The installation of the steel deck, if used, should conform to those requirements outlined by Factory Mutual 1-28. The typical installation criteria includes lapping ends of deck panels a minimum of two inches. The end lap should occur over the structural members. The sides of adjacent deck panels should be lapped a minimum of one-half of a rib. Once laid in place, the deck panels should be secured to the support members with either 1/2-inch (13 mm) diameter (Exposure 1) or 5/8-inch diameter (Exposure 2) puddle welds installed with weld washers or approved mechanical fasteners. Weld washers are typically required with metal decks that are 24-gauge or less. When weld washers are utilized, they should be minimum 16-gauge metal with a 3/8-inch diameter hole. Whichever attachment method is used, the maximum spacing should be 12 inches on-center in the field and six inches on-center in the corners and perimeters. There are four options for attaching side laps: stitch screws, button punched, top-seam welded, or side-seam welded. For metal decks of 22 gauge or less, stitch screws are recommended for side-lap attachment. Side laps should be secured three feet on-center (Exposure 1 and 2) and 30 inches on-center (Exposure 3). The spacing should be reduced 50 percent in the corners and perimeters. The dimensions of the area to increase the rate of attachment is determined by the smaller number of 0.1 times the lesser plan dimension, 0.4 times the eave height or a minimum of four feet.

testing wet density

The bonding capacity of lightweight concrete to galvanized steel deck produces excellent uplift resistance to meet UL Class 90 Wind Uplift Resistance Classification (Published in *UL Director*, Construction No. 110). Lightweight concrete also forms an interfacial bond with polystyrene board when utilized in construction to achieve the necessary uplift resistance.

Steel reinforcement can also be incorporated into the lightweight-insulating concrete matrix. Steel reinforcement is typically required for a two-hour fire-rated assembly. The steel reinforcement is typically a woven mesh consisting of 19-gauge galvanized wire twisted in a two-inch hexagonal configuration with an additional 16-gauge longitudinal reinforcement wire spaced approximately three inches on-center across the width. The steel reinforcement should have a minimum cross-sectional area of 0.026 square inches per linear foot and meet the tensile, bending, and coating requirements outlined in ASTM A 82. A common product that is used and complies with these requirements is Keydeck 2160-2-1619 as manufactured by Keystone Steel & Wire. The wire mesh should be placed in the middle of the desired top pour thickness (measured from top of steel deck, substrate, or EPS board) of the lightweight concrete. The wire mesh should be lapped a minimum of six inches at ends and butted or spaced no more than four inches apart at sides. The wire mesh should be placed with the longitudinal wires at right angles or perpendicular to the structural supports and cut at openings/penetrations in the deck.

One common problem experienced with lightweight-insulating concrete, particularly the cellular version, is the occurrence of shrinkage cracks during the initial curing process. Since the mix is composed of only cement, water, and fine aggregate and/or



PHOTOGRAPHY: PAUL HESTER AND LISA CAROL HARDAWAY

BERRIDGE CURVED AND STRAIGHT TEE-PANEL STANDING SEAM PANELS ARE USED AS A DESIGN ELEMENT ON THE LIBRARY'S CENTRAL STRUCTURE.

foam, movement in the substrate or just the natural curing process can result in cracks within the concrete. One option to reduce this cracking condition involves the inclusion of either steel wire mesh and/or inorganic fibers dispersed within the mix. The reinforcing mesh or fibers as well as aggregate allows the forces and stresses created by the curing process to be transferred to the matrix. The transfer of these forces allows the concrete matrix to resist these forces and consequently reduce the chance of cracking. The fibers can be either polyester, fiberglass, or polypropylene in nature and are added to the mix prior to the inclusion of the foam at a rate of approximately one to two pounds per cubic yard. One manufacturer of cellular concrete, Elastizell, provides a polyester fiber called Zellcrete Fibers. Fiber Mesh is a common manufacturer of polypropylene fibers, commonly used as an additive fiber to structural concrete.

Another practice that can be implemented during the placement process, particularly in hot and arid climates, to minimize or reduce the occurrence of cracks, is to apply water, via spray misting, to the newly placed concrete. If cracks do occur within the cured concrete, repairs can be performed to the affected areas. The lightweight concrete can be routed out along the crack, typically in a "V" shape to a depth of approximately 1/2- to 3/4-inch. Loose debris should be removed from within the crack, the surface of the concrete wetted, and a rich mixture should be troweled into the routed "V", striking flush with the adjacent surfaces.

Testing

Several testing procedures can be implemented during and/or after the placement of lightweight concrete for evaluation. Some of the common testing determines wet density, fastener pull-out resistance, compressive strength, and dry density. The first test, determination of wet density, is performed during the initial placement of the lightweight-insulating concrete. The wet density should be determined at various times during the day as the lightweight-insulating concrete is being batched and placed. The wet density should be obtained at both the hopper and the point of placement. It can be determined simply by placing the batched mixture in a container of known volume and weighing the

filled container. If the measured wet density is found to be within +5 percent of the specified wet density, then the batching and placement process would be considered to be functioning properly. If the wet density is found to be out of tolerance of the specified range, then the following events may be present: water/cement ratio is out of tolerance, batching equipment is not functioning properly, pumping system is deficient, placement hose is kinked or has loose connections, or the diameter of the hose is too large. The sample of the lightweight-insulating concrete that is to be used for testing purposes should be considered representative and not be collected at the beginning or ending of the placement operation.

The remaining tests are performed after the placement of the lightweight-insulating concrete. As stated earlier, a common rule of thumb used by field personnel is: If foot traffic does not leave an impression (i.e., footprints) in the lightweight-insulating concrete, then the concrete is suitable to receive the new roof. However, there are other more scientific testing methods to evaluate the suitability of the concrete.

The fastener pull-out resistance is a relatively quick test to determine if the concrete has reached an adequate "age" to allow installation of the new roof. The fastener proposed for use in the new roof assembly should be used and tested in several random locations throughout the subject area (approximately one test per 100 squares). The minimum pull-out resistance that is commonly required by manufacturers for the split shank fastener is 40 pounds per fastener. Care should be taken if evaluation of the lightweight concrete is determined only by performing pull-out resistance tests on fasteners. The concerns are twofold: 1) the concrete may not have reached the 28-day strength, and 2) galvanized steel fasteners reportedly can gain additional pull-out resistance as a bond develops between the lightweight concrete and the steel fastener as the concrete cures.

The pull-out resistance test can be performed using a sheet metal holding clamp that could be attached to a spring scale. The scale should have a range of 0 to 100 pounds with one-pound increments. Another pull-out tester than can be utilized is a hydraulic device with a twisting crank and dial gauge, commonly utilized for testing screw-type fasteners.

Another easily performed test to verify the density of the cured concrete implements a hand-held penetrometer, designed for performing field and laboratory evaluations of initial set of concrete mortars. This testing apparatus is comprised of a hand-held cylindrical tool (7 inches long by 3/4-inch diameter) with a circular probe/shaft with a 1/20th square inch of surface area. It is manufactured by ELE International and classified as a Concrete Mortar Penetrometer. The test involves pushing the shaft of the penetrometer into the lightweight-insulating concrete. The tool has a direct read scale on a range of 0 to 700 psi. The reading that is obtained from forcing the shaft into the concrete at a constant rate to a known depth provides an individual a relative indication of the compressive strength/density of the concrete. However, this test does not provide sufficient repeatable data nor the precision to use as a single source of evaluation.

Testing of the compressive strength of newly installed lightweight concrete is performed in accordance with ASTM C 495, "Standard Test Method for Compressive Strength of Lightweight-Insulating Concrete." This method covers the preparation and testing of molded cylinders (three inches diameter by six inches long) for lightweight concretes with oven-dry weights not exceeding 50 pcf. The test specimens are molded from a sample of the lightweight-concrete mixture obtained from the batching equipment prior to placement. The mixture is placed in molds, stored, and specifically cured. The molding process consists of placing the wet mixture in two approximate equal layers. After each layer is placed in the mold, the sides of the mold should be tapped until the top surface of the respective layer has subsided to a plane.

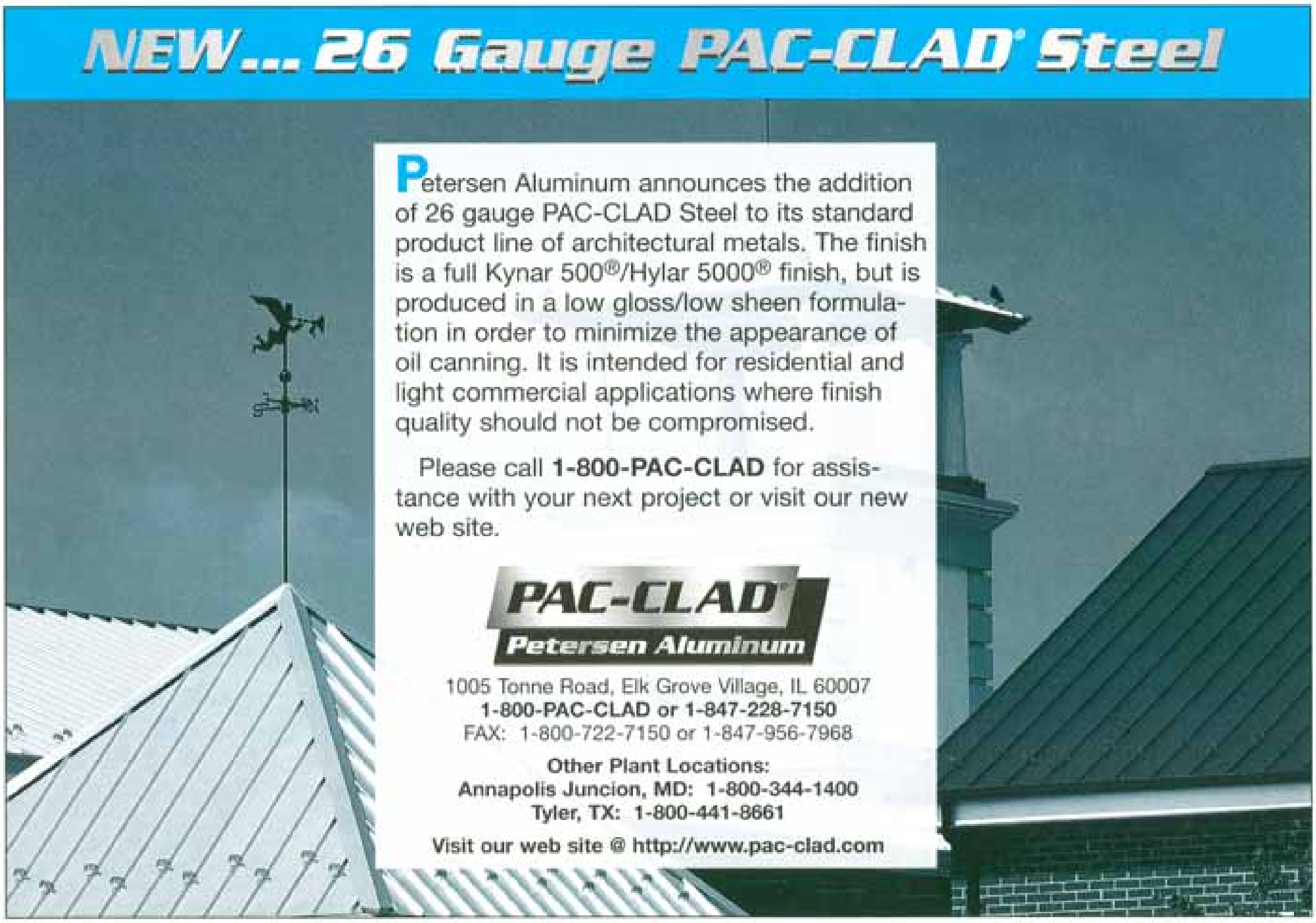
The ASTM procedure has specific procedures for curing, which generally involves initial moist curing followed by oven dry curing. It is critical that the samples are dried prior to testing. The most practical procedure is to moist cure (70 degrees Fahrenheit, +/-10 degrees) in the mold for the first seven days, strip the mold and cure in the appropriate environment (70 degrees Fahrenheit, +/-10 degrees) for the following 18 days, and then oven dried (140 degrees Fahrenheit, +/-five degrees) for three days. The sample should then be allowed to air cool until dry prior to testing.

Several factors can affect the results of the testing of molded cylinders: 1) The accuracy of the testing machine is a critical issue. The maximum load required to break the sample of lightweight-insulating concrete should not be less than 10 percent of the maximum load range of the testing equipment being used.

The testing equipment that is commonly used for testing compressive strength of structural concrete has a typical load range of 10,000 pounds. Ten percent of this load range equals 1,000 pounds, which exceeds the typical maximum compressive strength of lightweight-insulating concrete range of 200 to 400 psi; 2) The actual cross-sectional area of the cylinder can also have an impact on the test results. Even though the cylinder mold is commonly three inches in diameter, the actual diameter of the hardened concrete cylinder should be measured to the nearest 0.01 inch (0.3 mm). The recorded diameter should be determined by an average of two diameters measured at right angles to each other at mid-height of the sample. The difference of 1/10th of an inch less than the nominal three-inch diameter will result in a smaller bearing surface which can reflect a lower compressive strength reading of approximately 6-1/2 percent. The actual recorded height of the sample should also be measured to the nearest 0.01-inch (0.3 mm); 3) Preparation of the specimens can also have an affect on the sample. The concrete should be placed in the mold in two to three lifts. After each lift is placed in the mold, the mold should be tapped, or raised, and dropped approximately one inch to allow the lift/layer to settle. The concrete should not be rodded as is typically performed during the molding of cylinders for structural concrete. After the cylinder is molded, it should be left undisturbed for 16 hours and kept in the mold a minimum of seven days.

Testing the physical properties of existing lightweight concrete can be performed in accordance with ASTM C 513, "Obtaining and Testing Specimens of Hardened Lightweight-insulating concrete for Compressive Strength." This method covers obtaining and preparation of in-place lightweight concrete (minimum 14 days old). In general, the procedure consists of obtaining a bulk sample of the existing (cured) lightweight-insulating concrete and shaving/shaping the sample down to the desired size and number of cubes. The bulk sample obtained shall not include any cracks, spalls, or otherwise be damaged. The size of the shaped cubes shall be two inches by two inches (minimum), or four inches by four inches (maximum). The size of the cube is typically determined by the maximum thickness of the lightweight-insulating concrete. Four cubes (three for compressive strength, one for density) should be obtained for the appropriate testing. Since the samples are manually produced, the actual measurements of the cube shall be achieved to determine the true size and bearing surface. The specimens shall be oven-dried (140 degrees Fahrenheit, +/-five degrees) for three days prior to performing the tests.

To obtain the dry density of the lightweight-insulating concrete, the oven dry weight should be determined initially using cylinders, similar to those prepared for the compressive strength testing, molded and cured the same as the compressive strength specimens. However, after 28 days, the specimens should be placed in an oven at 230 + 18



degrees Fahrenheit (110 + 10 degrees Celsius) and weighed at 24-hour intervals until the loss of weight does not exceed 1 percent. Upon determining the oven dry weight and measuring the specimen, the dry density can then be calculated.

Summary

IN SUMMARY, lightweight-insulating concrete fills can provide challenging circumstances to those individuals involved in roof installation activities. However, with proper pre-planning, design, material selection, and installation, lightweight-insulating concrete will serve as a sound suitable substrate in which to install the new roof system and provide the desired features expected from the project personnel. *Karl Schaack*

Karl Schaack, P.E., is the branch manager of Price Consulting, Inc., of Houston.

See page 87 for answers to the self test.

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