SYSTEMS AND ROOF MEMBRANE PERFORMANCE

BY PHILIP M. CARKNER AND
RAYMOND C. WETHERHOLT, CPRC/CPWC/RRC

INTRODUCTION

The term "concrete" is not clearly understood by many, even within the construction industry. While the term is normally associated with sidewalks, foundations, basements, and structural frames for buildings, there are actually many different concretes, each designed for a specific purpose.

Lightweight Insulating Concrete (LWIC) is a special form of concrete. It has evolved as a material intended for use as an insulation and substrate for support and attachment of roofing membranes on low slope roofs.

CONCRETE—A GENERAL DEFINITION[1,2]

Concrete is a composite material made with cement, aggregates, admixtures, and water. Aggregates generally make up approximately three-fourths of the volume of concrete. Cement (most commonly Portland cement) determines the properties of the concrete such as strength, fire resistance, and stability. Admixtures enhance or confer special properties that may include set time, freeze-thaw resistance, strength enhancement, and plasticity of the concrete. Water provides the necessary workability and is the source of critical moisture for hydration of the Portland cement. Hydration of Portland cement is the chemical reaction responsible for strength development and will be discussed further below.

LIGHTWEIGHT INSULATING CONCRETE

Low density concrete (referred to as lightweight insulating concrete in this discussion) has been defined by the American Concrete Institute (ACI)[3] as "[Concrete] made with or without aggregate additions to Portland cement, water, and air to form a hardened material which, when oven-dried, will have a unit weight of 50 pcf (800 kg/m^3) or less."

The ACI further states that the largest single use for LWIC is as a roofing base and thermal insulation for industrial and commercial buildings with low slope roofs.

LWIC is "non-structural" in the traditional sense. There are other forms of concrete, including "lightweight," that are structural in nature. An excellent discussion of the distinctions between lightweight structural and lightweight insulating concrete can be found in Baxter[4].

LIGHTWEIGHT INSULATING CONCRETE SYSTEMS

The emphasis here is on the term "system." Today's LWIC installations are combinations of components, each of which has a specific function. The substrate, lightweight insulating concrete, and molded expanded polystyrene (MEPS) work together to create an LWIC system. These components and their functions are summarized below.

The Substrate

The function of the substrate is to support the LWIC system and the waterproofing membrane. The substrate is also a structural component of the building, and as such, supports live and dead loads, contributing to seismic and wind load resistance.

The substrate may be galvanized metal deck (bottom-slotted preferred), structural concrete (poured-in-place or pre-cast), or a sound, existing built-up roof membrane.

Traditionally, the metal deck used has been high tensile-strength, galvanized, corrugated form deck. There has been an increase in the use of bottom-slotted, galvanized, 1-1/2" deep B-Deck over the past few years. This is the result of increased structural requirements and wider availability of B-Deck as compared to high-strength, galvanized centering.

Lightweight Insulating Concrete

LWIC is comprised of several components, each of which has a specific function. The components are: aggregate, cement, air entrainment, and water.

Aggregate

Aggregates in LWIC are generally nonreactive fillers used to control density and to prevent accumulated shrinkage associated with cement paste curing and drying.

The predominant aggregate is vermiculite, which is a naturally-occurring, micaceous mineral that contains water trapped between a platey aluminum, iron, and magnesium silicate structure. When heated to approximately 1800 degrees Fahrenheit, it exfoliates to an accordion-like, platey, low-density (6-9 pcf) material. In addition to its function as a means of maintaining the LWIC's low density, vermiculite retains water necessary for hydration of the Portland cement, provides the "body" necessary to build slope, and reinforces the LWIC to minimize cracking.

Perlite is a naturally-occurring, glassy (siliceous), volcanic material that contains trapped water. When heated above 1600 degrees Fahrenheit, it expands to a closed-cell, low-density material. Some sources of perlite will experience what is known as "alkali expansion reaction" with the Portland cement. Alkali expansion is a condition that occurs with some siliceous aggregates when they react with the Portland cement and create a reaction product that occupies more space than the original aggregate. Therefore, it is often recommended that expansion or control joints be used when perlite aggregate is used.

Pregenerated foam is made by mixing solutions of surfactant with compressed air. These surfactants may be hydrolyzed protein or synthetic in nature. While they are not true aggregates, they are included here because their function is to maintain low density in the LWIC. LWIC made with pregenerated foam is generally quite fluid and is limited in its ability to build slope. It also contains less water because the air bubbles do not absorb water. This characteristic may lead to insufficient hydration and strength development of the Portland cement if proper external curing conditions do not exist. LWIC made with pregenerated foam may experience drying and shrinkage cracks due to lack of moisture and reinforcing aggregate.

Cement

The function of cement in LWIC (and in all concretes) is to bind the components together and generate strength.

The cement used in LWIC is Portland cement[1,2,5]. Portland cement is a complex mixture of minerals, including silica, aluminum oxide, calcium oxide, and ferric oxide obtained from limestone, shales, clays, slates, and pyrites. Types of Portland cement used in the United States are defined in ASTM C-150. Types I, II and III are commonly used to produce LWIC. Portland cement undergoes a chemical reaction when mixed with water. This reaction creates "hydrated gels" that form a solid mass and result in hardened material.

Air Entrainment

In LWIC, air entrainment is an alkali-resistant surfactant used with aggregate concrete. The function of air entraining admixtures is to generate air cells that assist in density control and to create a homogeneous mixture that does not segregate.

Water

Water provides the moisture necessary for cement hydration. It also creates fluidity necessary for pumping and finishing of the LWIC.

Insulation

Molded Expanded Polystyrene (MEPS) used in LWIC systems is defined in ASTM C578. Type I is the preferred material. It is used in the form of boards in various thicknesses, generally from 1 to 16 inches.

The MEPS boards are perforated with various configurations of holes and/or slots in order to allow the LWIC to flow through the boards and bind the system together. The MEPS functions as the primary insulating component of the system (nominal R-value, four per inch). This lightweight material is used to build thickness and generate slope-to-drain.

LWIC—PHILOSOPHY OF DESIGN

The basis of LWIC system design is the encapsulation of MEPS insulation with lightweight insulating concrete. In all designs, there is a layer of insulating concrete applied to the substrate, commonly referred to as the slurry coat. In most cases, MEPS boards are embedded in this first layer. Thicknesses of MEPS board are stepped to create positive slope-to-drain. Finally, a topcoat of LWIC is applied to create a smooth

LIGHTWEIGHT INSULATING CONCRETE

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American Concrete Association

sloped monolithic surface for application of the roof membrane. The membrane is attached with a mechanically-fastened base ply and vented at the perimeter. When the substrate is non-vented (i.e., not slotted metal), topside vents are placed in the field of the membrane.

This design concept uses the inorganic, noncombustible, insulating concrete to encapsulate the polystyrene insulation board, imparting strength, stability, wind uplift resistance, and fire resistance to the composite system. (See the article by Hubert Dudley on page 17 in this issue of *Interface* for more detail regarding fire resistance, wind uplift resistance, etc.)

Portland cement develops a natural bond to galvanized metal surfaces, structural concrete, and existing bituminous roof membrane surfaces. All the components of the system are moisture resistant. Portland cement is hydraulically bound and not adversely affected by the presence of moisture.

Similarly, MEPS is minimally affected by the presence of moisture. Mechanical attachment of the membrane base sheet (see Dudley), along with vented details, allow for vapor pressure relief which prevents membrane blistering from residual construction moisture or from subsequent roof leaks. It is not recommended to adhere built-up roof membranes to the surface of LWIC systems.

Experience has shown that care must be taken by the designer and contractor when using LWIC. It is susceptible to some of the same factors that affect structural concrete. These factors include moisture contained in the mix, shrinkage cracking, and strength variability. Water in the mix can affect the roof membrane performance (cause blistering). Therefore, the use of a "vented" or "coated" base sheet or an upside-down granular surface capsheet is recommended. The upside-down capsheet is relatively economical and provides reasonable assurance that the moisture beneath will not pass into the built-up roof system above. Inorganic products are recommended.

Venting residual moisture contained in LWIC systems is required for successful roof system performance.

LWIC can be affected by freezing (the same as structural concrete), causing it to scale or dust on the surface. Moisture may also be retained in the LWIC if placed during the wetter months of the year. Checking with the manufacturer's technical department to verify unit weights, pullout tests, and compressive strengths, is appropriate.

LWIC ROOF MEMBRANE PERFORMANCE

Lightweight insulating concrete systems are the most dimensionally stable and highest compressive strength roof insulating materials available for application of roof membrane materials. LWIC has a coefficient of thermal expansion an order of magnitude lower than organic materials[3]. This means that ten times less movement is experienced by the membrane as temperatures change.

The compressive strength of lightweight insulating concrete is three to 20 times greater than that of common board insulation materials (see *Figure 1*). This characteristic supports the roof membrane during construction and subsequent roof maintenance traffic throughout the life of the building.

Encapsulating the MEPS boards in LWIC eliminates movement experienced by the roof membrane at insulation board joints. Because insulating concrete is several times as dense as common board insulation products, it provides a "mass effect" which moderates the extreme temperatures seen by the roof membrane. It also reduces the rate of temperature rise and fall, minimizing thermal shock experienced by the membrane (see *Figures 2* and *3*).

We have observed that hot asphalt built-up roofs placed over LWIC tend to "heat age" slower than roofs placed over plastic foam insulation. This may be due to the "mass effect" or the more thermally conductive nature of LWIC compared to plastic foam insulation.

Finally, lightweight insulating concrete systems allow the contractor to create positive slope-to-drain during construction. This is particularly advantageous on renovation projects where the existing conditions frequently vary from the original drawings. Asymmetrical drain locations, high density penetrations, and limited site storage space also validate use of LWIC for creating a tapered substrate.

SUMMARY

LWIC systems have been in use for over 60 years. In their modern form they provide a number of benefits in addition to their primary function as roof insulation. LWIC systems provide the designer with a versatile means of providing slope-to-drain. Their high compressive strength and dimensional stability provide support for the roof membrane system and minimize stresses imposed on the membrane from dimensional movement. Thermal stresses from temperature changes are also reduced due to the mass of the LWIC.

Finally, because LWIC is a form of concrete, it is highly resistant to damage from moisture and is reroofable in most cases. LWIC systems are an environmentally responsible choice for roof insulation.

References

1. Ramachandran, V.S., "Concrete Admixtures Handbook Properties," *Science and Technology*, Second Edition, Park Ridge, NJ. Noyes Publications, 1995.
2. Lea, F.M., *The Chemistry of Cement and Concrete*, Third Edition, Chemical Publishing Co., Inc., 1971.
3. ACI 523.1R-92
4. Baxter, Richard, "Concrete Roof Decks: Considerations," *Architectural Specifier*, May/June, 1996.
5. Mindness, Sidney and Young, Francis J., "Concrete," Englewood Cliffs, NJ, Prentice-Hall 1981. ■

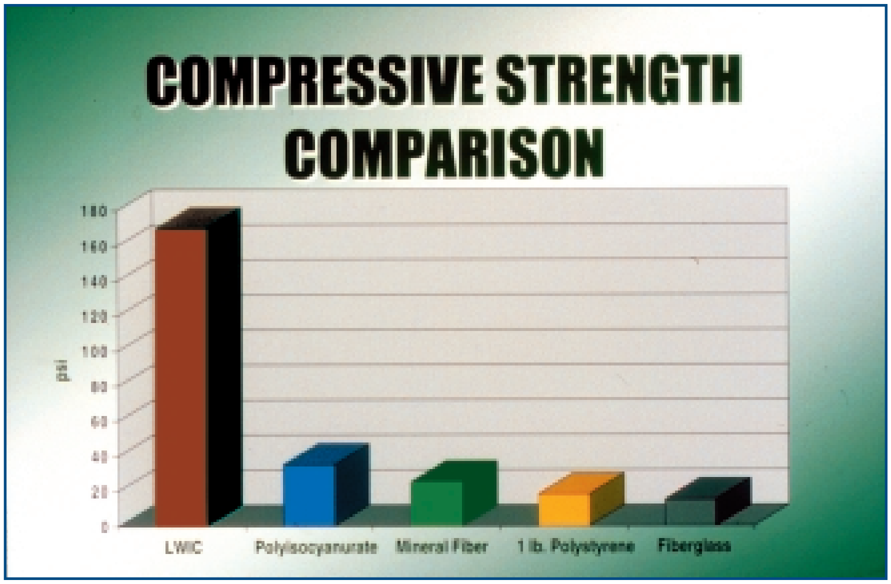


Figure 1

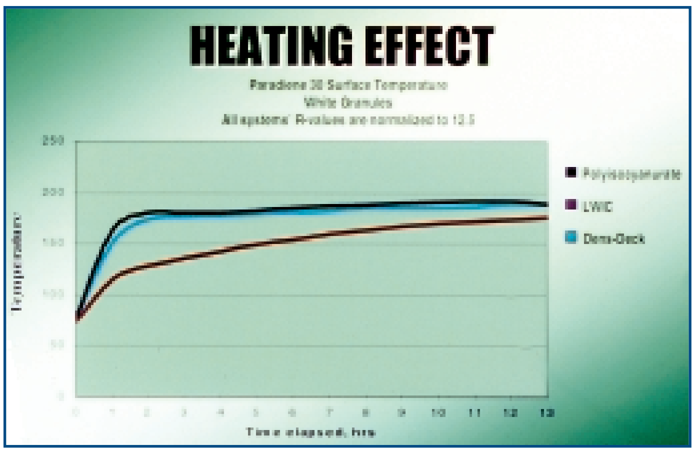


Figure 2

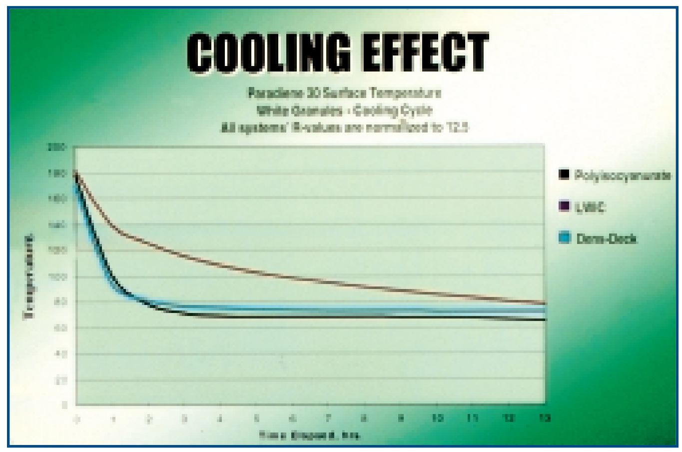
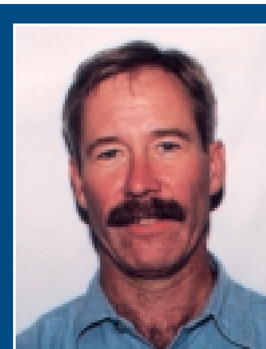


Figure 3

About the Authors

Philip M. Carkner

Philip M. Carkner is Research and Technical Support Manager for Siplast Roof Insulation Systems. He has been involved in construction materials research, product development, and marketing for 23 years. Carkner spent 19 years with W.R. Grace Construction Products Division prior to joining Siplast. He is a member of ACS, ACI, and ASTM. Carkner has a BA in chemistry from Potsdam College, Potsdam, NY, and a Ph.D. in inorganic chemistry from the University of New Hampshire.



Raymond Wetherholt CPRC/CPWC/RRC

Raymond C. Wetherholt, CPRC/CPWC/RRC, is the president of Wetherholt and Associates, P.S., a 15-year-old roofing and waterproofing consulting firm in Kirkland, Washington. He has worked with lightweight insulating concrete decks as well as hard rock concrete decks for over 25 years. Wetherholt is also a past president of the Institute of Roofing and Waterproofing Consultants (IRWC), which was recently absorbed by RCI. Ray may be contacted at rayw@wetherholt.com.