

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/m³) 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 Baxter⁴.

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 platy aluminum, iron, and magnesium silicate structure. When heated to approximately 1800 degrees Fahrenheit, it exfoliates to an accordion-like, platy, 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^{1,2,3}. 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

LWIC ROOF MEMBRANE PERFORMANCE

sloped
monolithic surface
for application of the
roof membrane. The mem-
brane is attached with a mechani-
cally-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, noncom-
bustible, insulating concrete to encapsulate the polystyrene insu-
lation 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 mem-
brane 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 con-
struction moisture or from subsequent roof leaks. It is not recom-
mended to adhere built-up roof membranes to the surface of
LWIC systems.

Experience has shown that care must be taken by the design-
er 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 mem-
brane performance (cause blistering). Therefore, the use of a
"vented" or "coated" base sheet or an upside-down granular sur-
face capsheet is recommended. The upside-down capsheet is rel-
atively 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.

Lightweight insulating concrete systems are the most
dimensionally stable and highest compressive strength roof insu-
lating materials available for application of roof membrane mate-
rials. LWIC has a coefficient of thermal expansion an order of
magnitude lower than organic materials³. This means that ten
times less movement is experienced by the membrane as temper-
atures change.

The compressive strength of lightweight insulating concrete
is three to 20 times greater than that of common board insula-
tion 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 move-
ment 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 draw-
ings. Asymmetrical drain locations, high density penetrations,
and limited site storage space also validate use of LWIC for cre-
ating 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 pro-
vide support for the roof membrane system and minimize stress-
es 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 resis-
tant to damage from moisture and is reroofable in most cases.
LWIC systems are an environmentally responsible choice for
roof insulation.

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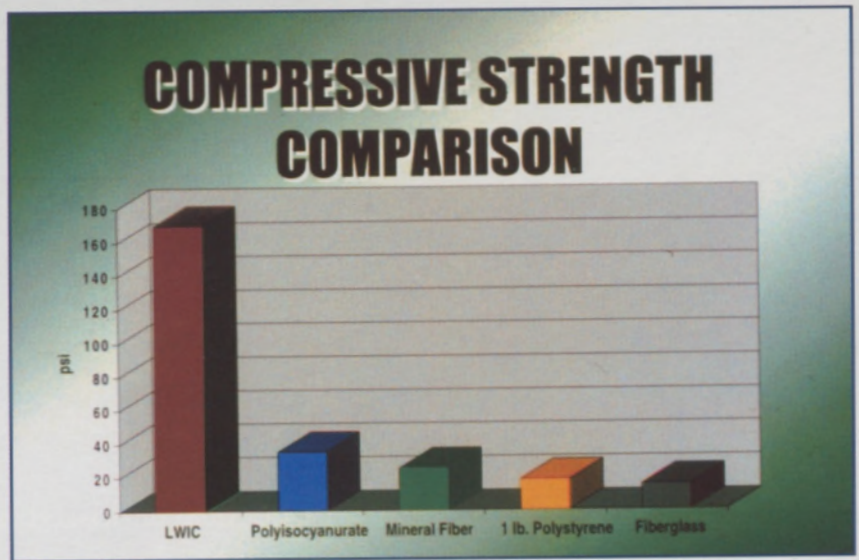


Figure 1

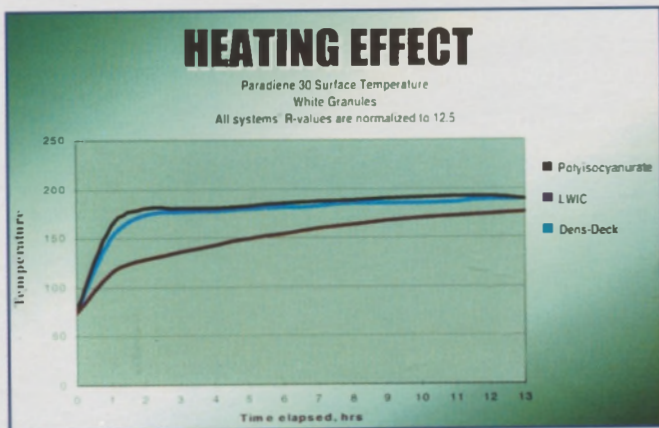


Figure 2

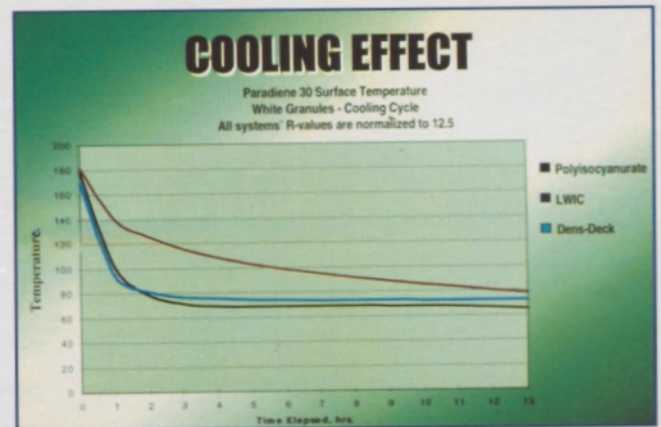


Figure 3

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 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.



**RAYMOND WETHERHOLT
CPRC/CPWC/RRC**