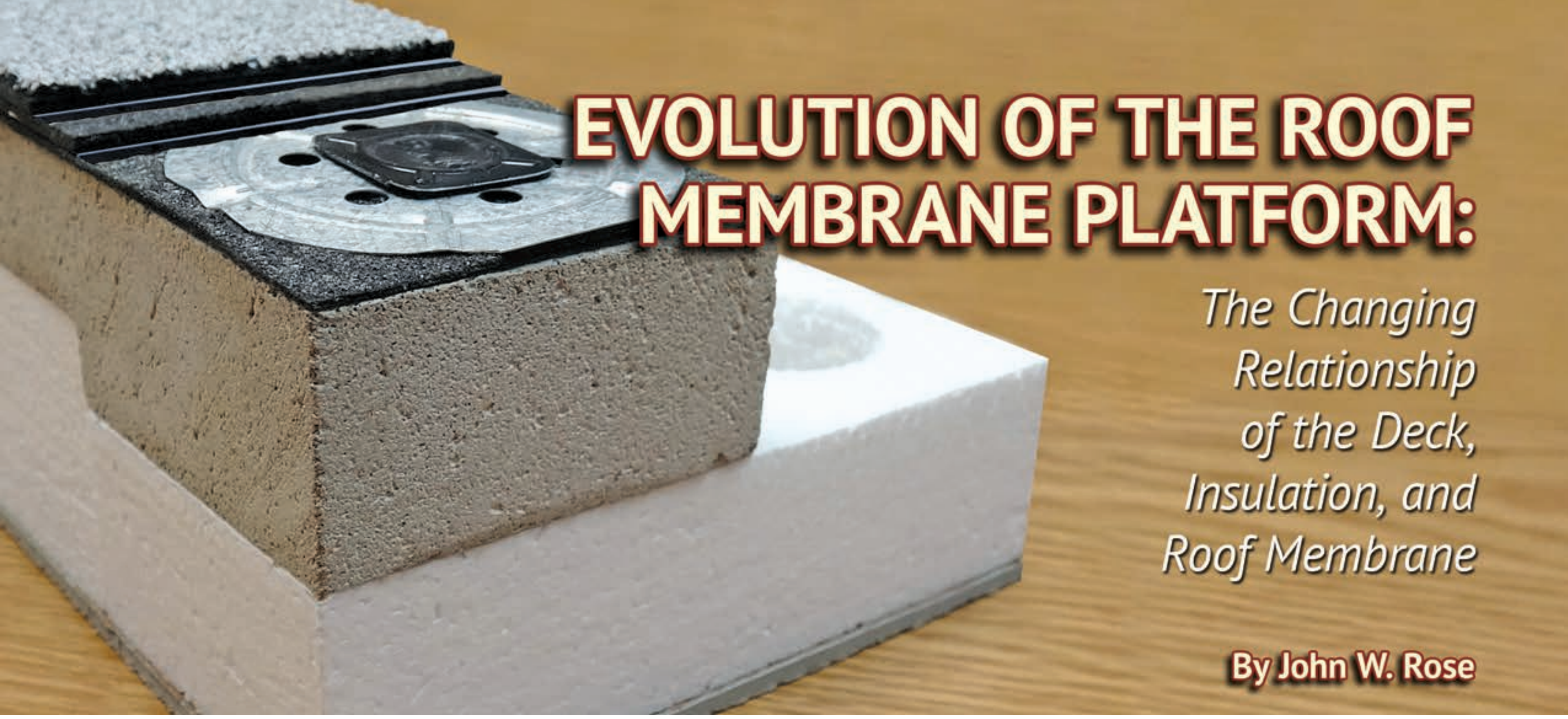

# EVOLUTION OF THE ROOF MEMBRANE PLATFORM:

## The Changing Relationship of the Deck, Insulation, and Roof Membrane

By John W. Rose

**ABSTRACT**

*The structural deck and roof insulation elements of a roof assembly combine to create a substrate platform for the roof membrane. During the past 30 years, changes in those substrate platform components and building code requirements imposed on the components have impacted roof membrane performance and longevity.*

*Platform components' properties, such as coefficient of thermal expansion, dimensional stability, R-value, moisture resistance, compressive strength, and density, may influence long-term roof membrane performance. This article addresses the role of the substrate platform in a successful roof assembly, including its components, properties, energy efficiency, and sustainability.*

The three components of a roof assembly—the structural deck, the roof insulation, and the roof membrane—combine to address design criteria, meet budget requirements, and achieve performance expectations. Two of those components—the structural deck and the roof membrane—have very clearly defined roles. The structural deck is there to provide overall support to the roofing system, and the roof membrane is there to protect against water intrusion. For years, in addition to providing thermal insulation for the building, insulation was there for the practical purpose of creating a more acceptable substrate for the membrane—to span the flutes of a steel deck, for example. However, as technology, building code requirements, and design issues have changed, so, too, has the role of insulation. Historically, the structural deck was the component of the assembly with the most significant impact on the roof membrane. Today, insulation is a dominant component of the platform for the roof membrane, and its influence on the roof membrane is more important than ever.

As a platform for the roof membrane, insulation needs to perform at many levels. It must resist applied loads both in-plane and out-of-plane, provide the most monolithic surface possible for roof membrane attachment, and offer the necessary dimensional stability. The platform should always be designed to allow for positive drainage where not incorporated by the structure and contribute some degree of resistance to heat flow and fire and wind resistance. (Additional design criteria may require the platform to help achieve sound reduction, building envelope sustainability, or green design standards such as LEED.) All of these benchmarks can make the design of the platform challenging.

If a core function of the insulation is to provide a suitable substrate for the roof membrane, then six key properties that impact roof membrane longevity should be considered in the selection of materials: coefficient of thermal expansion, dimensional stability, thermal resistance, moisture resistance, compressive strength, and density.

### COEFFICIENT OF THERMAL EXPANSION

Coefficient of thermal expansion (COE) is a material property that describes expansion and contraction in both length and volume per degree of temperature change. In the case of a roofing assembly, COE is a measure of how stable the platform is as the system experiences temperature fluctuations. Good dimensional stability (or low COE) in the membrane platform reduces the stress on adhered roof membranes (as described in the Koike Theory of Roof Strains[1]). Higher COE may result in a more unstable platform, which can cause elevated stresses at the insulation joints that subsequently can be transferred to the roof membrane.

Materials with a low COE demonstrate less movement and can, therefore, provide a more stable membrane platform (see *Figure 1*).

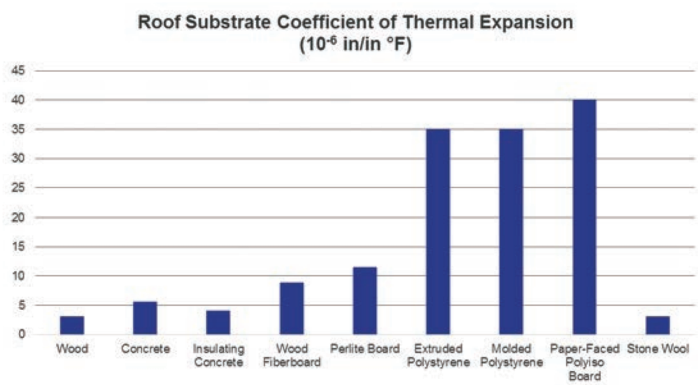


*Figure 1: Roof Substrate Coefficient of Thermal Expansion.*[3]

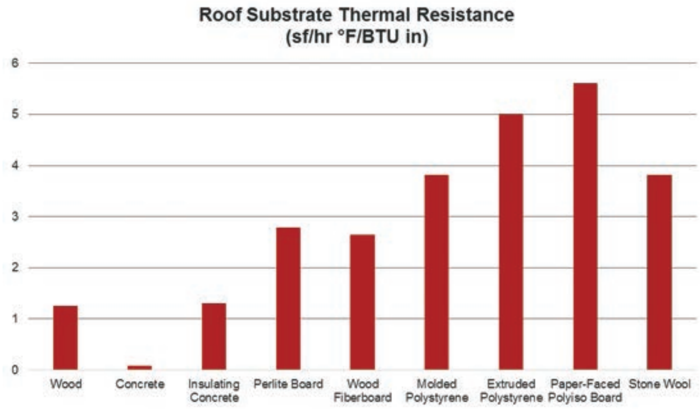


*Figure 2: Roof Substrate Thermal Resistance.*[4]

## DIMENSIONAL STABILITY

Dimensional stability of materials takes the COE one step further and describes dimensional changes of specific product constructions. ASTM D1037, ASTM D1204, and ASTM D2126 are some of the tests for dimensional stability of different roofing products, with the exposure times ranging from six hours to seven days. Other differences in these tests range from exposure conditions (temperature and relative humidity) to how the materials are dimensionally measured in the test. COE was selected as the comparative property because it provides a consistent means of evaluation across various products.[2]

## THERMAL RESISTANCE

Thermal resistance is a material's ability to resist heat flow. In roofing assemblies, it is the sum of the components' capability (R-value) to limit heat flow through the membrane and platform. Design R-values are generally established by the building codes or the owner's need to reduce HVAC cost.

Global conditions have created a renewed focus on energy efficiency. This focus, together with updated building code requirements, has produced a demand that has driven roof insulation R-value requirements into the R-30 thermal resistance range. High R-value systems can save energy and reduce greenhouse gas emissions, help design professionals meet energy-efficiency objectives, and allow building owners to take advantage of incentive programs for energy conservation. But not all of the effects of high R-value systems are positive. A high R-value beneath the roof membrane may thermally isolate the membrane from the consistent temperature of the building interior and contribute to greater and faster membrane temperature swings. Chemical reactions such as thermal oxidation of asphalt may also be accelerated by temperature, which can affect the overall service life of a roof. A high R-value system can also impact the membrane in other ways. For instance, materials with higher R-values per inch can have higher COE values, and are therefore less dimensionally stable. (See *Figure 2*.)

| MOISTURE RESISTANCE | |
|---|---|
| GOOD | MODERATE |
| Concrete | Wood |
| Extruded Polystyrene | Wood Fiberboard |
| Molded Polystyrene | Perlite Board |
| Insulating Concrete | Paper-Faced Polyiso Board |
| Stone Wool | |

*Figure 3: Moisture Resistance of Roof Insulations.*

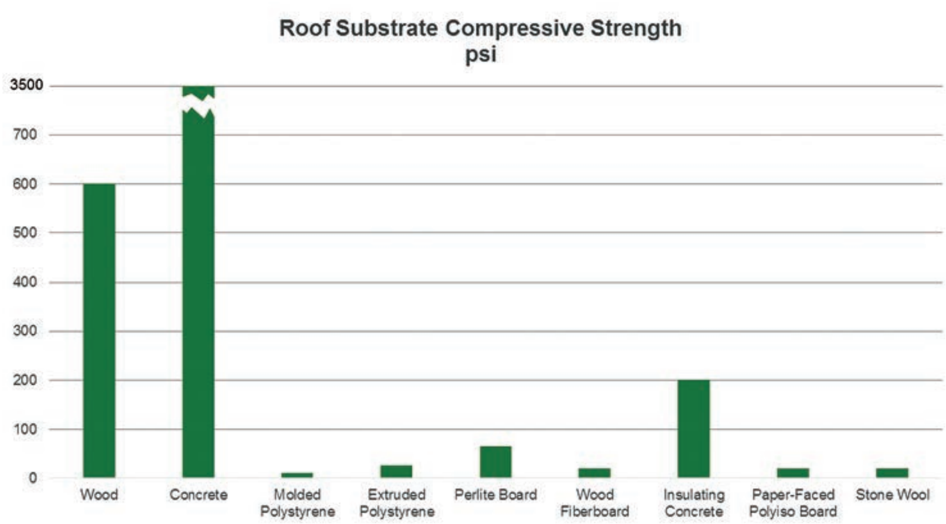


*Figure 4: Roof Substrate Compressive Strength.*[5]

## MOISTURE RESISTANCE

Despite our best efforts, during their lifespan, many roof assemblies may be impacted by some type of moisture issue. Regardless of the source, prolonged contact with moisture can deteriorate insulation and impact thermal resistance. The bond in the platform can be weakened by moisture, and fastener holding power can be diminished, which can affect wind uplift properties. Perhaps we need to consider a different perspective.

Generally, roof assemblies are designed to be dry and ideally would remain dry for the life of the assembly. This usually does not fit a real-world model. Choosing more moisture-resistant materials for the platform and designing the platform assembly to deal with the moisture can help contribute to the platform's reliability and longevity. Generally, roof insulations fall into two moisture-resistance categories: good and moderate (see *Figure 3*). Choosing more moisture-resistant materials and designing the platform to better deal with the moisture can contribute to the platform's reliability and longevity. Choosing roof insulation that is moisture-tolerant can be an added benefit.

## COMPRESSIVE STRENGTH

Compressive strength provides physical support to the membrane under roof traffic and offers some degree of impact resistance. Since the platform is the foundation for the roof membrane, higher-compressive-strength materials typically provide greater resistance to impact from weather conditions or from other trades on the roof throughout its lifetime.

Generally, materials with higher compressive strengths have lower thermal resistance values (see *Figure 4*), and in the case of high-density cover boards, are often used in conjunction with high R-value insulation where rooftop traffic is anticipated. (As a good design practice, cover boards should be used in all assemblies over insulation and under membranes to increase roof resiliency.)

## DENSITY

Density is a measure of mass per unit volume. Specific heat capacity is a material property that describes the amount of heat energy a substance can absorb before raising the material temperature by one degree. These two properties are the basis for a phenomenon known as the mass effect. Although it can vary some, the simple explanation is that the more mass a material has, the more heat energy it can absorb (i.e., heat capacity). Humans have been using the mass of materials to separate themselves from the outside environment for thousands of years. Whether it was a cave, a mud hut, or some other type of material used to build the structure, the higher the mass of the material, the greater the structure's ability to separate indoor and outdoor environments.

High R-Value materials are a natural choice when trying to reduce heat transfer in or out of a building (*Figure 5*). This choice, however, is not always the best for the roof membrane. Remembering that heat is one of the biggest factors in the aging of roof membranes, the mass (heat capacity) of the platform can have a significant impact on the roof membrane. Roof platforms with higher heat capacity have the ability to draw heat energy away from the membrane. This can help reduce the daily heat history of the roof membrane. Over the service life of a roof membrane, this can substantially reduce the total heat history, which may help lower thermal oxidation rates for asphaltic membranes and reduce the effect of heat aging for all membranes.

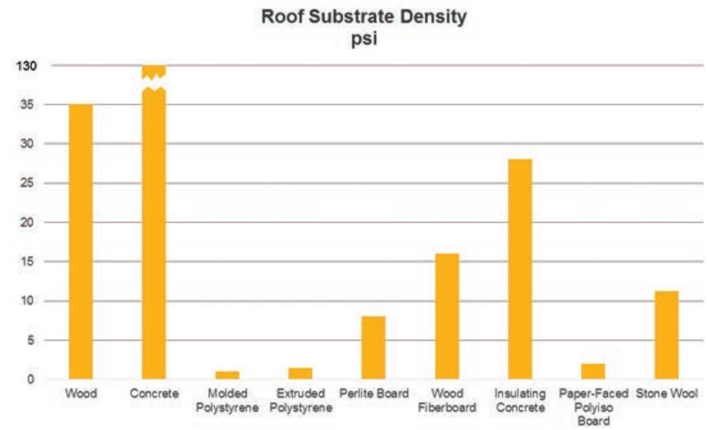

*Figure 5: Roof Substrate Density.*[6]

## THE EVOLUTION OF INSULATION

We have a historical perspective from which we can consider the six key properties of coefficient of thermal expansion, thermal resistance, moisture resistance, compressive strength, dimensional stability, and density. Prior to the early 1970s, most roof assemblies had little thermal resistance designed into them. Many roof insulations at that time had a thermal resistance of 10 or less. Roofing membranes were selected from a smaller pool of possibilities; most were comprised of several layers of built-up roofing (see *Figure 6*). These systems, if installed correctly, generally performed well.

How these six properties affected roof membrane performance began to change in the mid-1970s when more insulation materials with different physical properties

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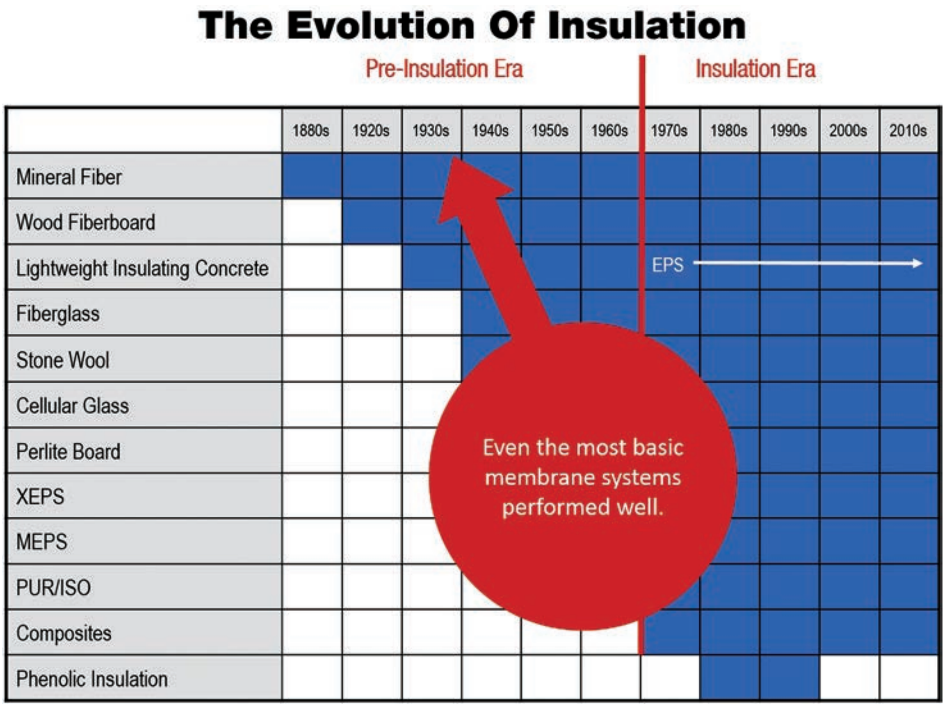


*Figure 6: The evolution of insulation: pre-insulation era.*

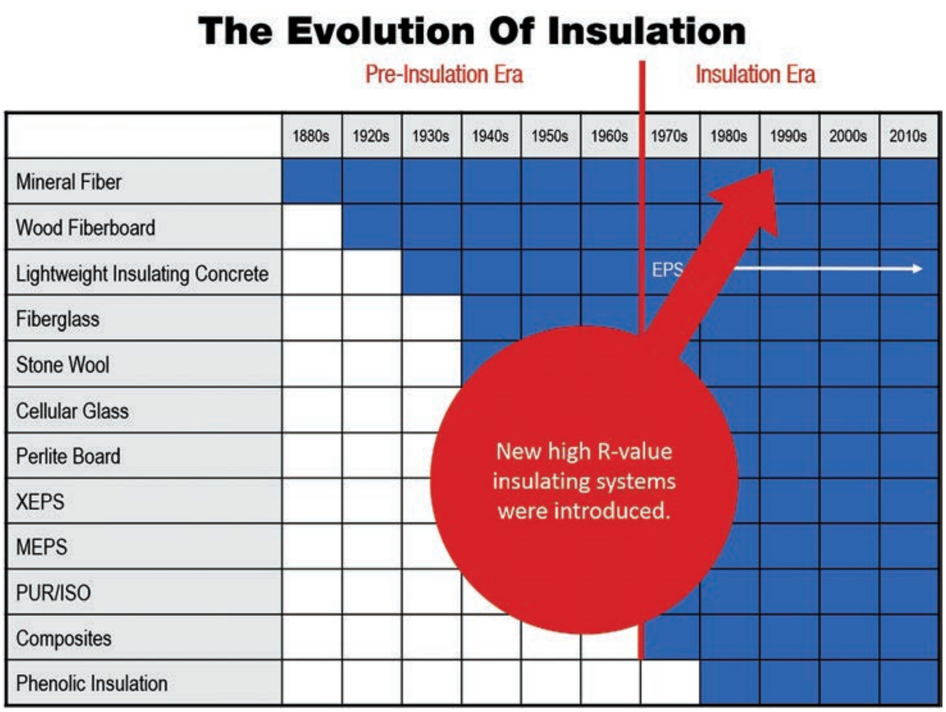


*Figure 7: The evolution of insulation: insulation era.*

entered the market (see *Figure 7*). Since then, roof assemblies have been moving toward increasing thermal resistance. While thermal efficiency may help reduce energy consumption, it can increase stress on the roof membrane. Heavily insulated assemblies can place materials with high thermal resistance comprised of low-mass, underneath-roof membranes. This may further isolate the membrane component from the platform assembly.

Finding materials that exhibit the best of the six properties discussed here can be challenging, but it is not impossible. One option for consideration is lightweight insulating concrete (LWIC). These systems can provide a high degree of performance for each of the six properties. Generally, LWIC provides high compressive strength, low COE, and relatively high heat capacity at the direct interface with the roof membrane. The thermally efficient insulation board is encapsulated by a cementitious fire-resistant material fill. LWIC systems are also inherently stable in the presence of moisture and designed to deal with internal and substrate moisture in a way that lessens the effect on system performance.

The insulation materials you select can have a significant impact on the performance of the roof membrane. Engineering the roof membrane platform to achieve a low COE and high compressive strength, while providing good thermal resistance, high mass, and moisture-resistance characteristics can provide better long-term performance of a properly designed and installed roofing system.

## REFERENCES

1. Michio Koike, Kyoji Tanaka, and Takashi Komiita. "Strains in Multi-Ply Membranes Caused by Joint Movement in Substrate." *Report of the Research Laboratory of Engineering Materials*. No. 3, 1978.
2. PIMA. "Technical Bulletin #107 – Dimensional Stability of Roofing Products." November 2011.
3. Rockwool. "(Dimensional) Stability on the Roof." December 28, 2017. Rockwool.com.
4. *The NRCA Roofing Manual: Membrane Roof Systems*. 2015. Chapter 4, pp. 155-178.
5. *Ibid.*
6. *Ibid.*

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