siplast®

Mass Effect

Substrate Influences on Modified Bitumen Roof Membrane Longevity.

How to Extend Roof Membrane Life

For building owners, the ultimate value of a roof is determined in large part by its serviceable life. The best way to estimate how long a roof system is likely to last is to consider the documented performance of that type of roof system in similar applications and conditions. Many studies have been conducted in an effort to predict the realistic life expectancies of various types of roofing membranes.

In the case of modified bitumen membranes, though many elements contribute to aging, the research points to temperature as the most significant factor. Basically, high membrane temperatures accelerate the aging process.

What contributes to heat buildup in the membrane? The primary factors are ambient (air) temperature, thermal (sun) load, and the ability of the membrane and substrate to absorb and release heat.

Taking Heat Off the Membrane

The substrate's heat capacity directly affects the temperature of the membrane it is in contact with. In simplest terms, heat capacity is the amount of heat an object can hold. To help understand heat capacity and its impact, consider two identical pans on a stove. Pan A contains two quarts of water, and Pan B contains four quarts. Even if the pans of water are heated at precisely the same rate, the water in Pan A will reach the boiling point before the water in Pan B, due to the smaller quantity - the smaller mass - of water in Pan A. The water in Pan B has a higher heat capacity than the water in Pan A.

Putting a membrane in contact with a substrate that has little heat capacity of its own will result in faster heat buildup in the membrane. Conversely, using a substrate with a high heat capacity will help to pull heat away from the membrane.

Heat capacity is calculated by multiplying specific heat by total mass (or weight) using the fomula:

Heat Capacity =
Specific Heat (J g^{-1} °C^{-1}) x Mass (g)

Specific heat is defined as the quantity of heat required to raise the temperature of one gram of a substance 1°C. The relationship between specific heat and total mass is the basis behind the term "Mass Effect."

Which Substrate Offers the Best Membrane Protection?

To determine which type of insulating substrate offers the most protection from heat to an SBS-modified bitumen membrane, a two-year study

Membrane Temperature Curve

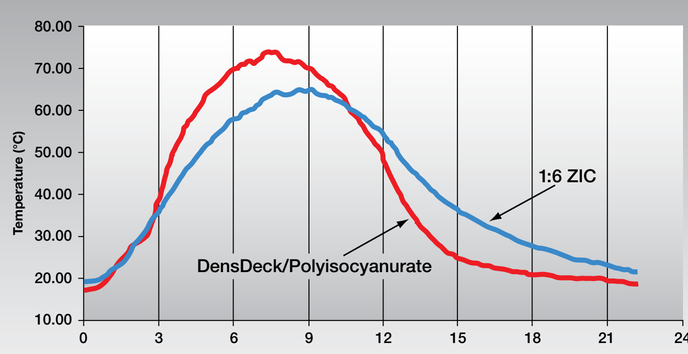

Figure A

Membrane temperature (diurnal cycle) for a typical summer day in the south-central United States.

Arrhenius Reaction Rate Model

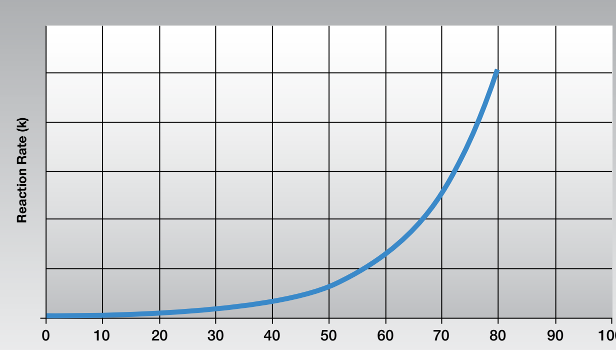

Figure B

was conducted using five different roof assemblies:

- 1:6 Siplast ZIC Aggregate Lightweight Insulating Concrete (2 inches thick).
- 1:4 Siplast ZIC Aggregate Lightweight Insulating Concrete (2 inches thick).
- DensDeck cover board (0.25 inches thick) with polyisocyanurate.
- Perlite cover board (0.75 inches thick) with polyisocyanurate.
- Cellular lightweight insulating concrete (2 inches thick).

In order to establish identical environmental conditions for the study, the roof assemblies were built with the same slope, R-value (adjusted to R-20), and membrane system. All were equally exposed to solar load and ambient temperatures.

Using probes installed at specific points in each roof assembly, temperatures were collected at 10-minute intervals throughout the day, over a two-year period. Over the course of the experiment, more than three million temperature readings were taken. The aging rate for each membrane was calculated based on specific membrane temperature readings for each membrane/substrate combination.

Temperature Data

Figure A shows the daily temperature swing for two of the subject roof assemblies, using readings taken on a summer day in Arkadelphia, Arkansas (south-central United States). The graph shows that the rate of temperature increase and decrease was significantly slower for a membrane installed over 1:6 Siplast ZIC Aggregate Lightweight Insulating Concrete than it was for a membrane installed over DensDeck/polyisocyanurate.

Applying Temperature Data to the Arrhenius Equation

To calculate the rate of membrane aging, the temperature readings collected during the study were plugged into the Arrhenius Equation, which is a mathematical formula that shows the relationship between temperature and rate of chemical reaction – in this case, between membrane temperature and rate of degradation due to oxidation (heat aging).

The calculated aging rate for each temperature was multiplied by the time interval. The summation of the resulting products yielded a value that corresponds to the aging that occurred over the two-year test period. Figure B shows that the reaction (aging) rate of the membrane doubles every time the membrane temperature increases by 18°F (10°C).

The Aging Curve

Figure D represents the aging curve calculated from the temperatures shown in Figure C. The line graphs clearly illustrate that the rate of oxidation (aging) increases at higher membrane temperatures, and that the variances in the aging rate are even more significant when the membrane surface temperature is above 140°F (60°C).

Comparing Substrates

Using the Arrhenius Equation, a relative value for membrane aging was calculated for each temperature measurement taken over each substrate. These values were summed to present an overall aging value, which allows a consistent comparison among substrates. The substrate shown to provide the lowest membrane aging value, 1:6 Siplast ZIC Aggregate Lightweight Insulating Concrete, was used as the baseline.

The Arrhenius Equation

The Arrhenius Equation is probably the most common model used in the interpretation of data obtained from accelerated aging tests. It was developed in 1887 by Swedish chemist Svandite Arrhenius. The equation is:

$$k = A \times e^{(-E/(RT))}$$

where: k = rate of reaction
A = constant
e = 2.718
E = activation energy
R = Rydberg constant
T = temperature (°C)

Membrane Temperature Curve

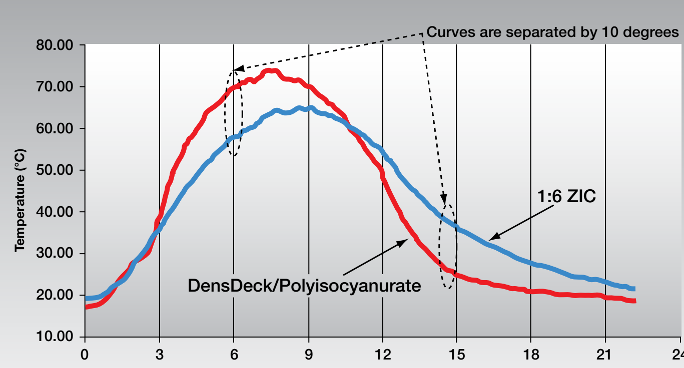

Figure C

Aging Curve

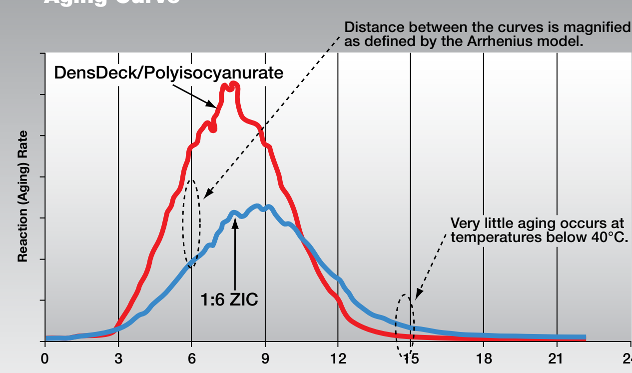

Figure D

The aging rate curve in Figure D is based on temperatures from Figure C (left). At each of the circled locations, where the curves display a membrane temperature difference of 18°F (10°C), the membrane aging rate doubles, as defined by the Arrhenius Equation.

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Figure E

Substrate	Percentage increase in aging in relation to 1:6 ZIC
1:6 ZIC Aggregate (2 inches thick)	Baseline
1:4 ZIC Aggregate (2 inches thick)	7.2 %
DensDeck cover board (0.25 inches thick) with polyisocyanurate	49.1 %
Perlite cover board (0.75 inches thick) with polyisocyanurate	53.1 %
Cellular lightweight insulating concrete (2 inches thick)	53.7 %

Figure E displays the results for each substrate as compared to 1:6 Siplast ZIC Aggregate.

Conclusion

The results of this study indicate clearly that the best substrate choice for extending membrane life is lightweight insulating concrete, because lightweight insulating concrete has the capacity to decrease membrane temperature and reduce membrane temperature fluctuations.

In this study, the modified bitumen membrane installed over the 1:6 and 1:4 Siplast ZIC Aggregate Systems experienced far lower aging rates compared to the other systems tested. The heat capacity of the ZIC Aggregate substrate is much higher than that of the other substrates tested.

Think about it. Rigid foam plastic board stock insulations with high R-values are intended to decrease heat transfer between the interior and exterior of a building. Therefore, they have less ability to absorb and release heat than traditional substrates such as concrete and wood plank, and the roof membrane is exposed to higher heat for longer periods of time.

By encapsulating rigid foam plastic board stock insulation in lightweight insulating concrete, the Siplast ZIC Aggregate System provides both high insulating values and higher heat capacity. This is important because, as we've seen, the more heat absorbed by the substrate, the lower the temperature build-up in the membrane and the slower its oxidation (aging).

For longer membrane life, the easy choice in substrates is aggregate based lightweight insulating concrete.

Cover Photo:
This business campus in northern California is protected by a Paradiene 20/30 System installed over Siplast Lightweight Insulating Concrete.

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