Research Summary
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# Expansion and Contraction of Roofing Insulation Systems

**Testing of roofing systems using common insulation materials**

## Project Overview

Dimensional stability is a measurement of a material's volume change in dimensions – length, width and thickness – in response to various environmental exposure conditions and is specific to a material. It is known within the industry that foam insulation products experience expansion and contraction when subject to temperature fluctuations at a higher rate than others. In roofing applications, this can be of concern from both an energy performance and durability viewpoint. Gaps created act as thermal bridges around the insulation and allow for air movement, convective looping, and moisture movement around the insulation. Additionally, dimensional stability is a concern in building construction if two materials that experience different expansion and contraction behavior are adhered, as they may exert forces on each other that may result in premature failure of materials and systems.

Roofing enclosure system design best practice requires double-layer insulation systems to minimize these effects. However, single-layer insulation systems are not uncommon. This research program was undertaken to demonstrate the expansion and contraction responses of three different exterior roofing insulation products when exposed to temperature cycling both as a material and as part of a full enclosure system.

Testing and evaluation was conducted by RDH Building Science Laboratories.

*Figure 1: Full scale roof assemblies, Phase 2a (from left: XPS, ROCKWOOL TOPROCK DD, Polyisocyanurate)*

## Test Assemblies Description

Three different off-the-shelf roofing insulation types were included in the study:

1. Stone wool (ROCKWOOL TOPROCK® DD)
2. Extruded polystyrene (XPS)
3. Polyisocyanurate (PIC)

All insulation materials were 3" (76mm) in thickness. When tested as a system, insulation (with and without a roof membrane) was installed over a metal deck substrate with a self-adhered air barrier/water resistive barrier.

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## Methodology

The research program can be divided into 2 distinct phases. Phase 1 included unrestricted material testing evaluating expansion and contraction on the x, y and z axes (length, width and thickness). Testing was conducted in a climate chamber consisting of a metal rack built into a highly insulated enclosure. A total of 6 samples were tested, 2 of each insulation types.

*Figure 2: Phase 1 testing chamber*

Phase 2 consisted of full-scale assembly testing of a single insulation layer roof assembly, both (a) with and (b) without a roof membrane, each using new insulation boards. The testing was conducted in a guarded hot box climate chamber developed by RDH Building Science Laboratories. The temperature on the interior side of the climate chamber was kept constant at 70°F (21°C). The temperature on the exterior climate side of the chamber was cycled between 144°F and -18°F (62°C and -28°C). A total of 7 temperature cycles were conducted, and photos were taken each time the temperature reached equilibrium to visually inspect and measure the expansion and contraction of the insulation material.

## Results

Phase 1 concluded that between the insulation materials, polyisocyanurate had the highest amount of strain (linear expansion), 15x more than ROCKWOOL TOPROCK® DD and 1.5x more than XPS.

*Table 1: Calculated strain (%) based on measured changes in length*

| Material | Strain (%) |
|---|---|
| **ROCKWOOL TOPROCK® DD** | 0.0 |
| **XPS** | 0.3 |
| **Polyisocyanurate** | 0.5 |

Pre-testing, initial gap sizes in the roof systems were noted up to 1/32" (0.8mm). Phase 2a results indicated that there were noticeable changes in the gap width with every change in temperature for both the XPS and polyisocyanurate insulation boards while there was no visually noticeable change in the ROCKWOOL TOPROCK® DD insulation boards. Additionally, with each subsequent temperature cycle, the gaps would increase at the low temperature setting for both foam plastic insulation systems (refer to Figure 3). During the high temperature settings, the foam plastic insulations would expand and decrease the width of the gap, however not to the same initial state and size, leaving permanent increased gaps between the boards (refer to Figure 4).

In Phase 2b, to visually inspect the expansion and contraction, flaps (taped and sealed during testing) were created over a single joint in each assembly. The results indicated that there was no visual difference for expansion and contraction of the insulation materials in comparison to Phase 2a.



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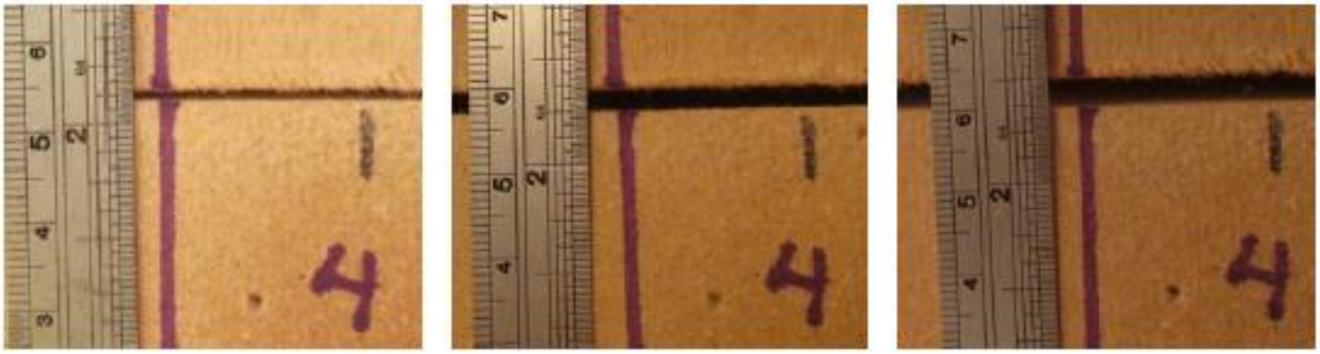


*Figure 3: Photographs of measurement location for polyisocyanurate during Phase 2a, cycle #1, #3 and #6 at -18°F (-28°C)*

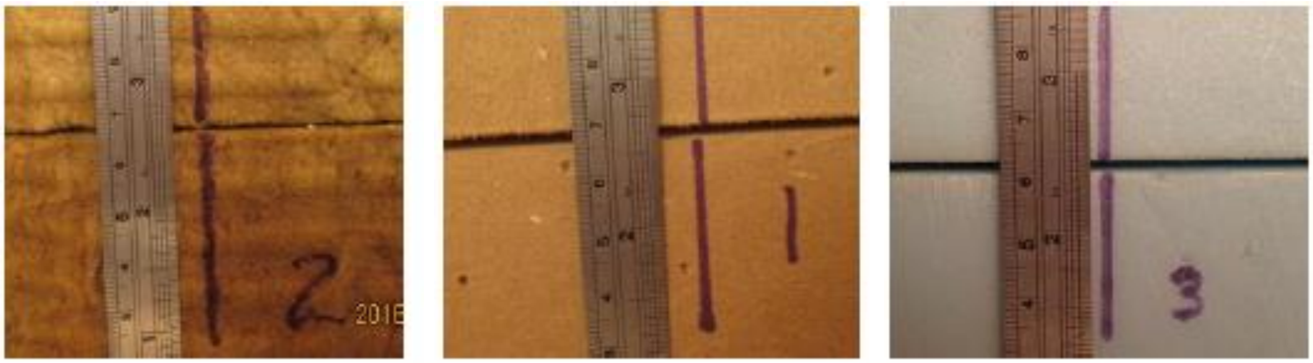


*Figure 4: Photographs of all three insulation materials (from left: ROCKWOOL TOPROCK DD, polyisocyanurate and XPS) at end of Phase 2a testing (once equilibrium was achieved) showing permanent dimensional changes.*

## Conclusions

The movement of insulation materials has implications for long term roof durability and energy performance. Roof investigations have shown that expansion and contraction of insulation has contributed to gaps that occur between insulation boards, as well as in-service failures of roof membranes. The results of this study demonstrate the superior dimensional stability of ROCKWOOL TOPROCK DD roof insulation in comparison to foam plastic insulation types, in both individual materials and full system testing. When tested as a full roof system, both with and without a roof membrane, foam plastic insulations result in permanent gaps between the boards. Thermal modelling[1] of the results from this study demonstrate up to 4x more thermal performance loss in a 4' x 8' polyisocyanurate roof in comparison to a stone wool roof.  Best practice for limiting performance loss and roof failures include designing for multiple layers of insulation with off-set joints and using dimensionally stable materials to limit risk of movement and increase long-term durability.

[1] Thermal modelling was conducted using HEAT 3v8.02 for a 4' x 8' roof system. Two 4' x 4' boards were assumed with 1 insulation joint. Thermal properties of the materials were obtained from ASHRAE Handbook of Fundamentals – 2017 and manufacturer technical data sheets where applicable.



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