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# Dimensional Stability of Rigid Board Insulation Products

Building enclosure investigations and renewals often reveal irreversible dimensional changes in rigid foam board insulation products, including expanded polystyrene (EPS), extruded polystyrene (XPS) and polyisocyanurate (ISO). Historically, these foam insulation board products have been found to both permanently increase or decrease in size within wall and roof assemblies when exposed to high and low in-service temperatures, resulting in gaps between boards. These gaps contribute to thermal bridging and the transfer of stresses onto membranes in the case of roofing applications.

It has been speculated that these dimensional changes are a result of thermal expansion and contraction due to the high in-service temperatures, which can often be experienced within wall and, in particular, conventional roof assemblies. Examples of expansion and contraction observed within in-service conventional roof assemblies are shown in Figure 1 and Figure 2.

In an effort to further understand the cause of the observed expansion and contraction of in-service rigid insulation products, a research study was undertaken by ROCKWOOL and RDH Building Science to investigate the dimensional stability of these products when exposed to temperatures ranging from -15°C to 90°C (5°F to 194°F), and to determine associated coefficients of linear thermal expansion.

The data used to compare the effects of temperature in this study was collected from ten different rigid insulation board products from seven manufacturers[1]:

- Two EPS insulation board products from one manufacturer
- Two XPS insulation board products from two different manufacturers
- Four ISO insulation board products from three different manufacturers
- Two stone wool insulation board products from ROCKWOOL; Toprock® DD, Toprock® DD Plus

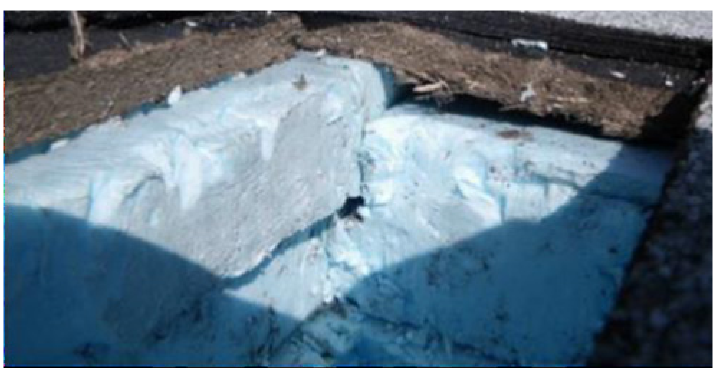

**Figure 1** Irreversible thermal expansion of XPS within conventional roof assembly potentially due to high in-service temperature.

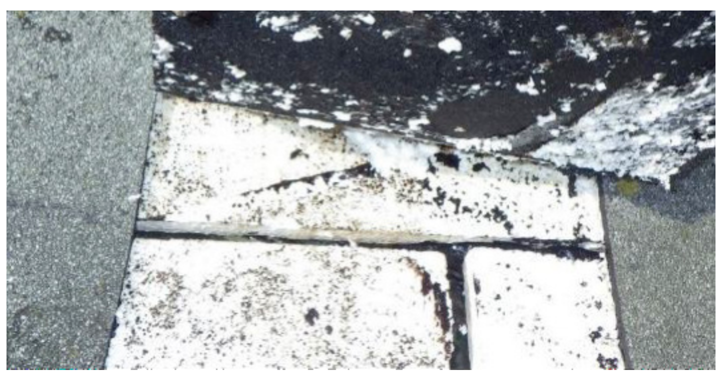

**Figure 2** Permanent shrinkage of EPS insulation in a conventional roof assembly, potentially due to high in-service temperature or initial application into hot asphalt adhesive.

[1] All rigid foam products used for this research study were obtained prior to 2015. It was our belief that the products selected were representative of the behavior of foam products available at that time. However, it is possible that other foam products, which were available, might have exhibited different performance characteristics. Since the completion of this study, some foam product manufacturers have made technological advancements that could potentially enhance the performance of their products.

The primary objective of this study was to assess the dimensional stability of different rigid board insulation products under a variety of temperatures that they may encounter during their service life. Additionally, the study aimed to determine the coefficients of linear thermal expansion and contraction for each type of insulation, and evaluate their performance limits at high and low temperatures. Specifically, the focus was on identifying the temperatures at which permanent deformation of the insulation products occurs.

## Expanded Polystyrene (EPS)

Both EPS insulation products tested showed linear thermal expansion and contraction between -15°C and 80°C (5°F and 194°F). The samples were observed to expand as temperature increased, followed by a return to their original dimensions upon cooling.

Above 80°C (176°F), significant inelastic contraction was observed, with boards contracting up to 2% smaller in comparison to their initial room temperature measurements. Figure 3 shows an averaged summary of the combined insulation dimensional changes for both EPS products.

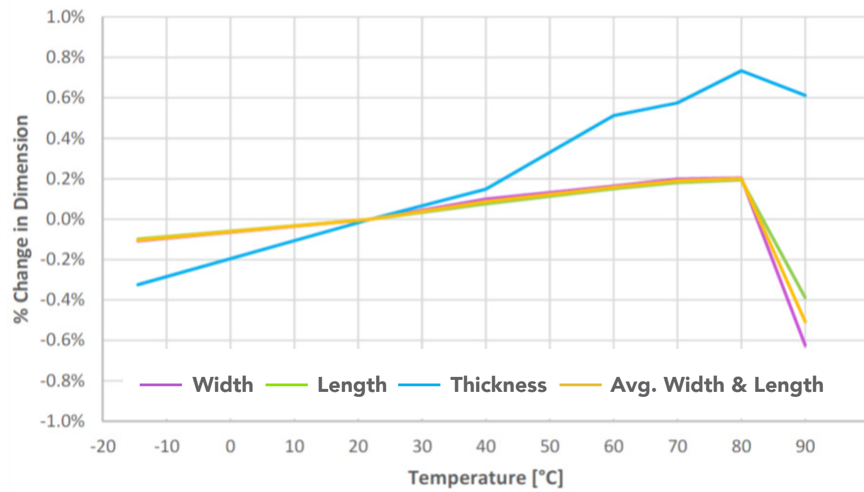


**Figure 3** Summary of Average Insulation Dimensional Changes for EPS

## Extruded Polystyrene (XPS)

Both of the tested XPS products showed dimensional expansion as the temperature increased. A summary of the XPS insulation dimensional changes is shown in Figure 4 for an average of both products.

During testing, XPS samples exhibited both elastic and inelastic deformation. At temperatures below 40°C (104°F), the XPS samples demonstrated an elastic behavior, regaining their original dimensions as temperatures returned to initial levels. However, as temperatures rose to 60°C (140°F) and beyond, the dimensional changes increased exponentially, and all tested XPS samples displayed permanent, inelastic deformation. Furthermore, at temperatures above 80°C (176°F) the dimensional changes exceeded the capacity of the testing equipment and could not be recorded (>4%).

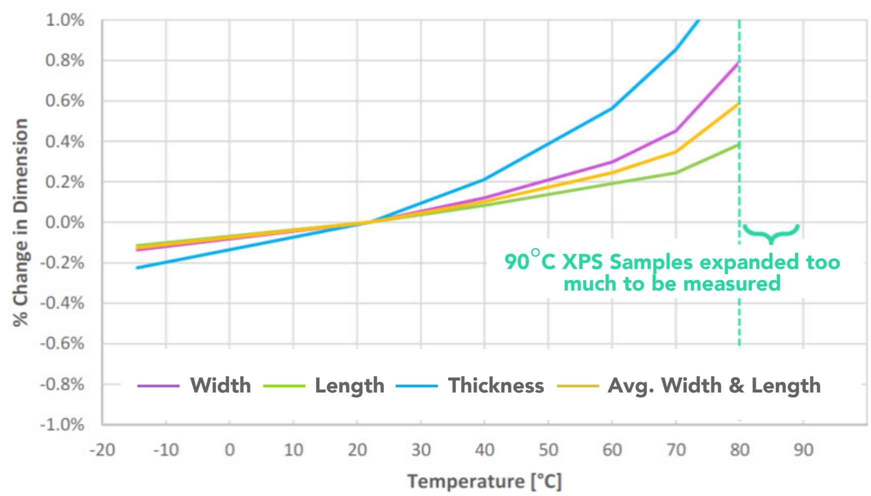


**Figure 4** Summary of Average Insulation Dimensional Changes for XPS

## Polyisocyanurate (ISO)

Three of the four ISO products tested showed dimensional expansion as temperatures increased. Figure 5 presents an averaged summary of these three ISO products. The most notable dimensional change was observed in the thickness. Of the three different foam plastic insulation types tested, the ISO showed the least predictable behaviour.

In addition, one of the four ISO products tested showed slight dimensional contraction as the temperature increased to 80°C (176°F). This was primarily observed in the length and width directions of each sample.

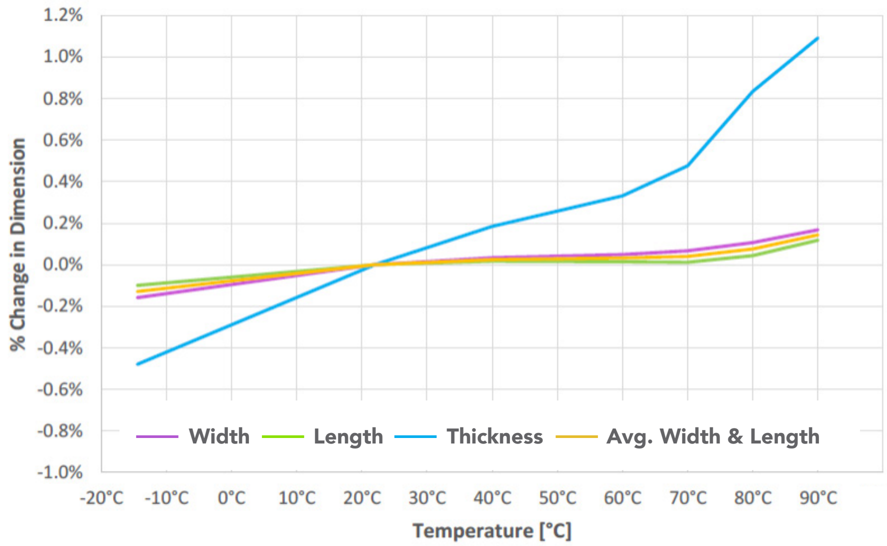


**Figure 5** Summary of Average IInsulation Dimensional Changes for ISO

The ISO samples exhibited a permanent reduction in their dimensions when exposed to temperatures up to 70°C (158°F). However, exposure to temperatures above 70°C (158°F) resulted in a permanent expansion of ISO's dimensions. The cause of this phenomenon is not clear but may be related to structural cell changes from off gassing at increased temperatures.

## Stone Wool

The stone wool insulation products that were tested maintained constant dimensions throughout the testing procedure. There were no significant indications that thermally induced expansion or contraction took place across the samples.

Figure 6 shows a summary of the dimensional changes of the stone wool insulation. The measurements taken after each stone wool sample returned to room temperature showed negligible indications of dimensional changes, especially when compared to the other insulation types.

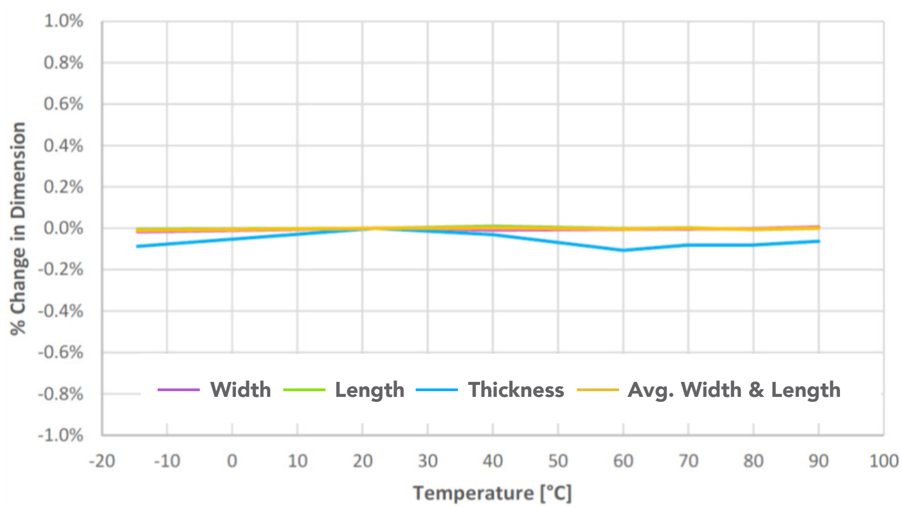


**Figure 6** Summary of Average Insulation Dimensional Changes for Stone Wool

Of the four insulation types tested during this study, RDH concluded that stone wool is the most dimensionally stable when exposed to high and low in-service termperatures.

# Summary of Results

Figures 7 and 8 summarize and compare the average dimensional changes in the length, width, and thickness of each product. Figures 9 and 10 show the average dimensional changes for each insulation type. Note the change in scale between the different figures.

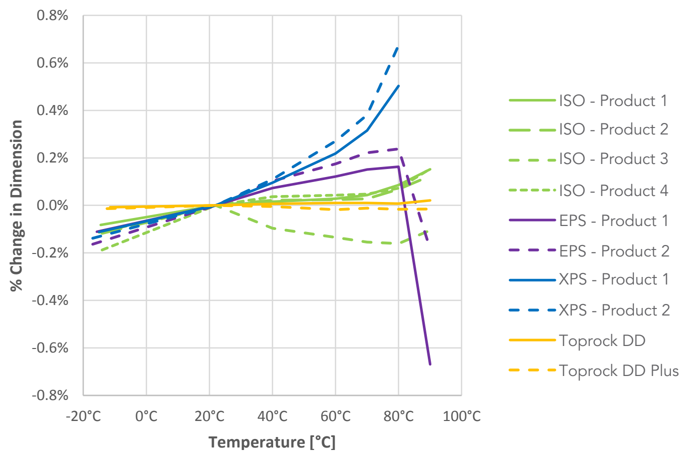


**Figure 7** Average Length and Width Dimensional Changes for all Tested Products

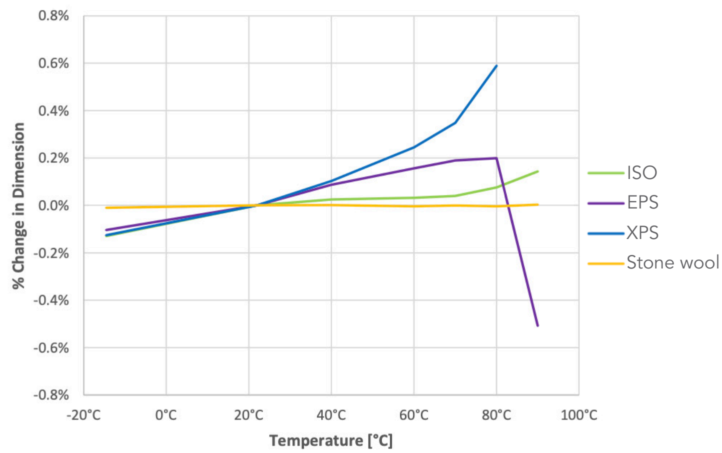


**Figure 9** Average Length and Width Dimensional Changes for each Insulation Type

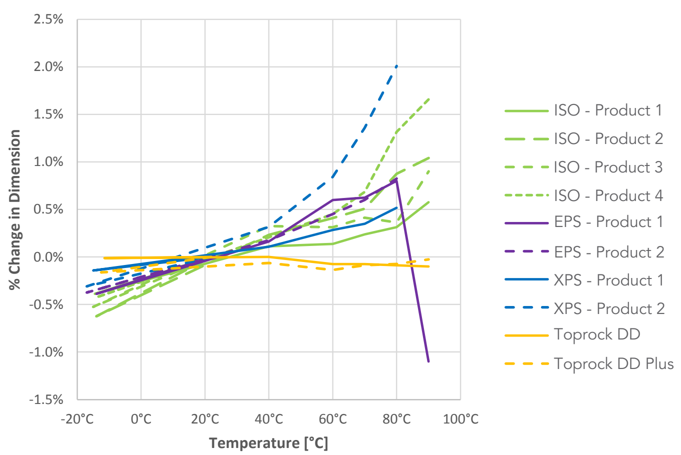


**Figure 8** Average Thickness Dimensional Changes for all Tested Products

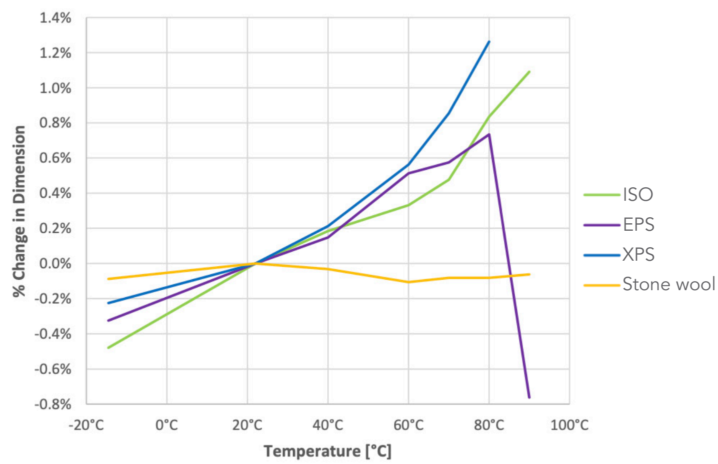


**Figure 10** Average Thickness Dimensional Changes for each Insulation Type

## Average Thermal Expansion and Contraction Coefficients

The data collected from testing was used to determine thermal coefficients of expansion and contraction for each insulation product for the length/width and thickness dimensions. These values were averaged for each insulation type, separated into four temperature ranges, and are presented in Table 1.

Published data from EPS and XPS manufacturers are shown for comparison. However, it should be noted that these values were measured using a different methodology which did not consider potential length, width and thickness differences of larger insulation samples.

## Comparison to Field Observations

Many insulation samples experienced more than a 0.5% change in dimension, in at least one of the directions (length, width, thickness). This is the equivalent, for instance, of ¼" of expansion or contraction in the length of a 4' long insulation board. This is consistent with the expansion and contraction of these insulation product types observed in field investigations.

Table 2 converts the dimensional changes measured on the 12" x 12" samples to the approximate dimensional changes that could be observed in 4' and 8' boards.

### **Table 1:** Average Thermal Expansion Coefficients ($10^{-6}$ M/(M °K))

| | **EPS** | | **XPS** | | **Polyisocyanurate**[1] | | **Stone wool** | |
|---|---|---|---|---|---|---|---|---|
| **Temperature Range** | **L/W** | **T** | **L/W** | **T** | **L/W** | **T** | **L/W** | **T** |
| **α (-15°C to 22°C)** | 29 | 89 | 34 | 63 | 35 | 131 | **≈0** | |
| **α (22°C to 40°C)** | 48 | 82 | 57 | 118 | 14 | 103 | | |
| **α (40°C to 60°C)** | 35 | 129 | 71 | 175 | 4 | 95 | | |
| **α (60°C to 80°C)** | 21 | 110 | 170 | 170 | 22 | 22 | | |
| **α – published** | 63[2] | | 49[3] | | None Found | | None Found | |

[1] The data for one of the four polyisocyanurate products tested were not representational of the other three polyisocyanurate insulation products and therefore were excluded

[2] Source: Plasti-Fab PlastiSpan EFS Design Manual (2004)

[3] Source: Owens Corning FOAMULAR® C-200 Extruded Polystyrene Rigid Insulation Product Data Sheet (2011)

### **Table 2:** Dimensional Changes on 4' and 8' Insulation Boards

| Dimensional changes (12"x12"samples) | Approximate expansion/contraction equivalent on 4' insulation board | Approximate expansion/contraction equivalent on 8' insulation board |
|---|---|---|
| 0.2% | 3/32" | 3/16" |
| 0.4% | 3/16" | 3/8" |
| 0.5% | 1/4" | 1/2" |
| 0.6% | 9/32" | 9/16" |
| 0.8% | 3/8" | 12/16" |
| 1.0% | 1/2" | 1" |

## Conclusion

The results of this research demonstrate that rigid foam insulation products (EPS, XPS and ISO) are dimensionally affected by changes in temperature. Elastic expansion and contraction was typically observed initially in the foam insulation products, but at elevated temperatures (varying between each insulation type) permanent inelastic deformation was observed, and in some cases significant warping of the insulation products. The gathered results were comparable among the products of each type of insulation, suggesting that the observed behaviour may be typical across other products having similar compositions.

Stone wool was the only insulation type measured to have negligible expansion and contraction when compared to the other insulation types.

### Key findings:

- XPS, EPS, and ISO insulation dimensionally contracted at temperatures below 0°C (32°F).
- EPS insulation elastically expanded at temperatures up to 80°C (176°F), above which it permanently contracted by up to 2%.
- XPS insulation exponentially expanded as temperature increased, with permanent, inelastic deformation taking place at temperatures above 60°C (140°F).
- ISO insulation showed both permanent thermal expansion and contraction as temperatures increased.
- **The thermal expansion and contraction in stone wool insulation was negligible when compared to the other insulation types.**

**The full study is detailed in the white paper "Dimensional Stability of Rigid Board Insulation Products" by RDH, from 01/30/2015.**

**To get in touch with the ROCKWOOL Technical Services team, visit rockwool.com/north-america/contact/ or call at 1-877-823-9790**

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