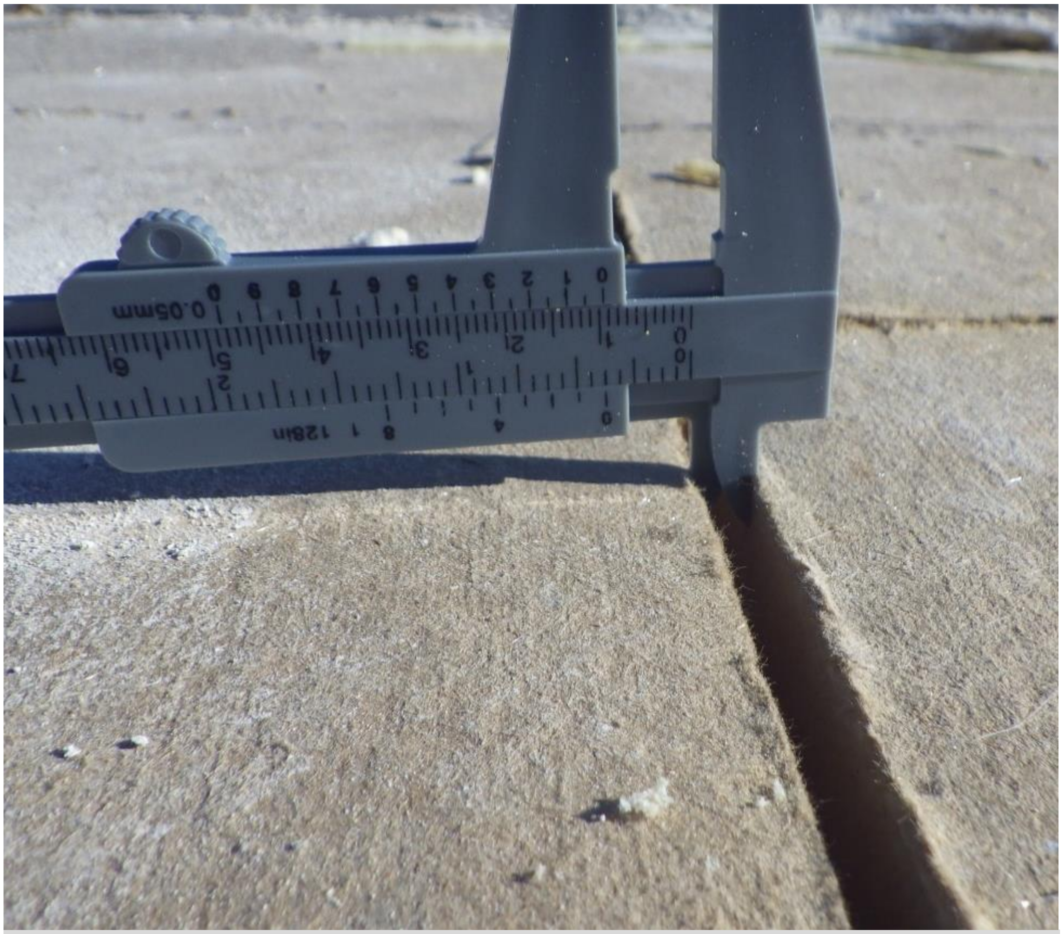
RDH BUILDING SCIENCE

Long Term Monitoring Study of Polyisocyanurate Roof Insulation Movement and Thermal Performance – 6 Year Report



To Mr. Laurence Matzek
RCABC Guarantee Corp.
9734 - 201st Street
Langley BC V1M 3E8

Submitted February 9, 2016 by
RDH Building Science Inc.
224 West 8th Avenue
Vancouver BC V5Y 1N5

RCABC
ROOFING CONTRACTORS ASSOCIATION OF BRITISH COLUMBIA

Executive Summary

In response to a number of observed issues and widespread concerns regarding the dimensional stability of polyisocyanurate (polyiso) roofing insulation, a long-term monitoring study was conducted of a conventional roof assembly in New Westminster, BC. This study was set-up to evaluate in-situ conditions which may impact the long-term dimensional stability and thermal performance of two types of polyiso roofing insulation.

The building monitoring program, which included temperature, relative humidity, and displacement sensors, was installed in the roof in 2009 and recorded measurements every 15 minutes for a period of almost 6 years. Results indicate that both types of polyiso roofing insulation shrank during the first two years after installation at a rate independent of temperature. In years three through six, one brand of polyiso continued to shrink, albeit more slowly and with expansion during periods of high temperatures, while the other brand of polyiso stabilized dimensionally.

In addition to its dimensional stability, concerns regarding the long-term thermal performance of polyiso have also been raised by the industry, particularly with respect to aging of insulation. This has potentially widespread implications with respect to worsened thermal performance of roof assemblies as the insulation ages. To better understand this phenomenon, the temperature-dependent conductivity of the aged polyiso was analyzed as part of this study. The thermal performance of samples that were aged in laboratory conditions for four years was compared to the thermal performance of samples that had been installed within the study roof for five and a half years. The measured results indicate that the conductivity of polyiso insulation is higher at cold temperatures than standard test conditions, and that field-aged polyiso provides less thermal resistance than the lab-aged polyiso.

Further research is recommended in order to isolate the causes of long-term dimensional instability and R-value degradation of polyiso, with the goal of creating a more thermally and dimensionally stable product.

Contents

1 Introduction

In response to apparent dimensional instability issues observed with polyisocyanurate (polyiso) roof insulation across North America, a long-term building monitoring project was initiated in 2009. At that time and consistently since the mid-2000s, reports of dimensional stability issues with polyiso insulation were common in the local roofing market, as were associated roofing issues and claims stemming from membrane failures and large gaps between insulation boards.

This research study was conceived by the team of RCABC, Wells Klein Consulting Group Inc., RDH Building Science Inc.1, and SMT Research with the intention of developing an understanding of the long-term dimensional stability and thermal performance of polyiso roofing insulation within conventional roof assemblies. In order to achieve this, the dimensional movement, relative humidity, moisture, and temperature of polyiso insulation installed within a conventional roof assembly was monitored from 2009 through 2015 (approximately 6 years to date) with integrated sensors and data logging equipment.

In addition to its dimensional stability, the thermal performance of polyiso has been theorized around the industry to worsen when used in-service. This has potentially widespread impacts in terms of building energy consumption as well as the moisture performance of assemblies. Therefore, to supplement the field monitoring component, 3rd party laboratory testing was performed to compare the R-values of lab-aged polyiso samples to those for samples that were removed from the monitored roof.

This report summarizes the findings from this study including results from the field monitoring component and laboratory testing of the R-values of the aged polyiso insulation.

[1] Please note, as of November 1, 2015, RDH Building Engineering Ltd. became RDH Building Science Inc. (please visit www.rdh.com/about-us/merger-announcement for more information).

2 Background

Numerous issues with conventional roofing assemblies are potentially attributable to dimensional instability of polyiso insulation and other types of roofing insulation. Movement of insulation itself can result in stresses on the roofing membrane as it pushes/pulls the membrane relative to its installed configuration. The type of insulation attachment, whether it be adhered, mechanically attached, or ballasted will likely have differing impacts on movement of the roof insulation.

Most commonly, dimensional movement of roof insulation has been theorized to manifest itself as large gaps between boards of the insulation and stresses within the membrane around penetrations, curbs, and parapets. These gaps could potentially create thermal bridges which bypass the insulation, and stresses in the membrane lead to wrinkles and/or tears in the membrane. An example of wrinkling and stressing of the roof membrane from a recently constructed roof in the Greater Vancouver area of BC where the dimensional instability of the polyiso insulation is thought to be a contributing issue to roofing failure is shown in Figure 2.1 to Figure 2.4. Several other such local examples exist for polyiso as well as other types of foam plastic insulation, including EPS and XPS.

Figure 2.1 Wrinkling and distortion of 2-ply SBS roofing membrane in a conventional roof assembly with polyiso insulation.

Figure 2.2 Distortion of 2-ply SBS roofing membrane in a conventional roof assembly with polyiso insulation.

Figure 2.3 Observed 3"+ Gap between parapet and insulation likely due to dimensional movement and shrinkage of polyiso insulation.

Figure 2.4 Damage to roof stack vent likely due to movement of underlying polyiso insulation.

Historically, the mechanism causing this dimensional change of polyiso roofing insulation has been poorly understood by the industry, and to compound this, significant variation between the brand of insulation, type of facer, and age of insulation has been anecdotally observed. It is generally understood that off-gassing of the blowing agent is a large contributing factor to the observed shrinkage, as fresh polyiso will tend to exhibit initial shrinkage and distortion (e.g. cupping or curling) as it ages. However, the relative contribution of this shrinkage to the observed effects is relatively poorly understood, and the effect of other potential factors including temperature fluctuations and moisture within the polyiso insulation on the dimension change of the insulation have not been thoroughly investigated.

To address these unknowns with respect to the shrinkage of polyiso insulation, this study conducted a long-term field monitoring of polyiso insulation installed in a conventional roof assembly.

3 Field Monitoring Study

3.1 Study Building and Roof Assembly

The study building is a five-storey reinforced concrete office building located in New Westminster, BC that was constructed in the early 1980s. The original roof assembly for the building had exceeded its useful service life and was being replaced which provided a good opportunity to integrate monitoring equipment into the new roof assembly. An aerial image of the roof of the study building and the study area is provided in Figure 3.1.

Figure 3.1 Aerial view of roof of study building in New Westminster, BC. Roof is outlined in yellow, study area is outlined in red.

Two different brands of polyiso insulation that are commonly used in the lower mainland of BC were included in the roof assembly to allow for a comparison of their performance. The primary insulation type for the roof was from a manufacturer that will be referred to as “Brand B.” For the purposes of the monitoring study, approximately a 300 square foot area at the southeast portion of the roof used “Brand A” polyiso instead to facilitate comparison.

Except for the brand of polyiso insulation, the roof assemblies are the same in both areas. The Brand A and Brand B polyiso are fiberglass faced and kraft paper faced respectively, and were both 3” thick (nominally) at the time of installation.

The roof assembly from the interior to the exterior consists of the following components (Figure 3.2):

- Existing reinforced concrete deck
- Torched, single-ply SBS vapour barrier/air barrier
- 3” polyiso insulation adhered to the vapour retarder with two-part polyurethane adhesive (Both Brand A and Brand B)
- Gypsum protection board adhered to the polyiso with two-part polyurethane adhesive
- Self-adhered SBS modified membrane base sheet

→ Torch applied, gray, SBS modified membrane cap sheet

Note that the roof is a fully adhered assembly, as all layers are held in place with adhesives, as opposed to mechanical fasteners.

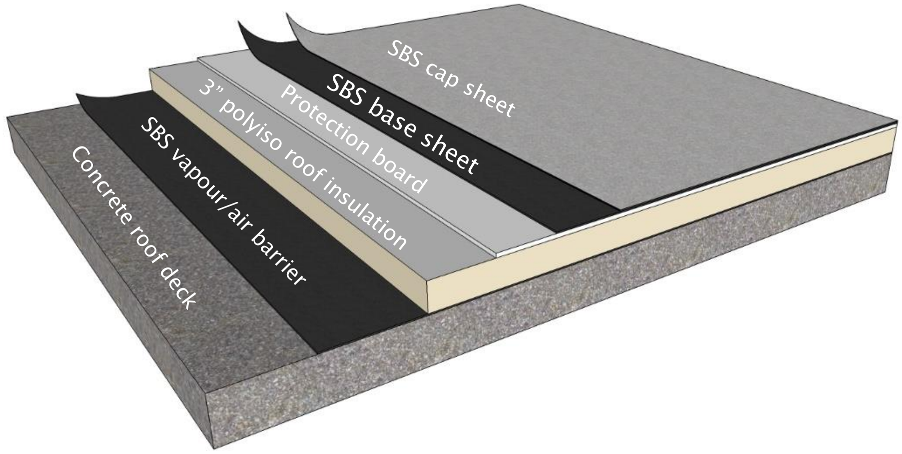


Figure 3.2 Schematic of the conventional roof assembly installed at the study building.

An image of the test site is shown in Figure 3.3. Note that the test site is largely unshaded by surrounding buildings and other objects.

Figure 3.3 Overview of test area at the study building located in New Westminster, BC.

The single layer of insulation boards were installed per 2009 RCABC guidelines for the roof with gaps as tight as possible. Current industry practice no longer permits a single layer of insulation, and instead requires two layers of insulation with staggered joints to lessen the negative impact of the insulation gaps.

3.2 Monitoring Equipment

In order to quantify the dimensional changes of polyiso insulation within the roof assembly and evaluate potentially relevant factors, two test areas within the center of each insulation brand were monitored with temperature, relative humidity, moisture content, and displacement sensors. The digital displacement sensors used for this study are accurate to 0.1 mm.

The majority of the sensors were installed around a central insulation panel in each test area away from edge effects and mechanical equipment. In total, seven 4'x4' boards of each brand of polyiso roof insulation were monitored, or 14 boards total, and 34 total sensors were installed. In this way, the dimensional stability of the insulation was measured in multiple boards and in different directions. A summary the sensors is provided in Table 3.1 and a guide to the location of these sensors on the study roof and within the roof assembly is shown in Figure 3.4 and Figure 3.5, respectively.

Figure 3.4 Location of sensors installed in roof assembly at test building in New Westminster, BC.

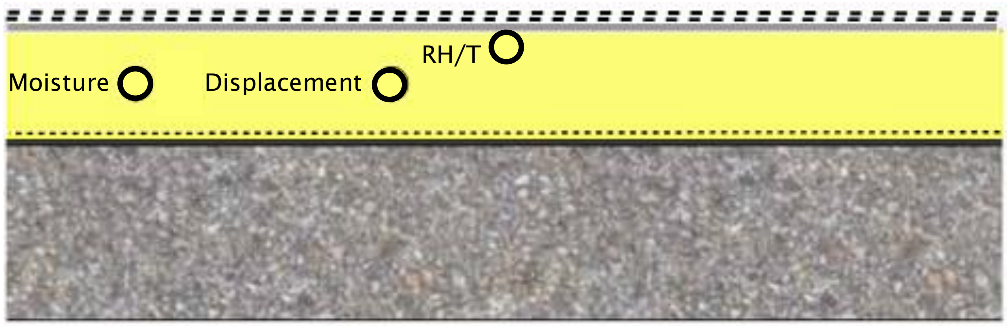


Figure 3.5 Schematic of sensor installation location within the roof assembly. Note that moisture and displacement sensors were installed at the core of the 3" polyiso roof insulation boards whereas the RH/T sensors were installed at the top.

TABLE 3.1 SUMMARY OF INSTALLED SENSORS					
Location	**Ambient Air Temperature**	**Core of Polyiso Temperature**	**Displacement**	**Relative Humidity**	**Moisture**
Exterior	1	1		1	
Brand A Test Area		2	8	2	2
Brand B Test Area		2	8	2	2
Interior	1			1	
Control			1		

The displacement sensors were embedded into a factory edge of the polyiso insulation and epoxied in place as shown in Figure 3.6. A rigid metal plate was permanently glued to the face of a factory edge of the polyiso insulation board immediately adjacent to the displacement sensor (Figure 3.7) to act as a solid contact for the plunger of the displacement sensor.

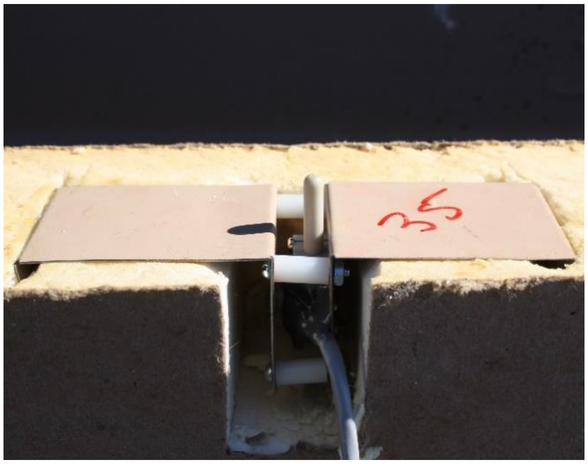


Figure 3.6 Displacement sensor Installed into the edge of a polyiso insulation board with the plunger fully extended. The plunger will contact the contact plate on the adjacent insulation board once installed.

Figure 3.7 Displacement sensor installed at joint between adjacent polyiso insulation boards. The plunger is now depressed and in contact with the plate on the adjacent board.

Temperature, relative humidity, and moisture content sensors were also installed into the insulation boards to monitor the potential impact that these parameters have on dimensional movement of the polyiso. Photographs of these sensors are shown in Figure 3.8 and Figure 3.9.

Figure 3.8 RH and temperature sensor during installation, installed into top surface of polyiso insulation. Typical of all RH/Temp sensors.

Figure 3.9 Closeup of RH and temperature sensor that was installed into top surface of polyiso insulation.

Installation of this monitoring equipment was performed on between September 10th and 14th, 2009 by representatives of SMT Research, RDH, and Wells Klein. Images of this installation are shown in Figure 3.10 and Figure 3.11.

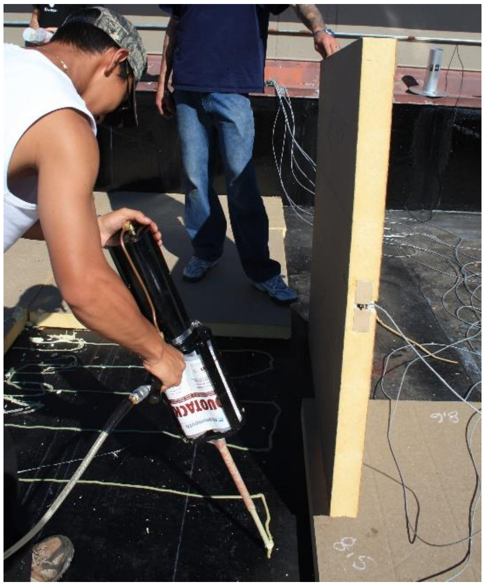


Figure 3.10 Study insulation board immediately prior to being adhered to air and vapour barrier on top of roof deck.

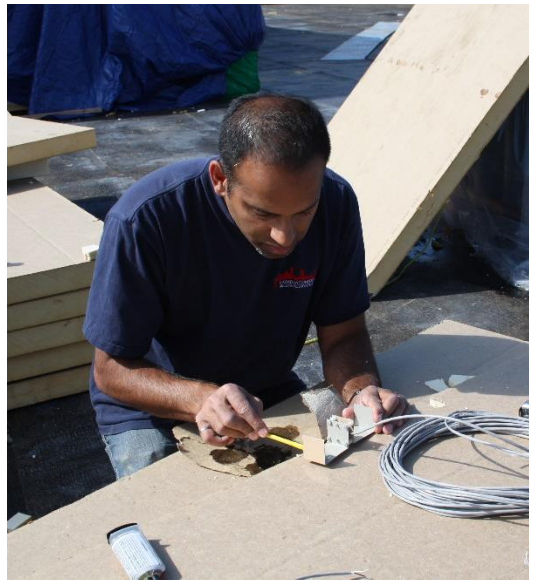


Figure 3.11 Installation of monitoring equipment by SMT Research.

Data from all sensors was measured and recorded every 15 minutes from September 2009 through August 2015. Monitoring occurred continuously from September 2009 through April 2011, June 2012 through July 2013, and April 2015 ongoing up to present day (January 2016). The monitoring system was shut-off between May 2011 and May 2012, as well as from August 2013 and March 2015.

3.3 Monitored Results, Observations, and Discussion

The dimensional movement of both Brand A and Brand B polyiso boards was measured over the 6 year monitoring period, though with large gaps in the data between May 2011 and May 2012 and August 2013 and March 2015 while the monitoring system was shut-off.

The measured dimensional movement of the Brand A polyiso samples is plotted in Figure 3.12. Data is presented on a daily basis, using the average of all readings recorded each day during the monitoring period. Negative numbers indicate shrinkage of the insulation while positive numbers indicate expansion.

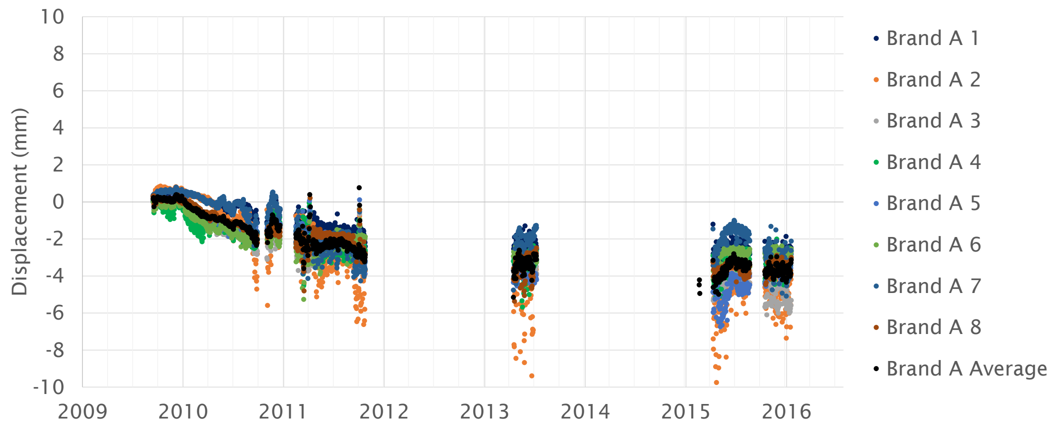


Figure 3.12 Brand A polyiso dimensional change over time for the 8 monitored locations. Note that the monitoring system was turned off during the time periods with no data.

The average dimensional change observed throughout all monitoring locations for Brand A polyiso is plotted in Figure 3.13, along with the insulation average temperature, measured at the core of the insulation.

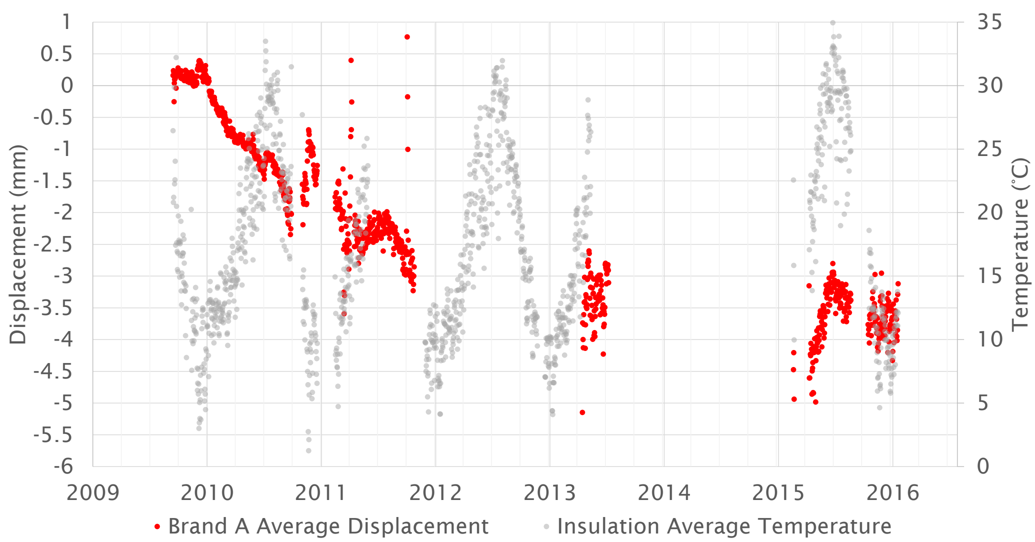


Figure 3.13 Brand A polyiso roof insulation average displacement (dimensional change) throughout the 6-year monitoring period, plotted alongside the average temperature recorded at the core of the insulation.

The results of the measured displacements for the Brand A polyiso indicate that it shrank relatively consistently for the first two years of monitoring (up to 3 mm on average), likely due to off-gassing of blowing agents from the manufacturing process. After this two year period, the movement of the insulation largely stabilized, but shrinkage appears to have continued at a more moderate rate up until the most recent measurements (up to 4 mm on average). Data from the period of February 2015 to July 2015 appears to indicate a correlation between temperature of the insulation and dimensional change.

The measured dimensional movement of the Brand B polyiso samples is plotted in Figure 3.14. Again, data is presented on a daily basis, using the average of all readings recorded each day during the monitoring period. The results show similar initial shrinkage of the

Brand B polyiso as compared to the Brand A; however, this shrinkage plateaus at approximately 2 mm whereas the Brand A continued to shrink up to a maximum of 5 to 6 mm. Again, the majority of shrinkage to date (6 years) occurred during the first two years after installation.

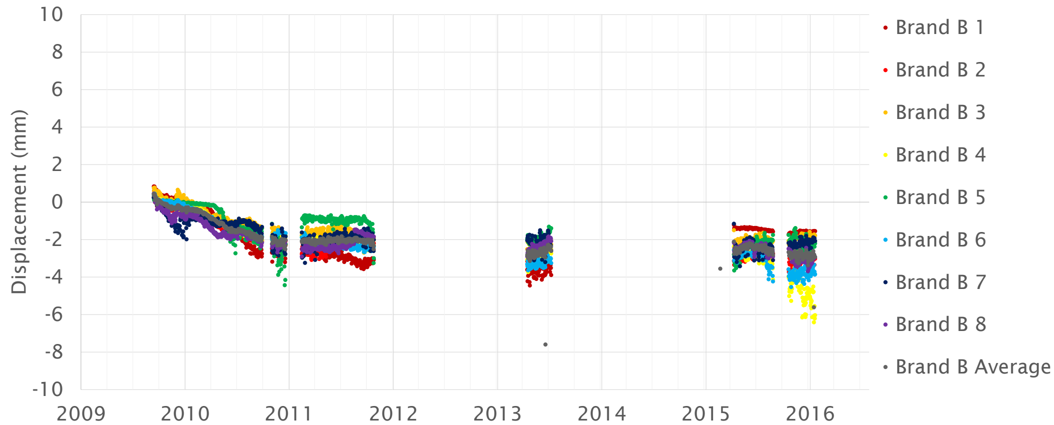


Figure 3.14 Brand B polyiso dimensional change over time for 8 monitored locations. Note that the monitoring system was turned off during the time periods where no data is shown.

The average dimensional change observed throughout all monitoring locations for Brand B polyiso is plotted in Figure 3.15, along with the insulation average temperature, measured at the core of the insulation.

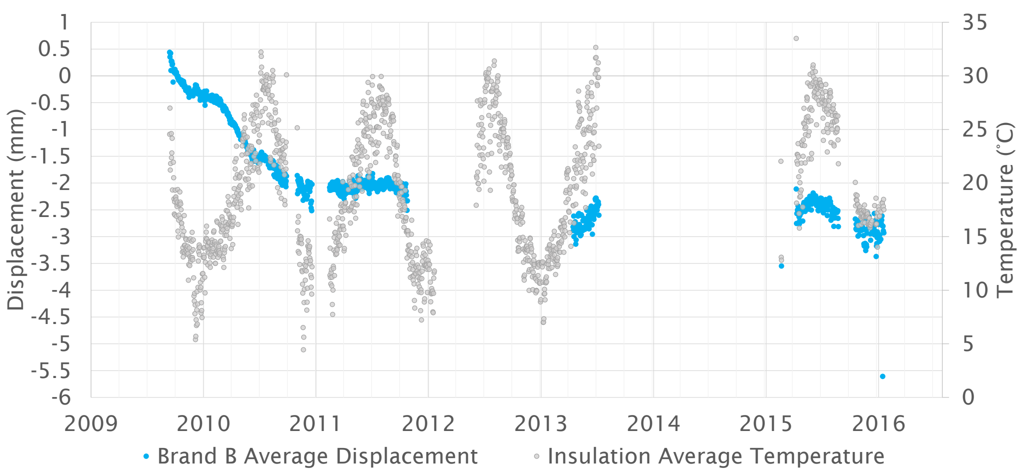


Figure 3.15 Brand B polyiso roof insulation average displacement throughout the 6-year monitoring period, plotted alongside the average temperature recorded at the core of the insulation.

The monitoring results indicate that Brand B polyiso also shrank during the first two years after installation; however, after January 2011, the average displacement remained relatively constant at approximately 2 to 2.5 mm of shrinkage.

The average dimensional change of both Brand A and Brand B polyiso is plotted in Figure 3.16.

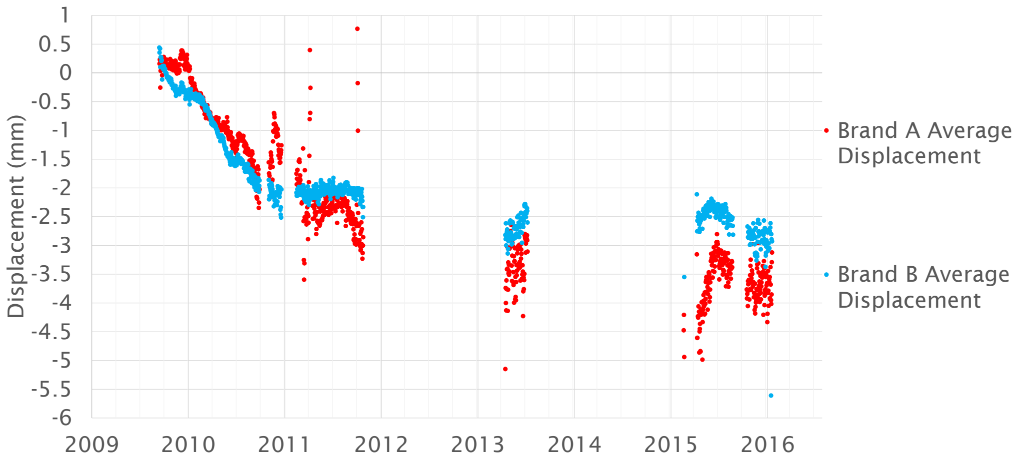


Figure 3.16 Dimensional change of Brand A and Brand B polyiso throughout the monitoring period.

Both Brand A and Brand B polyiso shrank approximately 2 mm during the first two years after installation, and then Brand B shrinkage nearly stopped while Brand A continued to shrink but at a slower rate. Further research is advisable to determine the factors contributing to this discrepancy in dimensional stability of the two insulation brands. A table comparing the average displacement of each insulation brand recorded during various intervals within the monitoring period is provided in Table 3.2.

TABLE 3.2 DIMENSIONAL CHANGE OF BRAND A AND BRAND B POLYISO

	2009-2010	2011-2012	2013-2014	2015-Present
Brand A Average Displacement (mm)	-1.43	-2.40	-3.43	-3.75
Brand A Dimensional Change (%)	0.12%	0.20%	0.28%	0.38%
Brand B Average Displacement (mm)	-1.62	-1.78	-2.72	-2.29
Brand B Dimensional Change (%)	0.13%	0.15%	0.22%	0.19%

In order to validate the dimensional change measurements, exploratory openings were made during a field review in February 2015.

In addition to the dimensional movement of the polyiso, the insulation relative humidity and temperature were also monitored to understand the potential impact of these factors on the measured movement of the polyiso.

The upper surface temperatures of the Brand A and Brand B insulation are plotted in Figure 3.17 along with the ambient exterior and interior temperatures. Throughout the monitoring period, the maximum temperature recorded near the exterior surface of the polyiso insulation was 54°C, while the minimum temperature was -9°C.

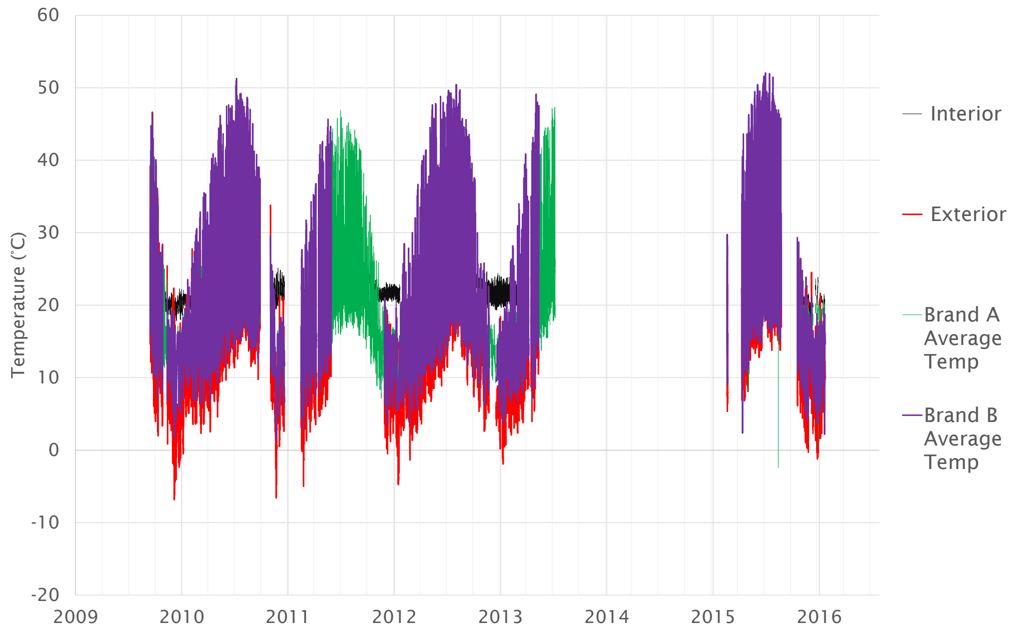


Figure 3.17 Temperature average of Brand A and Brand B polyiso, compared to interior and exterior temperature during the monitoring period.

A representative week of both hot weather and cold weather have been plotted in Figure 3.18 and Figure 3.19 along with the respective dimensional change of Brand A and Brand B polyiso over the course of these weeks in order to assess the impact of short-term temperature changes on the dimensional stability of polyiso roof insulation.

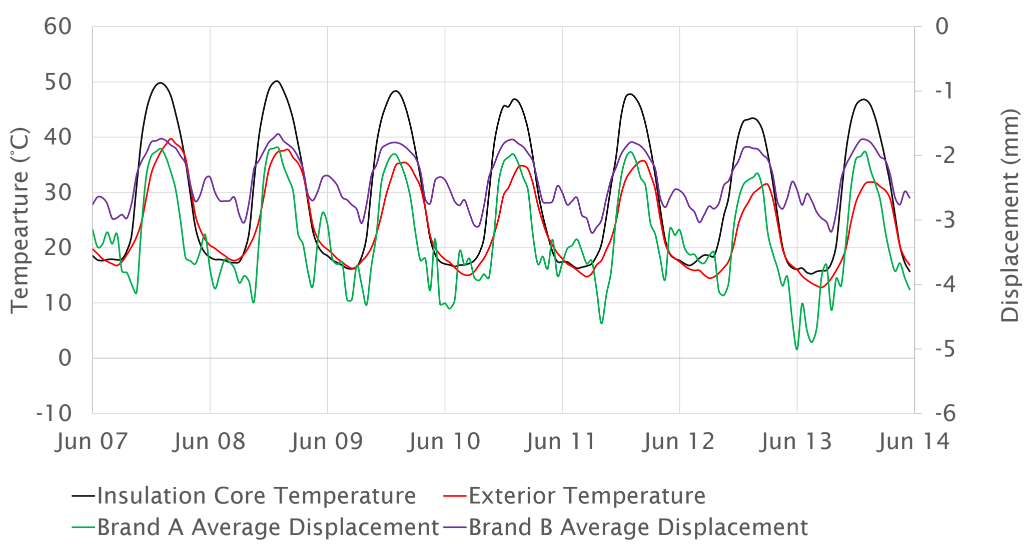


Figure 3.18 Dimensional movement of polyiso during representative week of hot weather from July 7th to 14th, 2015.

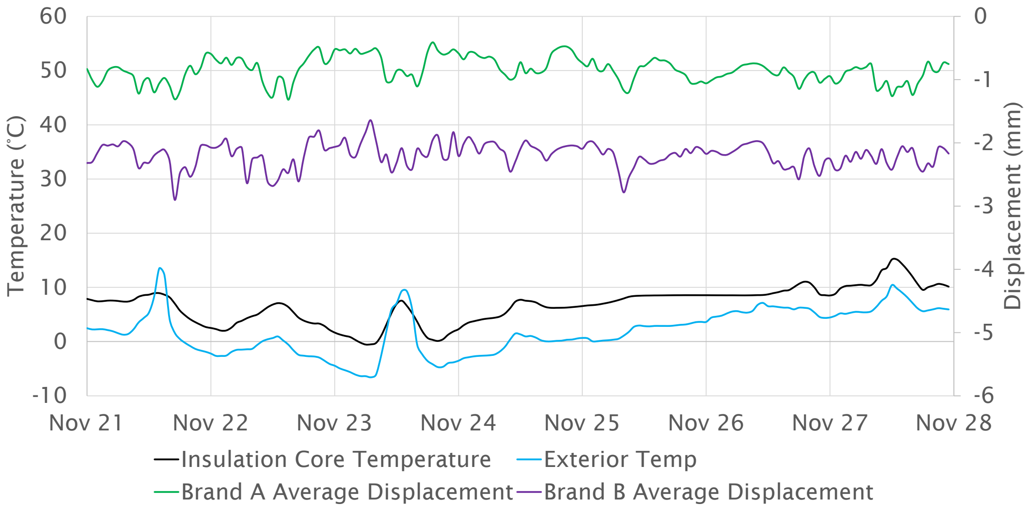


Figure 3.19 Dimensional movement of polyiso during representative week of cold weather from November 21st to 28th 2010.

During the week of hot weather, temperatures measured at the exterior sensor varied diurnally between 15 to 40°C, whereas during the week of cold weather, temperatures ranged between -5 to 15°C, but tended to change more gradually, with the exception of brief temperature spikes. This trend is manifested in the movement observed in the polyiso with far less dimensional change during the cold week than in the hot week, and movement following the diurnal change in temperature during the hot week but not the cold week in both Brand A as well as Brand B polyiso.

The relative humidity was monitored in both Brand A and Brand B polyiso, as well as exterior, and is plotted in Figure 3.20.

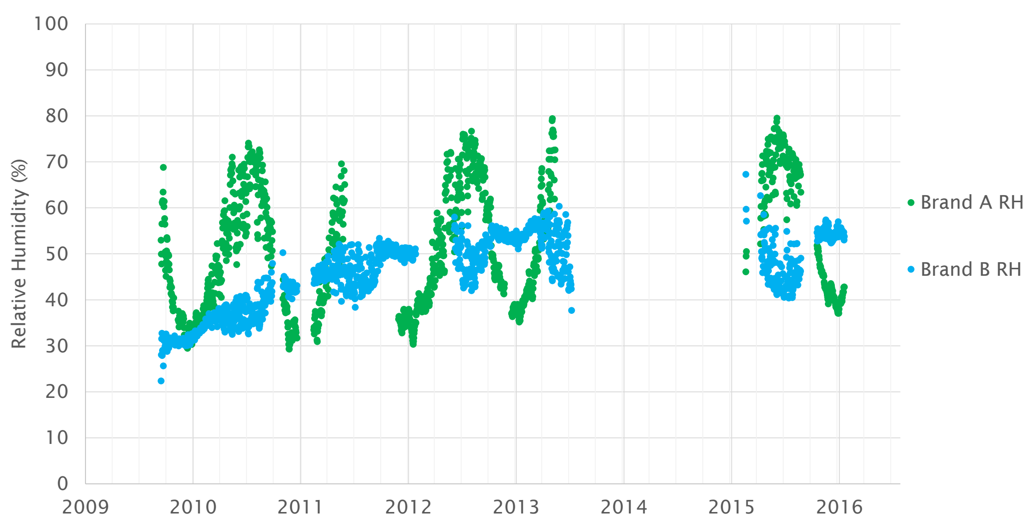


Figure 3.20 Relative humidity of Brand A and Brand B during the monitoring period.

The data indicates that the relative humidity within the upper layer of insulation is generally low, but that there are noticeable seasonal fluctuations, in particular in the Brand A polyiso. For Brand A, high relative humidity levels typically occurred during the winter, and lower levels occurred during the summer. There is a slight upward trend year over year indicating that some small amount of moisture may be accumulating within the assembly. This slight upward annual trend of increasing relative humidity within sealed conventional roofs has also been observed in other instances, and while investigation of the cause of this accumulation is beyond the scope of this report, further investigation is being conducted independent of this study.

The relative humidity levels measured within the roof assemblies indicate that the insulation remains relatively dry and that trends in the relative humidity levels do not appear to correlate with trends in the measured displacement of the insulation. The exploratory openings made in February 2015 confirmed dry conditions with no liquid water found within the assemblies, and also no evidence of past moisture accumulation, entrapment, or damage.

Relative moisture sensors were also installed in the polyiso insulation in order to identify any abnormal trends in the moisture within the insulation. However, this data was not correlated with actual insulation moisture levels, and is therefore not included in this analysis.

3.4 Summary of Dimensional Stability Findings

The data from the monitoring program, combined with observations made during the exploratory openings and field investigation, suggest that the polyiso insulation boards within the test roof has undergone dimensional movement of between 2mm - 6mm. Approximately half of Brand A's shrinkage and three-quarters of Brand B's shrinkage was measured to occur in the first two years after installation. This is most likely due to initial in-service off-gassing of blowing agents from the manufacturing process. After this initial shrinkage, dimensional stability of Brand B polyiso stabilized, while Brand A polyiso continued to shrink, although at a reduced rate.

The displacement measurements for both brands of insulation correlate over the short term with temperature, but not long term annual trends. No correlation between the dimensional stability of polyiso and the relative humidity measured was found.

The measurements recorded with the monitoring program were confirmed with visual observations through exploratory openings made in the roof assembly as discussed in the following section.

3.4.1 Exploratory Openings

After five and a half years of monitoring, exploratory openings were made in the roofs in order to confirm the shrinkage recorded by the displacement sensors and observe the physical condition of the insulation and roof assembly components. Roof openings were made on February 23, 2015 by representatives of RDH, Wells Klein, and RCABC. At the time of the openings, the roof surface was dry, and no liquid water was observed within the roof assembly. The monitoring data measured gaps between insulation boards of approximately 5 mm when the review was conducted, and exploratory openings were generally consistent with these measurements as gaps between the boards ranged from 1 to 6 mm. Photos of these exploratory roof openings are provided in Figure 3.21 to Figure 3.24. Supplementary photos are provided in the Appendix.

Figure 3.21 SBS roofing membrane being removed in order to visually inspect polyiso insulation

Figure 3.22 Overall shot of 4'x4' exploratory roof opening.

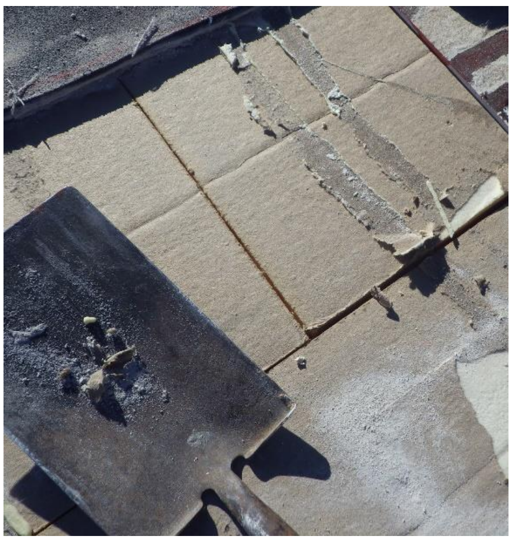


Figure 3.23 Polyiso insulation board exposed during exploratory roof openings.

Figure 3.24 ~5mm gap observed between edges of polyiso insulation boards.

In addition to the confirmed increase in gap size between insulation boards, measurements taken of the polyiso insulation boards exposed in the exploratory openings also revealed that the majority of both brands of insulation had shrunk by approximately 1/8" (3mm) in thickness from 3" to 2 7/8" (76 to 73 mm), as shown in Figure 3.25.

Figure 3.25 Polyiso insulation board thickness, measured at factory edge. Several of the exposed insulation boards appear to have shrunk in thickness during the course of the monitoring study, from 3" initial as purchased to 2 7/8" in-service.

The insulation thickness was not monitored as part of this study so it is not possible to comment on when or how this shrinkage occurred. Additional photos taken during this site visit are included in the Appendix.

4 R-Values of Aged Polyiso

4.1 Background

Since the initiation of this study in 2009, the roofing industry has become increasingly aware of the unique temperature dependency of the thermal conductivity of polyiso insulation alongside of separate long-term aging effects2. The published R-value of polyiso in 2009 was typically around R-6.0/inch (and often reported higher by many manufacturers) but later was downgraded to R-5.6/inch in 2014 throughout the industry . The R-value of polyiso has been widely observed to be optimized at the ASTM test temperature (22˚C), and at temperatures outside of this, performance is reduced. Further complicating the issue is the fact that the blowing agents used in the manufacturing of polyiso insulation have changed multiple times over the last 15 years to address concerns with greenhouse gas emissions, and each of the blowing agents has unique properties which affect the performance of the polyiso insulation.

As part of this study the thermal conductivity and effective R-values of the two installed brands of polyiso insulation were measured after having been lab aged or field aged. Lab aged insulation samples were measured in 2013 after being stored within the RDH materials lab for 4 years, and the field aged samples were removed from the monitored roof after five and a half years in service. The lab aged samples were tested as part of another research project performed by RDH3 but the results are included here for comparison.

4.2 Methodology

At the onset of this study in 2009, samples of both Brand A and Brand B polyiso roof insulation were set aside and kept in laboratory conditions for a period of 4 years. After four years of "laboratory aging," the R-value at select temperatures for the samples was tested using ASTM C 518-10 "Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus" test procedure.

Five and a half years after the onset of this study, which was one and a half years after the lab-aged polyiso was tested, polyiso insulation samples of both Brand A and Brand B were removed from the within the test roof assembly of the study building. These samples were approximately 12" x 12" x 2 7/8" in dimension. The temperature-dependent conductivity of the insulation samples were then measured by a third party lab using a new test procedure based on a modification of ASTM C 518-10 "Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus." This modified procedures was developed by RDH and is referred to as the converging delta-T method. While the standard ASTM method determines the conductivity of the insulation at the mean insulation temperature when exposed to a temperature difference, the converging delta-T method allows for the determination of the conductivity of the insulation at a specific temperature, independent of insulation thickness and the temperature difference across it.

[2] Building Science Corporation Info Sheet 502: Temperature Dependence of R-values in Polyisocyanurate Roof Insulation. April 11, 2013.
[3] RDH Building Engineering. Conventional Roofing Assemblies: Measuring the Thermal Benefits of Light to Dark Roof Membranes and Alternate Insulation Strategies. RDH.com. 2014.

4.3 Results & Discussion

Figure 4.1 provides the measured thermal performance of the field-aged polyiso insulation samples tested, in comparison to that of the lab-aged polyiso insulation samples. Note that the lab aged data reflects samples that were 4 years-old at the time of testing, and the field aged data reflects 6 year-old samples so these results are not directly comparative. Field-aged polyiso experienced a wide range of temperatures, whereas lab-aged polyiso was maintained at 22˚C and it is likely that this difference in conditions may have resulted in a difference in the aged thermal performance. In order to compare the more accurate results from the converging delta-T method with the results from the original ASTM test procedure, a conversion calculation is performed. This calculation iterates to determine the effective thermal performance of an insulation layer when exposed to certain boundary conditions by using the test data from the converging delta-T method to determine the conductivity of infinitesimally thin slices through the insulation.

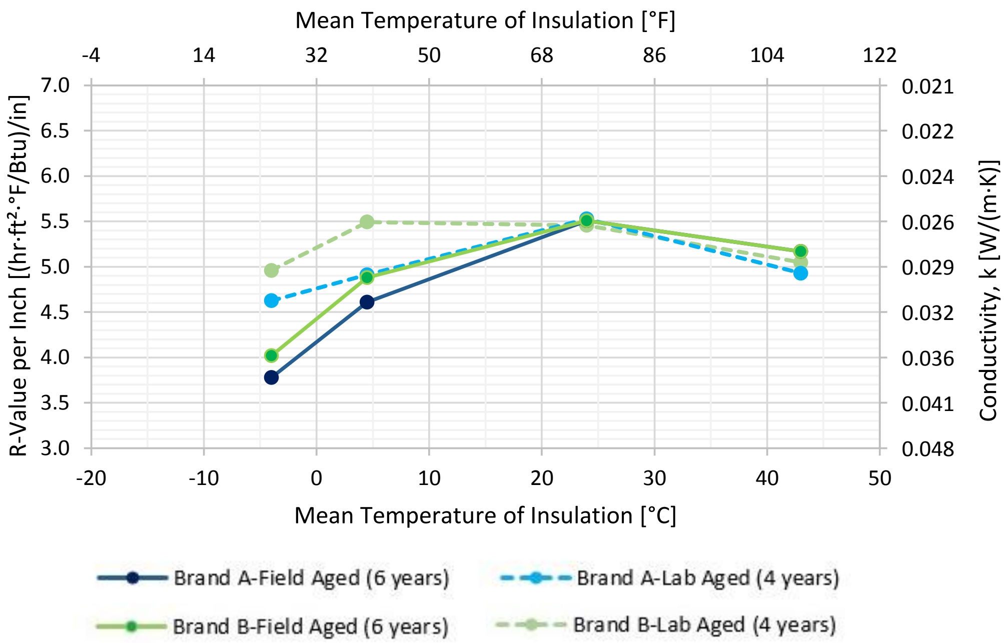


Figure 4.1 Chart of measured polyiso insulation thermal performance at various different temperatures

This testing indicates that the measured thermal performance of both the Brand A and Brand B polyiso insulation is reduced as at higher and lower temperatures as compared to the performance at approximately room temperature (24˚C).

For both Brand A and Brand B, the measured thermal performance of the polyiso insulation was found to be worse (higher conductivity) for the field aged samples than it was for the lab aged. This difference in performance is likely due to the more extreme exposure conditions to which the field aged samples were exposed, including a wider range of temperatures, and faster fluctuations in temperature. It is likely that this exposure worked to off-gas and degrade the polyiso insulation and consequently affected its thermal performance.

This testing also indicated that if polyiso provides optimal thermal performance at approximately 22˚C).

Finally, this testing confirms the LTTR/Quality Mark4 findings that polyiso R-value worsens with age, and suggests that long term thermal resistance should be taken into account when evaluating the thermal performance of roof assemblies using polyiso insulation.

[4] LTTR/Quality Mark Certification Program in accordance with ASTM C1289-11 2014. Polyiso.org. 2014.

5 Conclusion

A field monitoring study was initiated in 2009 to monitor the short and long-term dimensional movement of polyiso insulation installed within a conventional roof assembly. Two brands of polyiso were selected for the study and sensors were installed at key locations to measure dimensional movement, temperature, relative humidity, and moisture content.

After monitoring the roof assemblies for the past 6 years, both types of polyiso have shrunk by varying degrees creating 2-6mm gaps between the majority of the insulation boards. The majority of this shrinkage occurred during the first two years of service. The long-term moisture levels within the roof indicate that the monitored insulation remains dry and does not appear to be a contributing factor in the dimensional movement.

The thermal expansion and contraction of insulation products within conventional roof assemblies has been identified as a potential performance concern in the roofing industry. Not only can this movement potentially create gaps between insulation boards which can create short-circuiting of the insulation with respect to heat flow, but in conventional roof assemblies the insulation also provides the substrate for the roofing membrane, and dimensional changes in the insulation can result in adverse effects on the durability and integrity of the membrane and roofing system. Problems with creasing and ridging of membranes have been observed in the field along with stress concentrations and holes around fixed penetrations.

The thermal conductivity and R-values of lab and field aged insulation samples removed from the roof of the study building was also measured as part of this project. The results demonstrate a temperature dependant curve, similar to other polyiso samples tested, showing poor performance under cold temperatures. An apparent difference between the lab and field aged samples was also observed with field aging within a conventional roof showing increased degradation of the thermal resistance. At a mean insulation temperature of 24°C (industry standard) both lab and field aged samples had an R-value of R-5.5/inch; however; both lab and field aged polyiso R-values were much lower at hotter or colder mean temperatures, and field aged polyiso had a lower R-value at each cold/hot temperature tested than lab aged polyiso.

6 Closure

We trust that this report meets your needs at this time. Please do not hesitate to contact the undersigned with any questions or comments regarding the contents of this report.

Yours truly,

Andrew Stiffman | MBSc, LEED AP
Building Scientist
astiffman@rdh.com
RDH Building Science Inc.

Lorne Ricketts | MASc, EIT
Building Science Engineer (EIT)
lricketts@rdh.com
RDH Building Science Inc.

PROFESSIONAL
PROVINCE OF
G. H. FINCH
36017
BRITISH COLUMBIA
ENGINEER

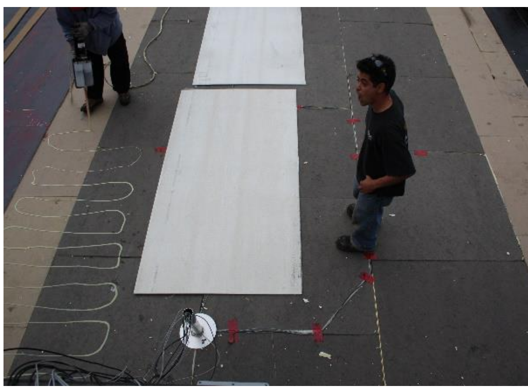
Graham Finch | MASc, P.Eng
Principal, Building Science Research Specialist
gfinch@rdh.com
RDH Building Science Inc.

Appendix

Sensor Installation Photos

Roof assembly constructed up to vapour barrier. Wiring for sensors during installation.

Displacement sensor installed with metal contact plate in polyiso roof insulation. This is typical of how all displacement sensors were installed.

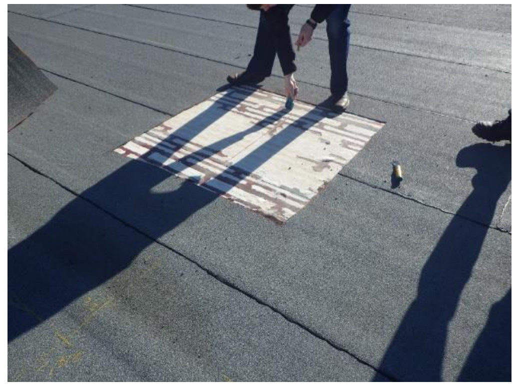


Protection board immediately prior to installation onto exterior surface of polyiso. Note the adhesive being applied.

RH, temperature and moisture sensors installed into polyiso insulation.

Site Visit Photos

Gaps between polyiso insulation boards, ranging from 2mm – 5mm. These measurements generally confirmed the accuracy of displacement sensor readings.

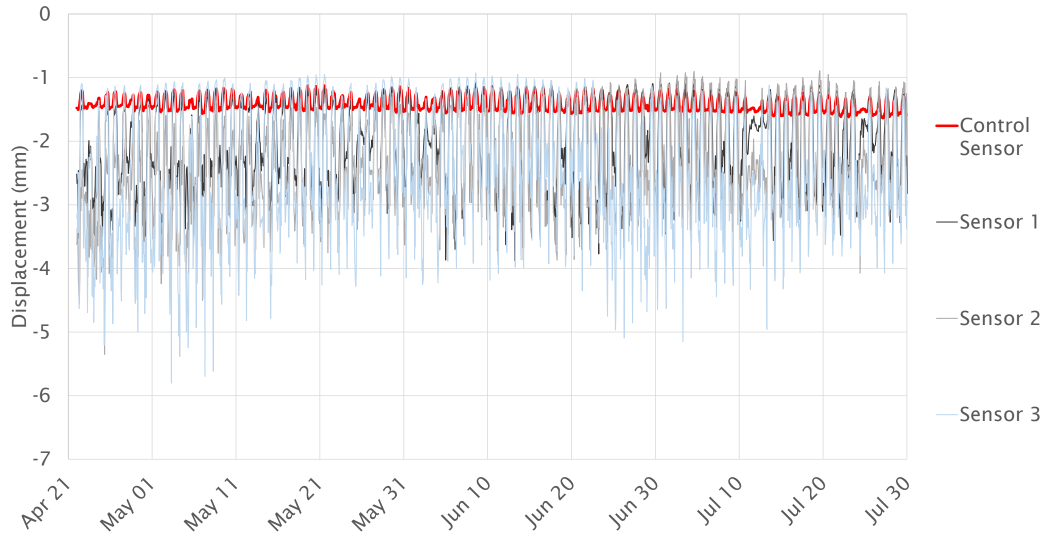


SBS membrane removed in order to observe dimensional change in polyiso as well as its overall condition.

Confirmation of Sensor Consistency

A control displacement sensor with its plunger fixed by a metal plate was also installed within the roof assembly to confirm that the sensor itself is not adversely affected by changes in temperature.

Displacement sensor with plunger restrained by rigid metal plate at consistent position in order to determine the temperature sensitivity of its readings.



Displacement readings of sensors installed in Brand B polyiso in 2015. Note that the red line, Control Sensor, represents the readings from the sensor that was installed with its plunger in a fixed position.

The readings for the control sensor demonstrate reasonably consistent measurements of this sensor (+/- 0.4mm). Some potential causes of this small fluctuation are vibrations across the roof assembly or thermal expansion of the metal restraining plate. The consistency of the control sensor suggests that the displacement sensors are not significantly influenced by temperature and consequently that any measured change in dimension is due change in the gap size between the adjacent polyiso boards.