**Appendix A**

**Sample calculation**

The following section demonstrates a sample calculation for determining percentage of total temperature difference across each insulation layer across the wall (Figure 6) in winter 2017. The maximum thermal gradient across the entire wall occurred between 0:00 – 06:00 AM on December 20, 2011 and the same time frame was used for analysis for the subsequent years. The calculation was performed on the data from 0:00 - 06:00 AM. on November 20, 2016, December 04, 2016, and January 09, 2017. Table A1 below shows the average measured temperatures on the selected time and dates.

Table A1: Maximum, minimum and average temperatures measured across the wall from 0:00 - 6:00 AM on November 20, 2016, December 04, 2016 and January 09, 2017.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Date | Average Measured Temperatures (°C) | | | | | | | | | | | | |
| **T32 - Exterior of Brick** | | | **T34 – Exterior of**  **1st XPS** | | | **T35 – VIP Exterior** | | | | **T36 – Exterior of**  **2nd XPS** | | |
| **Max** | **Min** | **Mean** | **Max** | **Min** | **Mean** | **Max** | **Min** | **Mean** | **Max** | | **Min** | **Mean** |
| Nov.20,2016 | 6.0 | 5.6 | 5.8 | 3.7 | 3.3 | 3.4 | -6.0 | -6.6 | -6.4 | -8.9 | | -9.7 | -9.3 |
| Dec.04, 2016 | 7.5 | 7.2 | 7.3 | 4.3 | 4.0 | 4.1 | -8.8 | -9.1 | -9.0 | -12.7 | | -13.1 | -12.8 |
| Jan. 09, 2017 | -3.0 | -3.5 | -3.3 | -6.0 | -6.6 | -6.3 | -18.2 | -19.2 | -18.7 | -21.8 | | -23.3 | -22.6 |

Temperature drop calculation for January 09, 2017 are shown below, the mean temperatures were used in the calculation:

∆TXPS1 = T32 – T34 = 3.0°C

∆TVIP = T34 – T35 = 12.4°C

∆TXPS2 = T35 – T36 = 3.9°C

∆TTOTAL = T32 – T36 = 19.3°C

%∆TXPS1 = ∆TXPS1/∆TTOTAL x 100% = 15.9%

%∆TVIP = ∆TVIP/∆TTOTAL x 100% = 64.2%

%∆TXPS2 = ∆TXPS2/∆TTOTAL x 100% = 19.9%

Table A2 below shows the calculated temperature drop for selected time and dates, as well as the average of the three.

Table A2. Percentage of temperature drop across each insulation layer and the winter 2017 average.

|  |  |  |  |
| --- | --- | --- | --- |
| Date | % of Temperature Drop Across Each Insulation Layer | | |
| **First XPS** | **VIP** | **Second XPS** |
| November 20, 2016 | 15.7% | 65.0% | 19.3% |
| December 04, 2016 | 15.8% | 65.0% | 19.2% |
| January 09, 2017 | 15.9% | 64.2% | 19.9% |
| Average | 15.8% | 64.7% | 19.5% |

It is to be noted that the exterior insulation layer includes 25 mm XPS and 6 mm flexible open-cell polyurethane foam. The thermal resistance offered by the 6 mm flexible open-cell polyurethane foam is negligible and was ignored in the calculations shown above. However, assuming the 6 mm flexible open-cell polyurethane foam contributed some thermal resistance, either 0.09 or 0.18 m2.K/W, the corresponding actual temperature drop across the exterior XPS (thermal resistance 0.97 or 1.06 m2.K/W) for Winter 2017 is calculated using the following equations respectively:

%∆TXPS2’ = %∆TXPS2 x (thermal resistance of XPS/ (total thermal resistance of XPS and foam)) = 19.5% x (0.88/0.97) =17.7 %

%∆TXPS2’’ = %∆TXPS2 x (thermal resistance of XPS/ (total thermal resistance of XPS and foam)) = 19.5% x (0.88/1.06) = 16.2%

Where %∆TXPS2’ is the percentage of the temperature drop across the exterior XPS assuming the thermal resistance of the 6 mm foam is 0.09 m2.K/W .

%∆TXPS2’’ is the percentage of the temperature drop across the exterior XPS assuming the thermal resistance of the 6 mm foam is 0.18 m2.K/W.

The temperature drop across wall components taking account of the thermal resistance contribution of the 6 mm foam (0.09 m2.K/W or 0.18 m2.K/W) are graphed in Figure A1 and A2 respectively. It is clear that the temperature drops across the exterior XPS are higher than the interior XPS in both scenarios, therefore, the exterior layer of XPS is a more effective thermal insulator than the identical interior XPS layer due to the cooler exterior temperature.

Figure A1 - Percentage of temperature drop across wall components (assume the thermal resistance of the 6 mm foam is 0.09 m2.K/W), relative to the drop across the entire wall. Data averaged for the winter months of 2012 - 2017 and spring months of 2018.

Figure A2 - Percentage of temperature drop across wall components (assume the thermal resistance of the 6 mm foam is 0.18 m2.K/W), relative to the drop across the entire wall. Data averaged for the winter months of 2011-2017 and spring months of 2018.