Development of Infiltration Modeling Parameters for a SIPs Building

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Abstract
Reduction of infiltration in the Equinox House, a residence under construction in Urbana Illinois, has been characterized through a series of blower tests as different joints and seams in the building were sealed. Equinox House is constructed with 30 cm thick SIPs (Structural Insulation Panels) wall and roof panels consisting of a Styrofoam core and oriented strand board sheathing on interior and exterior surfaces. Blower door tests were performed as each type of seam in the house was sealed. Wall to foundation connections, wall to roof connections, panel to panel connections, and miscellaneous gaps were examined. The effect of adding wall surfaces (drywall) to the building are also presented. The results show strong correlations between level of infiltration and the amount of labor and the amount of sealant used to lower the infiltration. The house infiltration was reduced to 0.37 ACH at 50 Pa. The correlation parameters, while specific to this type of construction, demonstrate how costs related to infiltration reduction can be formulated and utilized for optimal building design analyses.

Keywords superinsulated, supersealed, infiltration, ventilation, ach

Introduction

Uncontrolled infiltration is undesirable for many reasons. In almost any climate requiring air conditioning and/or space heating, uncontrolled infiltration impacts energy requirements. In the US, where typical residential construction methods result in significant uncontrolled infiltration, the "fresh" air entering the house does so through cracks such as sill plates, window jambs, door frames, flue vents and utility penetrations which are often regions containing dirt, moisture, mold, mildew, and vermin. Additionally, relying on uncontrolled infiltration for fresh air leads to stagnated regions within the residence where air is not purged, creating local regions of poor air quality.

Equinox House is a super-insulated, super-sealed residence recently constructed in Urbana, Illinois. Urbana Illinois is a region with hot, humid summers and cold winters. Figure 1 is a recent picture of Equinox House undergoing placement of exterior siding. After all wall and roof panels were installed, a series of blower door infiltration tests were conducted as silicone caulk was applied to all wall and roof panel seams. The effect of the sealing process and the cost related to the sealant and labor are presented in this paper. The goal was to reach an ACH (air change per hour) less than 0.6 in accordance with Passive House design standards before adding drywall to the interior of the house. The house construction process, sealing and infiltration measurement results, and the cost impact of the sealing effort are described.

Equinox Construction Methods

Equinox is a single story "ranch" type residence with 195 m^2 of indoor floor area and 54 m^2 of attached car garage. Due to the high ceilings, the interior, conditioned volume of the house is 790 m^3. The floor is concrete "slab-on-grade" construction with no insulation placed beneath. In Illinois, an uninsulated floor is generally more economical for maintaining comfort than an insulated slab floor.

The foundation wall surrounding the house was constructed with ICF (Insulated Concrete Form) block which has 7cm of expanded Styrofoam on the exterior and interior sides of the ICF.

Figure 2 is a photo of the ICF being placed around the building perimeter. Reinforced concrete, 15.2 cm thick, is poured between the Styrofoam sides of the ICF block, as shown in Figure 3.

Two layers of treated lumber 31 cm wide by 1.9 cm thick was bolted to the top of the concrete foundation wall, forming the base for the wall panels. Untreated lumber 29.2 cm wide and 3.8 cm thick was screwed and nailed onto the sillplate lumber. SIPs (Structural Insulated Panels) were placed on top of the sillplate lumber. A channel milled into the bottom edge of the SIPs wall panels fit over the 29.2 cm by 3.8 cm lumber, allowing nails to attach the wall panel to the sill. Figure 4 shows the installation of the first SIPs wall panel on the sill.

Figure 5 shows continued placement of SIPs wall panels and Figure 6 shows the last roof SIPs panel being placed on the house. The SIPs can be up to 2.4 meters wide by 7.3 m long with a thickness of 31.4 cm including the two layers of OSB (1.11 cm per OSB layer) and 29.2 cm of Styrofoam. Between each wall panel and each roof panel is a Styrofoam spline with an OSB layer glued on its outside layer. The spline is 7.6 cm thick and plugs into the 3.8 cm deep channels milled into the edge of each SIPs panel. Ringshanked nails are driven on each side of the panel seams into the spline to fix the walls and roof together. The walls and roof of the house required 5 days with approximately 6 to 7 laborers to erect. This consisted of two days to erect the house walls, one day to construct internal structural framing for the roof, and two days to install the roof panels.

During erection of the wall and roof panels, a line of urethane foam sealant was placed between each panel seam, and the splines were coated with a bead of panel adhesive. Generally, these steps should provide a high level of sealing for the house shell, however the construction of Equinox occurred in December, 2009 during wet, freezing weather, causing difficulties in applying the foam and panel adhesive. Therefore, one might find that the level of performance improvement due to additional panel sealing activities discussed in this paper may not yield the same level of performance improvement in SIPs homes installed under better construction conditions.

Infiltration Tests

Six series of infiltration tests were conducted with a Minneapolis Blower Door operated at 50 Pa. The tests were conducted over from March 2010 to June 2010. The first five test series consisted of several tests in which the amount of caulk, the time required to apply the amount of caulk to panel seams of a measured length, and the change of air changes at 50 Pa (ACH50) were measured. The sixth blower door test was conducted after drywall was applied to all interior wall and ceiling surfaces.

Figure 8 shows the change of ACH50 as a function of panel seam length. On average, leakage dropped 0.0067 ACH50 per meter of panel seam length. Some panel seams did show variations in the amount of leakiness. For example, the first 60 meters of seam sealing was the sillplate seam around the perimeter of the house. The sillplate seam shows 0.01 ACH50 reduction per meter of seam length, which is due to some waviness between the layers of wood in the sill plate and the connection to the bottom of the SIPs wall panels. The vertical seams between wall panels with the spline connections have a change of 0.0046 ACH50 per meter length, and are the data series from 60 meters to 200 meters in Figure 8. The additional seams consist of the wall to roof panel seams, and the roof to roof panel seams. The relatively "flat" regions of the Figure 8 plot at 150 meters, 250 meters, and 350 meters are locations represented by a region of roof panel seams, window perimeter seams, and door perimeter seams that did not display significant leakiness. The roof panel seams were between three panels that apparently had less leakiness than other panel seams. Possibly, the weather was somewhat better than the other construction periods and the foam sealant did a better job during that time. The windows and doors were foam sealed when installed, and these seals were relatively good. The last data point shown in Figure 8 represents the last blower door test performed after drywall was added. The drywall did reduce the infiltration, and most likely the effect of cladding the interior with drywall would have been more significant if the extensive panel seam sealing had not been performed. While this may have saved some cost, the danger of not sealing the panel seams is that moisture can move into various isolated regions of the panel seams and create rot at some time in the future.

Figure 9 shows the amount of silicone caulk applied to the panels seams, expressed in terms of tubes of caulk. A tube of caulk contains 0.283 kg of silicone caulk. The sillplate seam required 0.5 tubes of caulk per meter of seam, which as discussed previously consisted of multiple seams due to the multiple layers of wood that the wall panels are mounted on. The rest of the seams required approximately 0.18 tubes of caulk per meter of panel seam. Figure 10 shows the labor hours as a function of panel seam length. The sillplate seam required 0.1 hours of labor per meter of seam length while the other seams required approximately 0.04 hours of labor per meter of seam.

Impact of Panel Sealing Effort

The cost related to the sealing effort can be quantified in order to determine the payback of the sealing effort. For central Illinois, the cooling and heating seasons consist of 3900 C-day. On a simple basis, assuming that the infiltration under normal conditions can be estimated as ACH50 divided by 20, the uncontrolled house infiltration has been reduced from 120 m^3 per hour to 15 m^3 per hour. This represents a reduction of 3300 kW-hr of sensible thermal energy conditioning, which with a heat pump having a coefficient of performance of 3 represents a reduction of 1100 kW-hr of electric energy. With a value of $0.12 US per kW-hr, the savings is $130 per year.

The silicone caulk costs $4 US per tube for a total of $300 US for 75 tubes of caulk. Construction labor for caulking is valued at $20 US per hour, with a total cost of $340 for 17 hours of labor. The total sealing cost of $640 for caulk and labor therefore results in a simple payback of 5 years.

Summary

This study provides quantitative data related to the effort and cost of super sealing a residence in the US. Although the data are for one house of one particular design, the results show that the effort expended on sealing a house prior to installing the interior finishes can be quantified and that the payback for sealing the house are favorable. Several questions remain to be answered. Several houses of any type of construction should be evaluated for a better statistical measure of sealing effort and costs. Improved construction practices may help reduce the cost associated

with sealing effort and cost. Finally, the durability of a sealing method needs to be examined in order to know whether the effort has a lasting effect or is only effective for a period of time less than the lifetime of the home.

Figure 1 Photo of the Equinox House in Urbana Illinois in May 2010.

Figure 2 ICF (Insulated Concrete Form) foundation wall used for Equinox perimeter.

Figure 3 Concrete poured in ICF foundation wall.


Figure 4 Placement of the first SIPs wall panel on the foundation wall sill plate.

Figure 5 Continued placement of SIPs wall panels around the house perimeter.


Figure 6 Installation of SIPs roof panels on Equinox.

Figure 7 Completed SIPs panel installation with house wrap and windows installed.

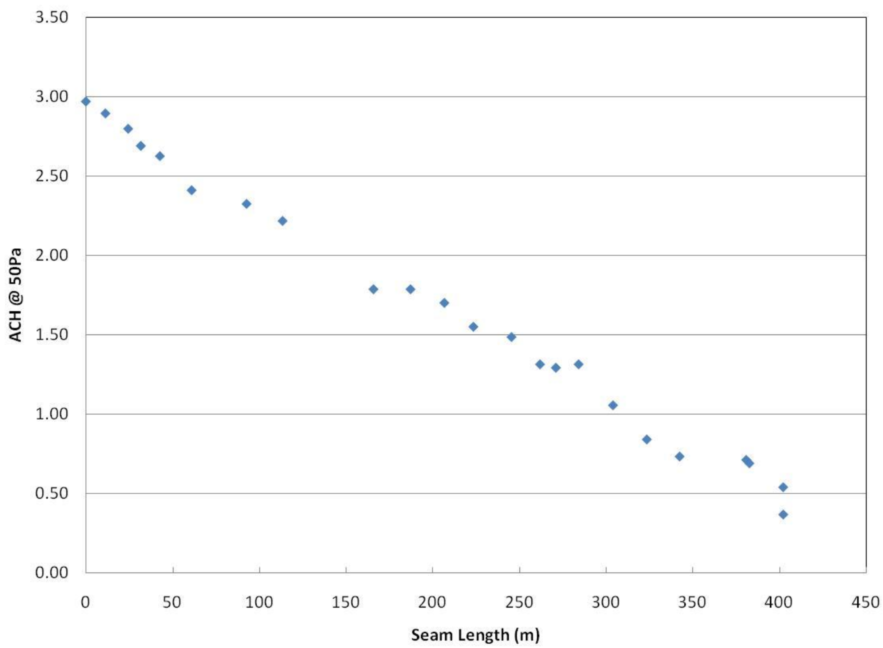

Figure 8 Reduction in infiltration (air changes per hour) as a function of panel seam length.

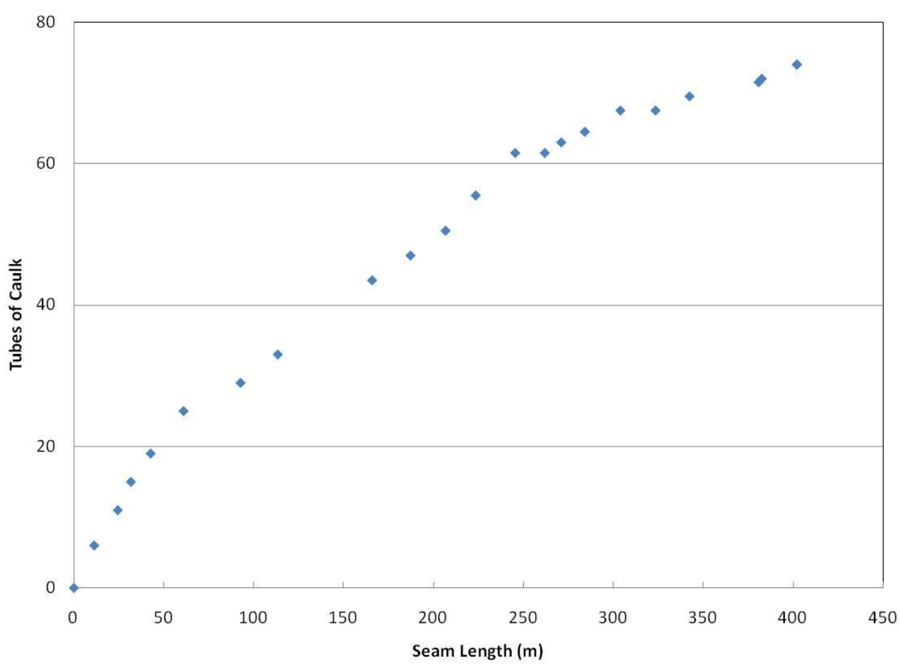

Figure 9 Tubes of silicone caulk (x grams per tube) as a function of panel seam length.

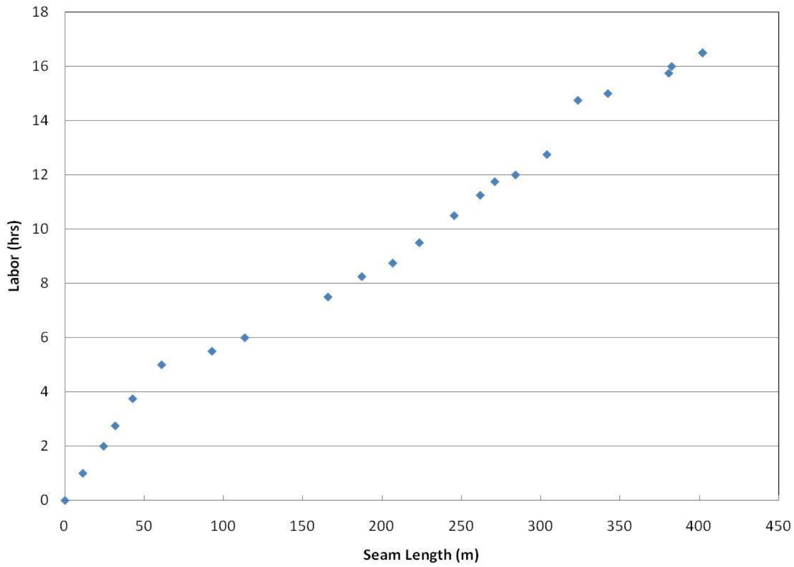

Figure 10 Hours of labor required for sealing panel seams as a function of seam length.