White Paper

Using Infrared Thermography of Existing Masonry Walls to Target Retrofit Efforts and Lessons for Future Additions

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04 January 2013
Overview

Infrared thermography (IRT), also known as thermal imaging, is a quick, non-contact and non-destructive method for mapping the surface temperature of building elements. These temperature mappings can reveal anomalies, such as thermal bridges, moisture condensation or air infiltration, that have a negative impact on building energy performance, material longevity and occupant comfort. In a partnership between Portland State University and BOORA Architects, the authors used IRT to study the variety of existing masonry wall and roof assemblies at a Central Catholic High School (CCHS) in Portland, Oregon to identify potential areas of concern that could be addressed in upcoming remodeling efforts and with the addition of a new wing in 2013. As a relatively urban high school, CCHS is a single, two-story building that has already undergone ten distinct additions increasing the square footage of the original 1938 building by a factor of eight. Each addition has used different wall and roof assemblies with brick masonry as the most common exterior material. This paper will highlight the results of the IRT study and its impact on the remodeling efforts. In particular, uninsulated basement walls and the seams between additions showed significant heat loss during the IRT study. This project provides important lessons for future additions and energy retrofits of similar existing buildings.

Personnel

Corey Griffin and Heather McWilliams from the Department of Architecture at Portland State University were responsible for collecting measurements, analyzing the images and writing this report. Abby Dacey of BOORA architects acted as liaison between the researchers and Central Catholic High School, providing background information on the existing buildings. Students from Central Catholic were invited to participate in taking measurements. Unfortunately, due to the unpredictable weather during November and December 2011, measurements need to be taken with little advanced notice and student participation was minimal.

Data collection

Measurement were taken under relatively ideal conditions. The greater the air temperature differential between interior and exterior the more apparent any thermal anomalies will be. Consequently, measurements were taken during the morning hours between 9 and 11 am after the heating system has been operating during the later fall/early winter on November 4, 2011 as well as December 5 and 6, 2011. The outdoor air temperature on November 4 was 42 °F. It was 32 °F and 34 °F on December 5 and 6 respectively. Morning was the best time to gain access to the interior and exterior of the building as classes were in session. Measurements were taken during a cloudy day or night to avoid interference from incident solar radiation (direct sunlight) heating exterior surfaces. Measurements cannot be taken in the rain as it can scatter the infrared radiation between the exterior surface and the detector. Due to an unusually rainy November, it took over a month to find three different occasions that met the minimum standard for taking useful IRT measurements.
One of the goals of these IRT measurements was to confirm the construction assemblies of the ten additions and the original 1938 building. BOORA provide a plan with the assumed structural systems (figure 1.1). The IRT images were able to confirm the original 1938 building is wood framed, as heat loss through studs is visible (figure 1.2). The IRT images contradict the assumptions made about the 1991 theater addition. The heat loss through steel studs is clearly visible in IRT images from the interior of this space (figure 1.3). It is a better assumption that this addition consists of light gage steel studs and not masonry. IRT images were not able to confirm the construction of the 1946 addition, as it was difficult to gain access to these classrooms. Measurements were not able to be taken on the roof due to lack of access, but this might not have yielded any insights into the roof structure due to insulation.

Heat Loss

There are two primary locations for heat loss in the existing buildings, seams between additions and foundation walls. As seen in figures 2.1 through 2.5, many of the seams between additions showed signs of heat loss. This heat loss could be due to a lack of insulation at these connections, infiltration or a combination of both. It is difficult to assess the primary cause without disrupting the normal
operation of the mechanical systems. The cause of heat loss at the foundation or basement walls found along most of the perimeter is more clear: a lack of insulation. Figures 3.1 though 3.5 highlight the range of uninsulated walls across the CCHS campus. Even if spaces in this lower level are not occupied as classrooms, there is still significant heat loss from the building through these walls.

There are two secondary areas of concern for heat loss at CCHS. The first is the construction of the 1991 theater addition. It uses steel studs for the walls and uninsulated doors (figures 4.1 and 4.2). Both of these are significant thermal bridges as it appears there is no continuous, external insulation on this addition. The final areas of concern are the walls of the 2002 addition (figure 4.3). There are areas of heat loss located near the ceiling line that could correspond to areas where batt insulation has fallen in the wall cavity or an under-insulated section of the wall in general. These hot spots could also indicate locations where warm interior air is penetrating the wall cavity. If this is the case, there could be a potential for condensation in these walls. As noted in figure 2.4, there are also concerns about heat loss around the elevator shaft that is also a part of this 2002 addition.

Conclusions and Recommendations

One of the primary sources of heat loss that should be addressed in any retrofit of the existing CCHS buildings are the uninsulated foundation or basement walls. It should be relatively easy to add insulation to the interior of these walls and significantly reduce heat loss. Here is a link to a recent article on insulation retrofits for concrete basement walls: http://www.greenbuildingadvisor.com/blogs/dept/musings/how-insulate-basement-wall. While this article pertains mainly to residential basements, the findings and recommendations are applicable to this project. Adding continuous, rigid insulation to the 1991 theater addition would reduce its heat loss as well as replacing the uninsulated doors which also show signs of infiltration around the perimeter. Better seals and weather-stripping for all doors are recommended.
Two major sources of heat loss not discussed in this paper include the windows and roofs of all buildings. Many windows at CCHS were found to have air conditioning units inserted in them during the winter. These were the sources of the greatest heat loss in the building envelope. Any single paned windows should be replaced as the windows showed as much heat loss as the uninsulated foundation walls. The window frames also showed significant heat loss. As we were not able to gain access to the roof for these measurements, it is unclear how much heat is currently being lost through the roof. It could be a source of significant heat loss depending on how each addition was constructed.

In terms of future additions, care should be given to the design of the seam between the addition and existing buildings. This study has shown this a source of heat loss in the existing CCHS campus.
figure 2.1 - Heat loss at seam between 1991 theater addition and classroom wing.

figure 2.2 - Heat loss at seam between 1946 additions.

figure 2.3 - Heat loss at seam between 1940 classroom wing and 2002 addition. Also note the heat loss near the ceiling line in the 2002 addition.
figure 2.4 - Heat loss at seam between elevator shaft and 2002 addition. Also note heat loss from space attached to elevator shaft.

figure 2.5 - Heat loss at seam between 1946 additions.
figure 3.1 - Heat loss at uninsulated foundation walls.

figure 3.2 - Heat loss at uninsulated foundation walls. Also note “hot spots” in brick walls below windows. These are the location of heating units in the classrooms. Some heat is being directly lost through the walls to the exterior.

figure 3.3 - Heat loss at uninsulated foundation. Note that uninsulated concrete from 1940 addition shows the same value of heat loss as glass. Header over new doors added as part of 2002 addition is insulated.
figure 3.4 - Heat loss at uninsulated foundation/basement walls.

figure 3.5 - Heat loss at uninsulated foundation/basement walls. Also note the greater heat loss at corners. This is not a seam between two different additions, but it is still a source of heat loss.
figure 4.1 - Walls of 1991 theater addition are steel stud walls. These are interior photos so stud location will be cooler than the rest of the wall. Doors in this addition are not insulated.

figure 4.2 - Heat loss at uninsulated doors in 1991 theater addition.

figure 4.3 - Unusual heat loss near the ceiling line in the 2002 addition. One potential cause is insulation falling in between steel studs.