

BUILDING FOR ENERGY EFFICIENCY

Thermal imaging of post frame and other construction methods

This article is based upon a May 2010 report prepared for the National Frame Building Association by Double G Consulting (the complete report may be found at nfba.org/technicalarticles). The purpose of this study was to illustrate points of heat transfer in different building types using thermographic images. Builders and design professionals familiar with post-frame buildings know these buildings use fewer structural components to create an exceptionally economical, energy-efficient and environmentally friendly building because fewer structural members are needed, which creates wide spaces between posts with fewer breaks in insulation, and that wood has natural insulating properties compared to steel or masonry structural components. Post-frame construction is therefore believed to reduce some of the heat transfer observed in other construction methods because of wider insulation cavities and less thermal bridging. To illustrate these concepts, thermal images that provide visual examples of heat transfer were captured. The images highlight inefficiencies that may be caused by thermal bridging effects of nonwood structural components, compressed insulation and interruptions in contiguous insulation. Some of the examples could be improved with additional measures, which would further distinguish their construction costs compared to those for post frame, but the images are not to be taken as typical of all buildings of the types presented. Differences in building construction and quality can influence the energy efficiency of any building.

In 2010, the National Frame Building Association retained Double G Consulting to take thermal images and measure air infiltration in commercial buildings of different construction types. Specifically, the NFBA proposal specified that Double G inspect commercial buildings with the following construction types: post-frame building, wood stud-framed building, masonry building and steel-framed building.

This was a qualitative analysis of a relatively small sample of buildings, not a scientific comparison of different building types. The focus was on commercial facilities. In return for access to their building, participating owners received an individual report with a building analysis and recommendations of steps that could be taken to make their building more energy-efficient.

THERMOGRAMS

When viewing thermograms, realize that the colors themselves are not as important as the range of color; typically the wider the range of color, the greater the surface temperature differences of the captured objects. For example, the left image in Figure 1 is of a wall just after a hand had been pressed against it for a few seconds. The right image in Figure 1 is of an exposed flame on a gas range and shows a much broader spectrum of color when one compares the range of colors to the range of colors in the bar to the right of the image.

It is important to note that a given color does not correspond to the same surface temperature in two different images. For example, in Figure 1 the area surrounding the flame is roughly the same color as the wall in the opposite image despite obviously being very dif-

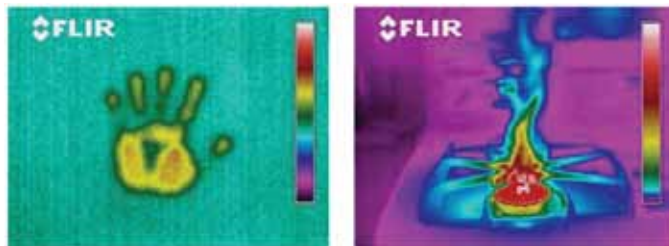


Figure 1. Thermograms of a wall just after a hand had been pressed against it (left) and an exposed flame on a gas range (right).

ferent in temperature. Blue is not always what one perceives as cold, and orange is not always what one perceives as hot; blue is simply colder, and orange is simply hotter than the median temperature of objects captured in the image.

Surface temperature variations that appear in thermograms of building envelopes can be due to variations in the thermal conductivity (or thermal resistance) of materials, and/or air movement (and hence heat transfer by convection). Other sources of variations include reflective surfaces and wet surfaces. Air movement through a thermal envelope is called air infiltration when the air moves from outside to inside, or air exfiltration when the air moves from inside to outside.

It is important to realize that thermal imaging cannot be used to quantify heat transfer. Thus, although a thermogram may indicate a region of elevated heat gain or heat loss, it cannot be used to determine the actual amount of the elevated heat gain or heat loss. Thermal imaging is often used to identify problem areas for further study.

EXAMPLE OF A POST-FRAME BUILDING

An image of the post-frame building investigated as part of the NFBA thermal



Figure 2. Post-frame building involved in thermal envelope study.

envelope study is shown in **Figure 2**. This structure was a mixed-use facility (office and commercial retail) with R-19 fiberglass insulation in the walls, R-38 cellulose insulation in the ceiling, and R-8.1 polystyrene insulation encasing the perimeter of the foundation.

The post-frame building's blower door test measured 4,700 cubic feet per minute of leakage at 50 pascals of differential pressure. This infiltration appeared to occur at electrical and plumbing penetrations, a problem that can be investigated (and subsequently resolved) with minor measures taken prior to completion of construction. Differential surface temperatures may also indicate higher heat-transfer rates where insulation is interrupted by posts or laminated wood columns and at floor-to-wall junctures, or thermal bridging.

Figures 3, 4, and 5 are images taken inside the post-frame building. Figures 3 and 4 are typical exterior wall images. The temperature of the receptacle in **Figure 3** is very near that of the surrounding area, which indicates that the receptacle is not associated with a change in temperature due to air infiltration and/or a reduced thermal resistance. Similarly, the thermogram in **Figure 4** shows uniform temperatures along the wall surface.

Figure 5 shows a region above the suspended ceiling. Although there are no signs of air infiltration or exfiltration at seams between corrugated steel panels, a spot on the electric conduit does register a colder temperature than the surroundings. Thermal bridging may be caused by a steel electrical box, bracket or screw.

EXAMPLE OF A STEEL-FRAME BUILDING

An image of the low-rise steel-frame building investigated as part of the NFBA thermal envelope study is shown in **Figure 6**. This facility housed a news publishing business and featured R-19 fiberglass insulation in the walls and R-19 fiberglass insulation in the ceiling. The perimeter of the foundation was not insulated. This was a massive building combined with major air leakage points; it was not possible to depressurize the building.

As shown in **Figures 7–10**, significant variations in thermal envelope heat transfer likely due to heat transfer were observed in this building, particularly at eave struts, roof purlins and columns. These variations were due primarily to compression of the fiberglass insulation at these framing members. When viewing the thermograms in **Figures 7, 8 and 9**, note the varia-



Figure 3. Thermogram indicates no abnormal heat transfer at the receptacle.



Figure 4. Typical exterior wall. Thermogram indicates no abnormal heat transfer.



Figure 5. Cavity above suspended ceiling. Although no signs of air infiltration or exfiltration at panel seams appear, a spot on the electric conduit does register a colder temperature than that of the surroundings.



Figure 6. Rear view of low-rise steel-frame building involved in thermal envelope study.

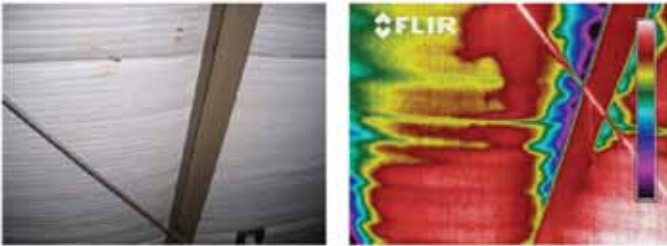


Figure 7. Thermogram of a single roof purlin shows increasing drop in surface temperature as thickness of insulation decreases near purlin.



Figure 8. Thermogram shows similar temperature profiles for adjacent purlins.



Figure 9. Image shows lowest temperatures occurring where insulation is compressed by eave strut. Exterior corners in all buildings are generally associated with greater heat loss per unit area.



Figure 10. Covering around each steel column showed a similar temperature profile, a pattern indicating elevated heat transfer at column locations.



Figure 11. Masonry building involved in thermal envelope study.

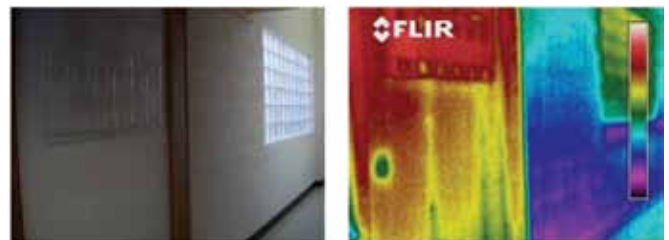


Figure 12. Images of the transition between the insulated and non-insulated concrete block walls in the masonry building.

tion in the temperature across each steel framing member. Inside flanges have temperatures closer to the building's interior temperature, while the flanges in contact with the compressed insulation have measurably lower temperatures.

During the analysis of the steel-frame building, lower surface temperatures were located near base plates, indicating higher heat transfer due to the lack of foundation perimeter insulation in this particular building.

EXAMPLE OF A MASONRY BUILDING

An image of the masonry building investigated as part of the NFBA thermal envelope study is shown in **Figure 11**. This structure was a utility facility. The front office portion featured concrete block furred out with 2x2 lumber and insulated with R-5.8 fiberglass batts. The rear portion of the structure was untreated concrete block ($R = \sim 1.0$). Ceilings were insulated with R-19 fiberglass batts. There was no foundation insulation.

The thermogram in **Figure 12** is as definitive as you will find in thermal imaging. In this case, it shows the difference a small amount of wall insulation can make, as well as elevated heat transfer near an uninsulated foundation. The thermogram in **Figure 12** also shows the interior surface of the glass block and mortar between the glass block to be at a higher temperature than the surrounding concrete block. This is most likely due to transmittance of solar radiation through the glass block.



Figure 13. Wood stud-framed building involved in thermal envelope study.



Figure 14. Air infiltration into a wall cavity during blower door testing.



Figure 15. Thermogram shows lower surface temperatures in areas backed by wood studs.

EXAMPLE OF A WOOD STUD-FRAME BUILDING

An image of the wood stud-framed building investigated as part of the NFBA thermal envelope study is shown in **Figure 13**. This structure was a restaurant with 4,125 square feet of conditioned space and featured walls with R-11 fiberglass batt insulation and ceilings with R-38 cellulose insulation. The foundation perimeter was not insulated.

The wood stud-framed building was relatively leaky, with a measured infiltration of 10,300 cubic feet per minute at 50 pascals of differential pressure. Blower door testing revealed measurable air infiltration at bottom and top plates, as well as air exchange between wall cavities and the adjacent attic zone as a result of electrical and other penetrations through the framing (see **Figure 14**). These penetrations can be resolved with appropriate measures.

The most significant air leakage in the wood-stud building was at the ceiling, as evidenced by the lower temperatures

around the suspended ceiling grid in **Figure 14**.

As shown in **Figure 15**, the stud-wall building showed reduced thermal resistance at wall studs, indicated by the streaking color in the wall. Depending on the size of framing used for a wall (2x4, 2x6, etc.) and the spacing of the studs, the heat loss through framing can vary from 33 percent to 49 percent of the total (Seifert, n.d.).

SUMMARY AND CONCLUSIONS

Four buildings with different framing were subjected to thermal imaging analysis. The results of this investigation showcase how thermal imaging can be used to identify locations of elevated heat gain or heat loss and how the combination of thermal imaging and blower door tests can be used to pinpoint locations of air infiltration or exfiltration.

This study underscored the importance of sealing cracks or spaces between framing materials in a buildings thermal envelope and showed both the measurable difference a small amount of insulation can make and the impact of compressing fiberglass insulation.

Finally, this study showed that a uniformly insulated thermal envelope is readily achievable with post-frame construction. There are fewer breaks in insulation where bridging may occur compared to stud-framed structures. Wood structural components do not conduct heat as readily as steel or masonry structural components. Wood posts and heavy trusses used for post-frame require fewer structural materials to be installed, so fewer materials are required. The primary building materials are renewable wood structural components and recyclable steel or other types of cladding. The thermograms help illustrate where thermal bridging may occur. Given these factors and the comparatively low cost of post-frame buildings, post-frame construction may be among the most cost-effective ways to build for sustainability and energy efficiency.

John Fullerton is president of Heartland Perma-Column, Baldwin City, KS. He may be reached at 785.594.5696 or info@heartlandpermacolumn.com. This article is based upon a 2010 report prepared for the National Frame Building Association by Double G Consulting of Madison, WI.

REFERENCES

Seifert, R. D. (n.d.). "Effects of studs on heat loss and insulation value of walls." New York: Active Zero-Energy Innovations. Retrieved from <http://activezeroenergy.mobi/?p=63>.