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# Infrared Imaging as a Means of Analyzing and Improving Energy Efficiency of Building Envelopes: The case of a LEED Gold Building.

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**Abstract**

Today many designers claim that they are engineering green or LEED certified buildings. LEED is an evaluation system that rates how sensitive buildings are to the environment and the objective of LEED is to reduce emissions through development of highly efficient mechanical systems, designing of durable and efficient wall systems and by providing additional thickness to insulation. Unfortunately currently there are many cases where these wall systems and insulations are supported by thin steel studs, which are highly conductive of energy and are 400 times more conductive than wood.

The aim of this paper is to investigate the use of thermal bridging in a LEED certified building. Thermal bridging is a major source of heat loss through studs and wall systems in many buildings worldwide. The investigated building is Gold certified building built in 2011 located in Toronto, Canada. The exterior walls consist of a copper and brick cladding and steel studs. Using thermal imaging, as a non-destructive testing method, this research investigates and identifies the location of thermal bridging. This study recommends how to integrate infrared imaging into the LEED certification process and how to improve the future design of efficient wall systems.


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*Keywords:* LEED building, thermal imaging, thermal bridging, efficient building envelope

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## 1. Introduction

Today many designers claim that they are delivering green buildings or LEED certified buildings. LEED is an evaluating system that rate how buildings are sensitive to the environment and the objectives of these green buildings are to cut the greenhouse gases by installing high efficient mechanical systems, designing durable and efficient wall systems by providing additional thicknesses to insulations. Unfortunately, in most cases these wall systems and insulations are supported by thin steel studs which are highly conductive of energy and are 400 times more conductive than wood [1]. The aim of this paper is to investigate thermal bridging in a LEED Gold certified building (Fig. 1), which is a major source of heat loss through studs and wall systems. The investigated exterior wall consists of copper, brick cladding and steel studs (Fig. 1 and Fig. 2). Using thermal imaging as a non-destructive testing method, this research investigates and identifies the location of thermal bridging.

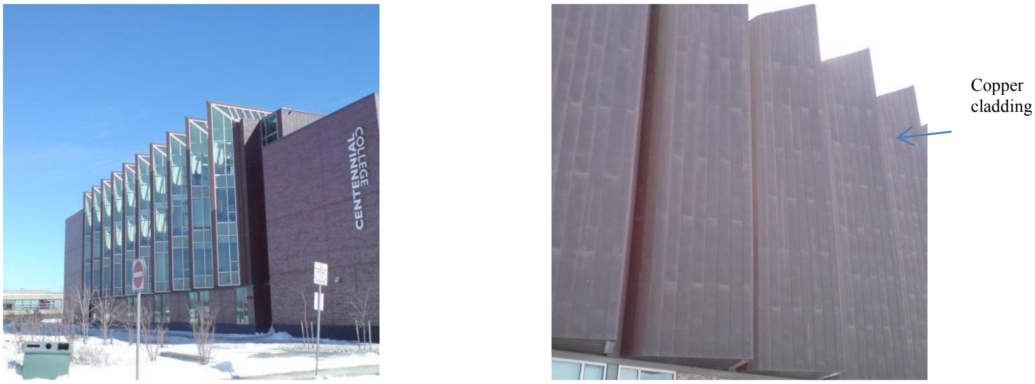


Fig 1- (a) Investigted building, Northern Elevation (b) Copper cladding on the Northern part of the building

## 2. High efficient buildings (LEED) and Carbon reduction

Buildings consume 30% to 40% of all primary energy worldwide and are responsible for 50% of total emissions [2]. Green buildings are becoming an important aspect in the construction industry. As a result of this shift the construction industry is seeing a large surge in green building programs and initiatives especially throughout developed countries. Owners and Investors are learning about the advantages of green building and construction related material manufactures are becoming more aware about environmental benefits of their products. Builders are adapting to new techniques and technologies that purport to reduce environmental impact. Lenders, insurers, municipalities, code officials and design professionals are reinterpreting their roles in terms of green design objectives. Green buildings are the forerunner of sustainable development in this era; by focusing on social, economic, and environmental balance of sustainability [3, 4].

Green buildings have the potential to create environmentally efficient buildings by incorporating an integrated approach of design in order to reduce the negative impact of building on the environment and occupants. Additionally rating system like LEED offer an effective framework for assessing building environmental performance and integrating sustainable development into building and construction processes; as it can also be used as a tool for designing sustainable design strategies and decision-making processes [4, 5]. Furthermore, LEED also reduces operating and maintenance costs, market value of the building, while occupant comfort and productivity is increased [6].

## 3. LEED Energy Efficient Building

LEED rating systems is a framework developed by the USGBC (US Green Building Council) and CaGBC committees as a third-party verification of green buildings in order to assess the environmental impact of buildings. In LEED NC- 1.0, the "energy and atmosphere" (EA) category includes three prerequisites (no points assigned) and six credits (a total of 17 points). It is possible to earn a maximum of 17 points associated with the six credits listed under the EA category, which constitutes 24% of the maximum total points (70 points) that one can score in LEED evaluations [7]. The LEED® Canada NC rating system applies to new construction and major renovations of commercial and institutional buildings, i.e., buildings regulated by Part 3 of the Canadian National Building Code. It also applies to retail, mid- and high-rise multi-unit residential buildings (MURBs), public assembly buildings, manufacturing plants, and other types of buildings (CaGBC). Fig. 2 shows achieved credits under Energy and Atmosphere, 8 points were awarded under "Optimize Energy Performance" and 1 point was under "Best Practice Commissioning".

| 9 | Energy & Atmosphere | | Possible Points 17 |
|---|---|---|---|
| Y | Prereq 1 | Fundamental Building Systems Commissioning | Required |
| Y | Prereq 2 | Minimum Energy Performance | Required |
| Y | Prereq 3 | CFC Reduction in HVAC&R Equipment | Required |
| 8 | Credit 1 | Optimize Energy Performance | 1 to 10 |
| | Credit 2.1 | Renewable Energy, 5% | 1 |
| | Credit 2.2 | Renewable Energy, 10% | 1 |
| | Credit 2.3 | Renewable Energy, 20% | 1 |
| 1 | Credit 3 | Best Practice Commissioning | 1 |
| | Credit 4 | Ozone Protection | 1 |
| | Credit 5 | Measurement & Verification | 1 |
| | Credit 6 | Green Power | 1 |

Fig. 2- Achieved points (investigated building) under the LEED NC- 1.0 under Energy & Atmosphere.

Table 1-Energy performance and energy standards used for energy simulation, CAGBC.

| | | Credits | Requirements |
|---|---|---|---|
| LEED | Energy & Atmosphere | Optimize Energy Performance | Reduce design energy cost compared to the energy cost of the MNECB OR ASHRAE/IESNA 90.1-1999 reference building for energy systems regulated by these standards. Compliance shall be demonstrated by using whole building energy simulation using the same compliance path (MNECB/CBIP or ASHRAE 90.1) as was used for EAp2. The calculation of percentage energy cost reduction shall exclude "non-regulated" loads. |

Table 1 shows the energy performance standards (Model National Energy Code for Buildings (MNECB) / ASHRAE/IESNA 90.1-1999) used for performing energy modelling and simulation to determine the overall energy efficiency of the investigated LEED building. 10 Points were awarded under this section for percentage reductions in design energy cost relative to MNECB and ASHRAE 90.1. 10 points were awarded if they achieved a 64% reduction using MNECB standard and 60% reductions in design under ASHRAE 90.1.

Modelling the building envelope is based on input on the R value of various building envelope components. Thermal bridges throughout the steel studs and window to wall connection are approximated in the calculation. The energy modelling software and calculations used does not calculate the real R value of various interface components such as window to wall interaction nor the thermal bridges formed by steel framing. Under the LEED, Energy and Atmosphere there is a lack of rigorous inspections to identify the performance of the building envelope, unfortunately, there is no testing is in place to check the efficiency of building envelopes. Often well-designed building envelopes, if badly executed, results in a considerable loss of energy.

## 4. Thermography and Building envelope performance

IR thermography, thermal imaging, and IR imaging are commonly used terms for non-destructive testing methods and non-contact diagnostics technology that has a broad range of building applications including: assessment of the continuity of insulation and façade energy efficiency; identifying locations of air leakage; monitoring internal air temperatures [8, 9]. The use of thermal infrared (IR) imaging is a valuable tool for inspecting and performing non-destructive testing of building elements. Detecting where and how energy is leaking from building envelopes [9]. As a qualitative survey technique, in site analysis can be conducted by using IR thermography to evaluate the building envelope surfaces [10]. The eye cannot detect the infrared (IR) radiation that typically falls between wavelengths of 2-15 µm that is between the visible and microwave portion of the electromagnetic spectrum. IR waves of 0.7- 25 µm are close to visible light but with a wavelength that is longer than visible and shorter than microwaves. IR waves of 25-1000 µm are closer to the microwave region. All objects radiate energy that is transported in the form of the electromagnetic waves, which travel at speed of light [9].

Building thermography is principally a qualitative test method on the basis that an IR camera is used to inspect surface temperature variations in the search for irregular thermal patterns that may correspond with defects in the building envelope such as missing insulation, thermal bridges or air leakages [11]. Building envelopes are designed to provide certain indoor conditions, protect the interior from the outside and give the building its external appearance [12]. Therefore IR thermography can be used in building envelopes to detect not only heat losses, missing or damaged thermal insulation in walls and roofs but also thermal bridges, air leakages and sources of moisture. IR thermography can also be employed in building diagnostics for the determination of the thermo physical properties of building envelopes [13]. It is suggested that building IR thermography on external building elements should be performed either at night or during a cloudy day. This was found to be important in order to avoid the problem of temperature increase which occurs as a result of the incident solar radiation and the impact from the absorbed solar energy, which presents a time lag of a few hours [13].

## 5. Investigated Building

The investigated building was built in 2011 and is an educational building located in Toronto, Canada. The Library building at Centennial College is a four story building has a gross floor area (GFA) of 9400 $m^2$. The certified LEED Gold was designed by Diamond Schmitt Architects and certified by the Canadian Green Building Council in 2011 under LEED NC 1. The building's main wall systems are cast in place concrete with modular bricks, which are used for cladding along with fiberglass rigid insulation.

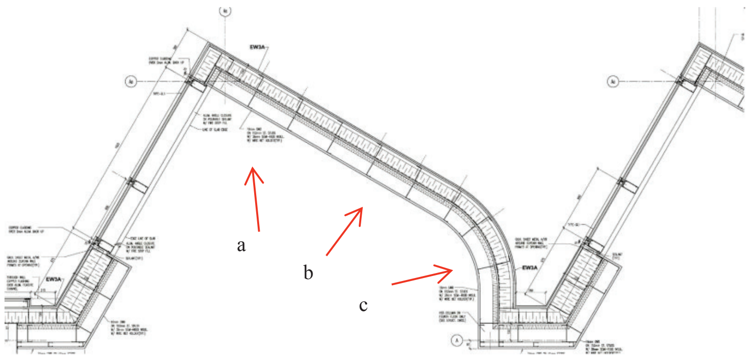


Fig. 3- Architectural detail of the investigated building, arrows shows the locations of different shots taken by the IR camera.

The second prevalent main wall system is the copper (Fig. 1 and Fig. 3), composed of 152 mm steel frame system, an air/ vapour barrier, a 100 mm rigid insulation, steel sheathing and cladded with copper panels and window frames are of aluminium. The exterior walls oriented towards the northern side are built with brick and copper cladding (metal studs, rigid insulation and drywall) see detail Fig. 3.

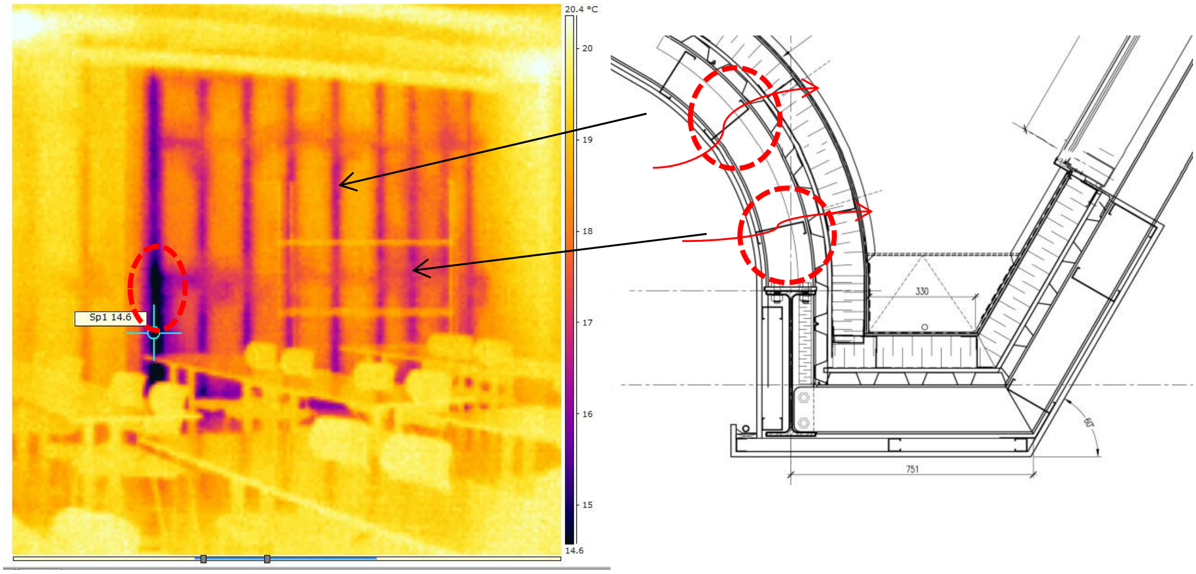


Fig. 4- (a) Thermal imaging showing cold surfaces of the steel studs (b) Construction detail shows different layers of the exterior wall: Copper cladding, Z girts, rigid insulation, metal clad, steel studs and drywall.

### *5.1- Assessing the thermal Bridging*

Building envelopes are designed to provide comfort indoor conditions, protect the interior from the outside and give the building its external appearance. The exterior wall with its components is designed with a higher thermal resistance R value that will reduce heat gains in building during the summer time and heat losses during winter. To analyse the efficiency of the building envelope it is critical to analyse the thermal bridges [10]. Thermal bridges are vital points in the investigation of building envelopes. Thermal bridges occur when a conductive element passes through or bypasses the thermal barrier. Thermal bridges provide a path of lesser resistance through the insulation, allowing more heat to bypass the thermal barrier and raise or lower interior temperatures.

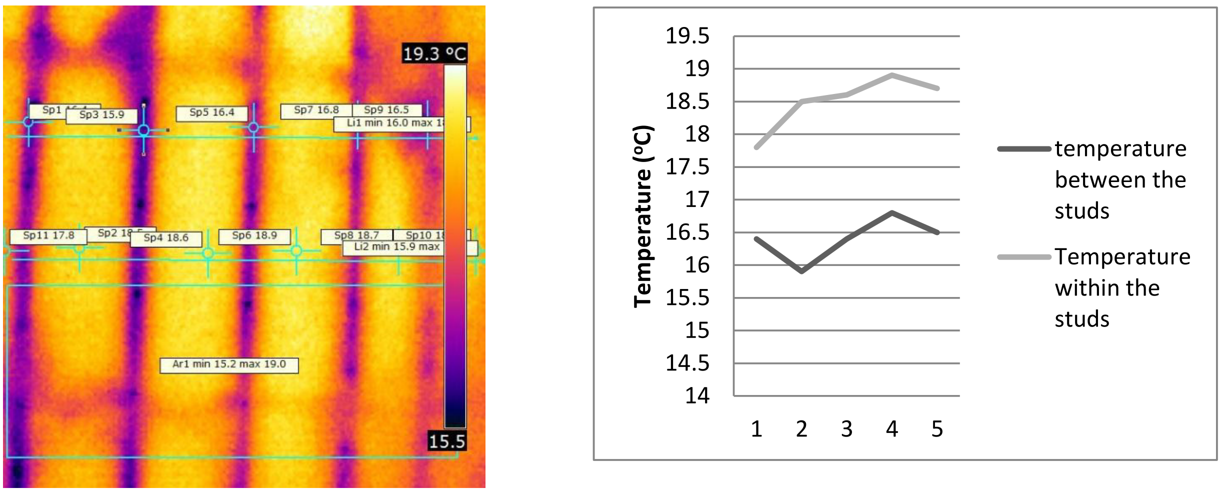


Fig. 5- (a) Thermograph showing temperature differences within the steel stud wall (b) Thermogram of the steel stud wall showing differences between the temperatures between the steel studs and the temperature within the steel studs.

In Fig. 4 IR thermography was used in to detect missing thermal insulation and thermal bridging in the building envelope [13]. As it is noticed in Fig. 5 and 6, the IR thermograph shows temperature differences between the steel studs, the thermogram Fig. 5 (b) below shows the temperature differences that vary between 15.9 °C (Sp3) degree and 18.9°C (Sp6).

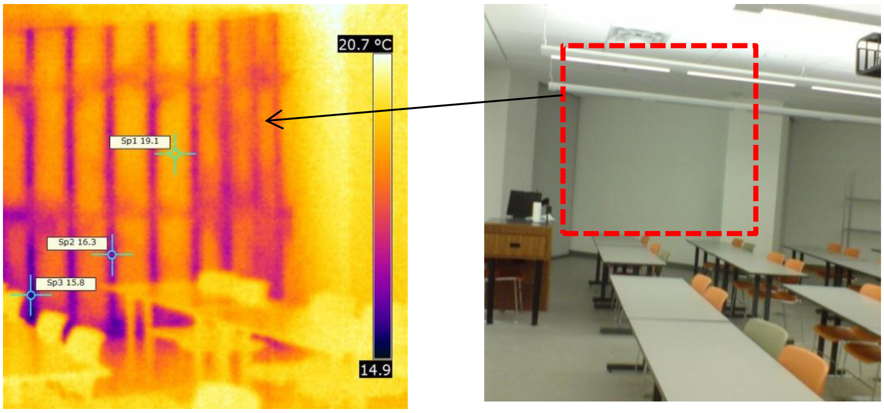


Fig. 6- (a) Thermograph showing thermal anomalies (thermal bridging), in purple cold steel studs temperature reading sp3 15.8 C (b) investigated wall, internally looking at a classroom

Fig. 5 and 6 shows thermal bridging throughout the steel studs, using thermal imaging to detect temperature differences indicates building envelope's health and efficiency. IR imaging enables the detection of major problems such as thermal bridging.

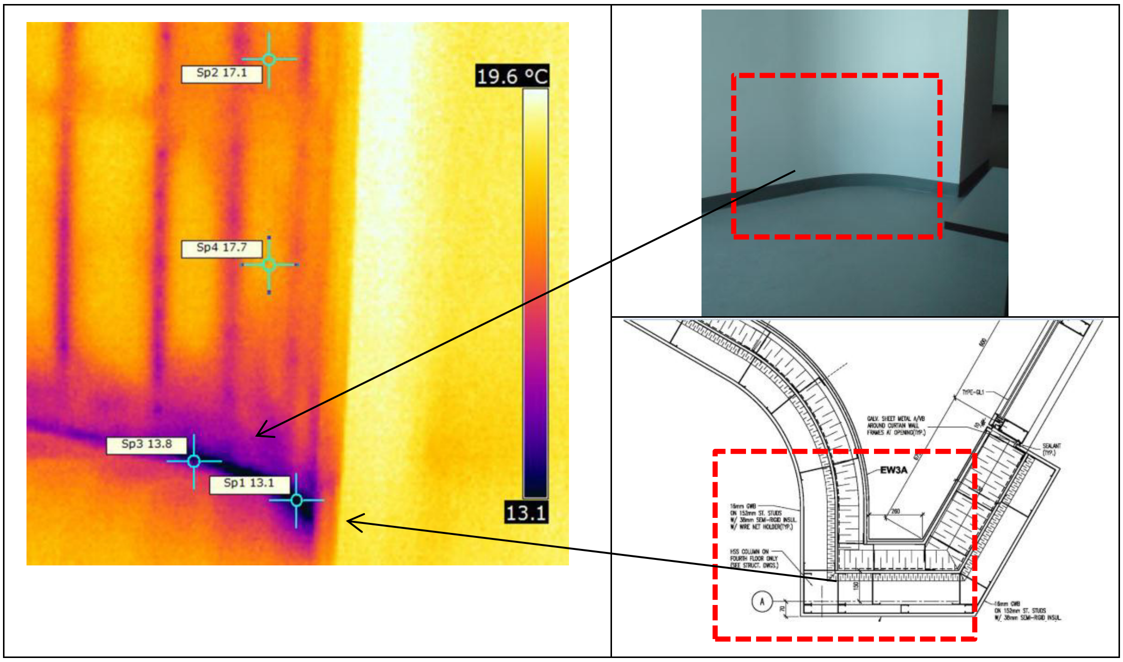


Fig. 7- (a) Thermal anomalies; temperature reading between the slab and the wall is 13.1 C

Fig. 7 shows details and thermal anomalies where the wall meets the floor. The thermograph shows a lower temperature of 13.1 (Sp1) degrees Celsius.

*5.2- Assessing continuity of thermal layer window and the wall*

Fig. 8 shows a thermograph of the interior window. Temperature reading show a very low temperature of 9.7°C (Sp1) along the window frame while the highest temperature reading is 19.4 °C (Fig. 7 a) a difference of 9.7 °C. To avoid unplanned heat loss through window frames it is important to ensure that the thermal control of the window frame (the thermal break) is aligned with the thermal control layer of the wall [14].

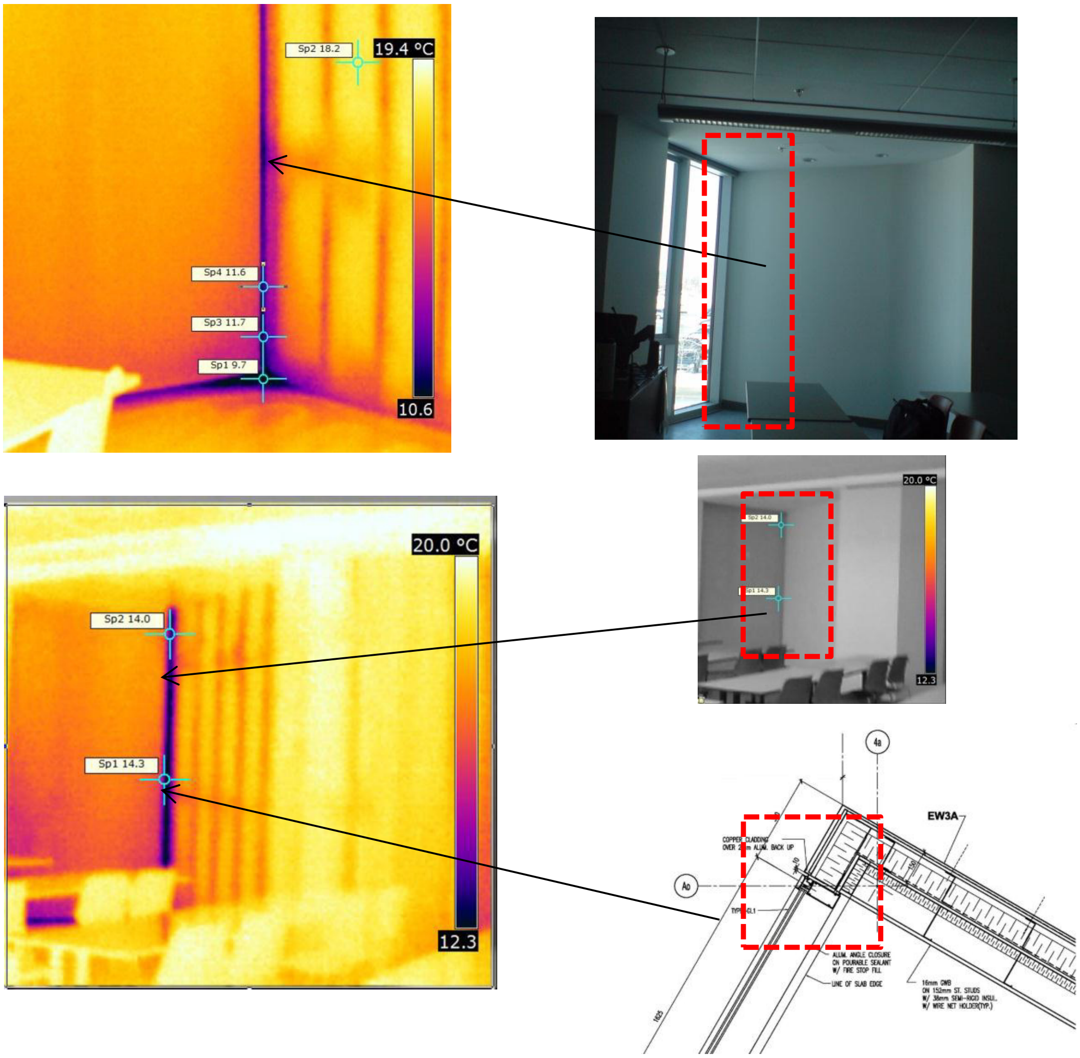


Fig. 8- (a) Thermograph of the interior window (connection between the exterior wall and the window), temperature reading 9.7C.

## 6. Conclusion

The aim of this paper is to use infrared thermography in an attempt to investigate thermal bridging in a LEED Gold building located in Canada. Infrared thermography is used in this research as a qualitative test method to inspect surface temperature variations in the search for irregular thermal patterns that correspond to thermal bridging. The energy modelling software and calculations used in LEED do not calculate the accurate R value of various interface components, such as window to wall interaction, nor do they locate the thermal bridging created by steel framing. This study also identified a lack of rigorous building inspection and diagnostics within LEED Canada, which evaluate the efficiency of the building envelope. This study proposes to inspect thermal losses using infrared imaging in order to investigate possible thermal bridging. (See Table 2)

Table 2- Introducing Infrared inspection in LEED certification will increase the energy efficiency of buildings and diagnose building envelope deficiencies

| | | | Prior to construction | During construction | Tools |
|---|---|---|---|---|---|
| LEED | Energy Efficiency | **Building envelope** | • Building simulations<br>• Energy modelling<br>• R value Calculations | • Inspecting insulation<br>• Inspecting thermal bridging<br>• Continuity Air Barrier<br>• Air tightness | • Infrared Imaging<br>• Infrared Imaging<br>• Visual inspection<br>• Blow door tests |

Building envelopes are designed to provide comfortable thermal indoor conditions, protect the interior from the outside and give the building its external architectural appearance. As this study shows, the introduction of infrared imaging as a means of analysing and improving the energy efficiency of building envelopes can result in an enhanced LEED rating system. Further investigation of similar case studies are of course necessary to suggest a permanent use of the infrared imaging as a means of analysing and improving energy efficiency of building envelopes.

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