COMPARING THE EFFECTIVENESS OF REDUCING INTERIOR OVERHEATING WITH HIGH PERFORMANCE LOW-E GLASS VERSUS SMART SHADING GLASS

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ABSTRACT

A trial glazing replacement project was conducted at a 28-storey, residential rental, high-rise tower located in Downtown Vancouver, where there have been ongoing issues with high solar heat gain through the windows in the tower suites during the summer months. Suites located at the south and west elevations, and at higher floor levels generally experience the greatest heat gain. Heat gain is increased when the blinds are opened. Windows are the primary vertical cladding element on the building.

The high heat gains and desire to open blinds have resulted in the need for supplemental cooling via portable air conditioning units. However, the use of the units creates large demands on the building's energy use, and require effort to move, temporarily install, maintain, and store the units. As such, the Owners have been looking into alternative options to address the overheating issue such as glazing replacement with electro-chromic self/smart shading glass or a high performance low-e coated/spacer glass, in order to eliminate or reduce the need for air conditioning units, but still allowing residences to keep their blinds open to enjoy the views from the tower.

As full glazing replacement on a high-rise tower requires a large capital investment, an in-situ glazing replacement trial was conducted at two sample residential suites in order to evaluate the effectiveness of implementing a glazing replacement program with either smart shading glass or high performance insulating glazing units without supplemental cooling.

The trial was conducted at two upper floor suites (at the 26th and 23rd floors), both located at the south-west corner of the tower, and ran over the summer months of 2016 (July and August). These suites were selected because they both have the same exposure, are located at higher levels in the building, both have ongoing issues with summer time overheating, and have the same layout, so trial results could be compared. All the existing glazing at the 26th floor suite was replaced with smart shading glass, and all the existing glazing at the 23rd floor suite was replaced with a high performance low-e glass. The new trial glass was placed into the existing window frame assemblies, which are thermally broken, aluminum framed, window walls, that generally span from floor to ceiling. The two trial suites were un-occupied for the duration of the trial.

IGU properties for each of the trial glass are as follows:

Properties	High Performance Low-E Glass	Smart Shading Glass
Solar Heat Gain Coefficient	0.272	0.09 to 0.41
Visual Light Transmittance	64%	1% to 58%
Spacer Material	Stainless steel warm edge	T shaped, black silicone foam
Gas Type	90% argon	>90% argon, >10% air
Centre of Glass U-value	0.239	0.290
Type of Coating and Location	Triple-silver, magnetic sputter vacuum deposition Low-e coating on #2 surface	Electro-chromatic coating on #2 surface
Thickness of Glass and Air Space	6mm tempered inboard and outboard glass with 12mm air space	6mm tempered inboard and outboard glass with 12.7mm air space

An occupied suite at the 20th floor with the same exposure as the trial suite, with a portable air conditioning unit was also monitored for the duration of the trial, in order to compare the data from the trial suites, to data from a typical higher level, occupied suite, where the occupant had control over the interior temperatures, and could adjust it to favorable conditions.

Data loggers were placed in the living rooms and bedrooms of the trial suites, as well as the occupied, air-conditioned suite, to collect interior temperature, relative humidity, and lighting level data for the summer months. Data was collected in the trial suites, between July 4, 2016 to August 23, 2016. Data in the occupied suite was collected between July 4, 2016 and August 11, 2016. The data collection period in the occupied suite was reduced due to error issues with the data logger, likely from the suite occupants moving the data logger.

Figure 1: Typical Trial Suite Floor Plan

The trial ran with the operable windows closed in the trial suites between July 4 and 28, 2016. The operable windows were opened and bathroom fans turned on for the remainder of the trial, to see if allowing passive ventilation would affect the interior suite temperatures. The window operation in the occupied suite was controlled by the suite occupant, and it is not known if they were opened or closed during the trial.

Data collected at the end of the trial was analyzed and evaluated to better determine if glazing replacement with either one of the trial glazing would help resolve the interior overheating issues, and mitigate the need for supplement cooling. Past weather for the trial period data was also collected from Environment Canada, to be graphed against the trial data.

CONCLUSION

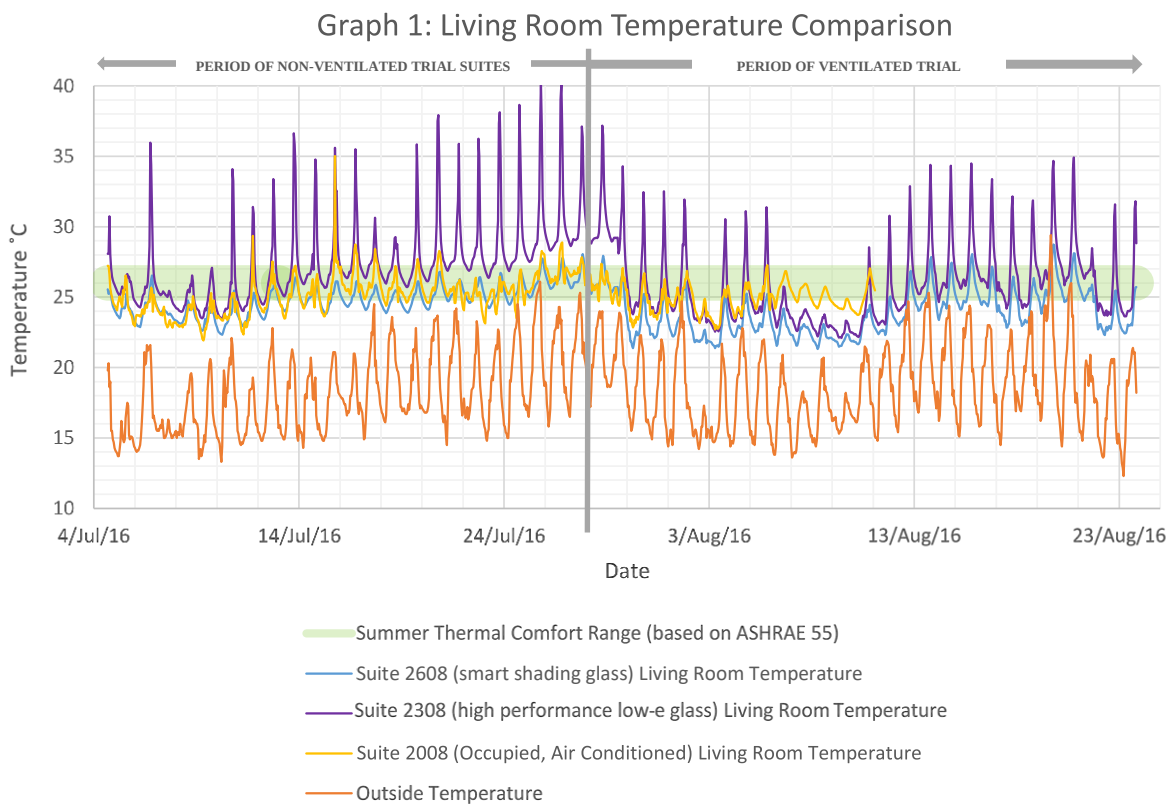
Review of the trial data showed that the interior temperature in all suites was generally warmest between 5:30pm to 7:30pm daily, with the highest temperatures usually recorded around 6:00pm. The suites were generally coolest between 6:00am to 7:00am. As such, the suites were generally warming up between 7:00am to 8:00pm, and were cooling down between 9:00pm to 6:00am during the trial.

The warmest outside temperatures were generally between 4:00pm to 6:00pm, with highest temperatures usually recorded around 4:00pm daily. Outside warming and cooling patterns were generally the same as in the trial suites, except with the outside peak temperature generally being around two hours before the

interior peak temperatures. The average outside temperature between 4:00pm to 6:00pm in July during the trial period was around 22.6˚C. The average outside temperature in August between 4:00pm to 6:00pm during the trial period was 23.2˚C. The highest outside temperature recorded during the trial was 29.4˚C on August 19, 2016 around 4:00pm.

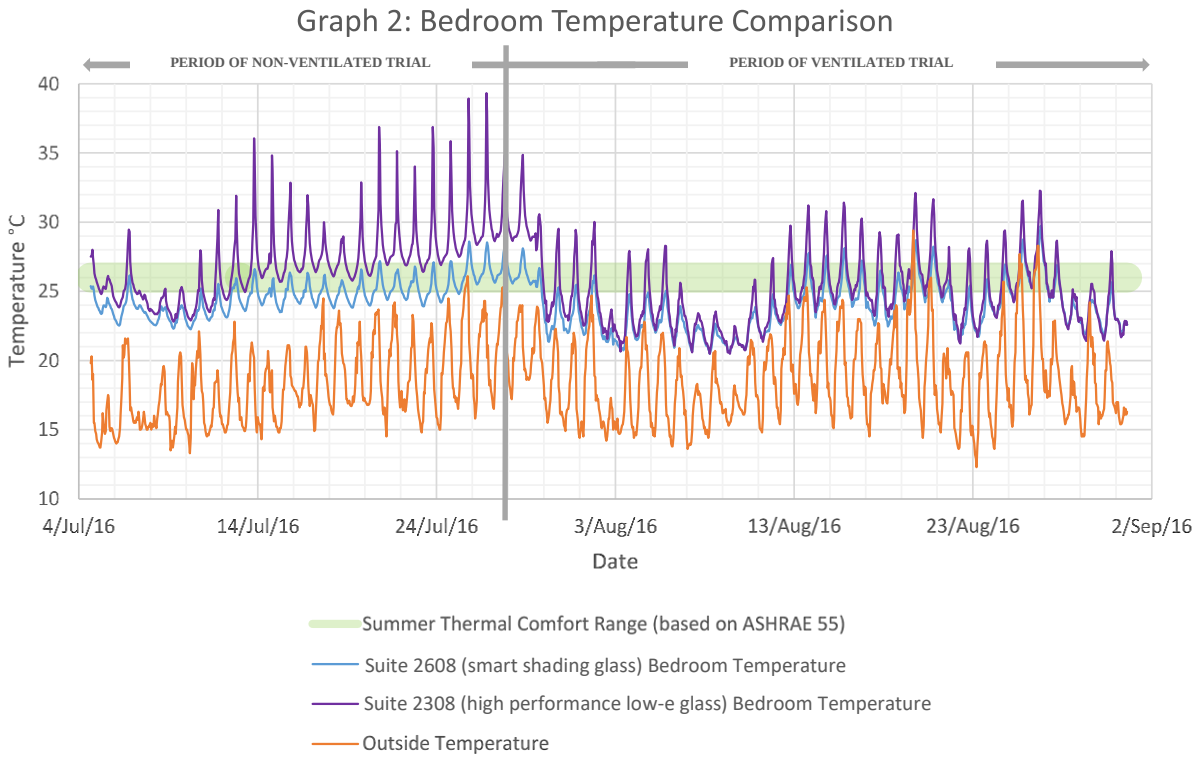
The trial data collected has been graphed to show the temperature comparison between each suite, and how the interior temperatures relate to the outside temperature (refer to Graphs 1 and 2).

The comparison graphs also highlight the summer time thermal comfort range of 25˚C and 27˚C for 40% to 50% interior relative humidity, which is based on ASHRAE Standard 55-2010 Comfort Zones. Although actual thermal comfort is largely based on personal preference and a number of factors such as humidity, air speed, metabolic rate, radiant temperature of surrounding surfaces, amount of clothing being worn, etc., the ASHRAE Standard 55-2015 Comfort Zones range should represent a temperature range which most people would find favorable. The thermal comfort range on the graphs help illustrate how often the interior suite temperatures were within a favorable thermal comfort temperature range.



Graph 1 Note:

1. *Suite 2008 temperature increased to over 35˚C at 6:00pm. The Resident(s) may have been out during this time and the A/C unit was likely not turned on.*
2. *Data was collected between July 4, 2016 and August 11, 2016 in Suite 2008, the data collection period in this suite was reduced due to error issues with the data logger, likely from the suite occupants moving the data logger.*



The average peak temperature difference between the trial suites on the warmest days was about 6.5˚C during the trial, with the 26th floor suite (smart shading glass) being the cooler suite. Temperatures in both suites generally rise and fall at the same time, and in a similar pattern. Based on the lighting level data, it appears the 26th's floor glass begins to tint as temperatures in the suite rise from the sun's intensity into the suite, and helps to keep the suite from reaching the peak high temperatures experienced in the 23rd floor suite (low-e glass).

The average peak temperature in the 26th floor suite (smart shading glass) was generally around 3˚C to 5˚C warmer than the exterior peak temperature. The average peak temperature in the 23rd floor suite (high performance low-e glass) was generally around 10˚C to 15˚C warmer than the peak outside temperature, which indicates that solar heat gain through the glazing can cause interior temperatures to be significantly warmer than exterior temperatures on sunny days.

During the cooler, cloudy/overcast and/or rainy weather days the temperatures in both the trial suites recorded similar temperatures, with the 23rd floor suite generally only being one to two degrees warmer, which is relatively close considering the average peak temperature difference between the two suites.

Based on the data collected from the trial, the smart shading glass can reduce heat gain in the suites comparably to the occupied air-conditioned suite and generally within the summertime thermal comfort range suggested by ASHRAE 55. For most suite occupants, the average peak temperature in a suite with smart shading glass will likely be cool enough that supplemental cooling would not be required. However, it is important to keep in mind that thermal comfort is largely dependent on personal preference, and the average summertime peak temperature of around 26˚C may still be considered too warm for some occupant who would still request that supplemental cooling be provided.

Also, as the trial suites were un-occupied for the duration of the trial. Occupant activities such as using electronic equipment, cooking, bathing, etc., could increase interior temperatures to levels, which may still require air-conditioning for some residents. Base on the trial data from the occupied suite, occupant activities would likely raise the average interior temperature by one to two degrees.

The installation of a high performance low-e coating on the window glazing did not effectively reduce the interior temperature to a comfortable range and air-conditioning would likely still be required to cool the suites if blinds are left open. As such, this was not considered to be a suitable management option.

In order to keep the tower suites sufficiently cool during the summer, shading the glass or providing supplemental cooling is needed to keep temperature within ASHRAE comfort zone suggestions.

A cost comparison of the two options was completed as part of the trial in order to provide the Owners with the information on how each option would impact them financially. The cost to replace all existing IGUs at the tower suites with smart shading glass was estimated to be around $6,252,000. The cost to install chilled water fan-coil air conditioning in all the tower suites was estimated to be around $7,672,000 (not including ongoing costs for energy, water, and maintenance of the air conditioning system).

The study also provided a summary of the advantages/benefits and disadvantages/risks of each option as follows:

Smart Shading Glass	Fan-coil Air Conditioning
Advantages/Benefits: • Effectively reduces summertime temperatures • Reduces light in suite to more comfortable levels • Reduce need, or possibly eliminate need for air-conditioning • Will reduce building's overall energy use • Will reduce suite occupants' energy bill costs.	Advantages/Benefits: • More occupant control over how much cooling is provided to the suite • Can provide more cooling to the suite compared to glazing replacement
Disadvantages/Risks • Invasive repair which requires extensive wiring installed throughout the suites • Some suite occupants may still desire air conditions to sufficiently cool their suites to their personal preferences • Less occupant control over suite temperature • Involves replacing glass before end of its service life • New technology possibly having unforeseen issues/costs	Disadvantages/Risks • Higher cost solutions • Invasive repair which requires major mechanical upgrades to the building • High ongoing maintenance and operation costs • Increased energy use and cost for the building • Does not address light intensity into the suite and occupants may still be required to close blinds which will limit their views

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