The IMPACT of Exterior Insulated Shutter Systems

Introduction

The impact of interior shutter systems was investigated by a companion article that appeared in Sustainable Building & Design, May 2014 issue [1]. As described in Reference 1, clients and architects seem to have used glazed curtain walls as the primary assembly, without taking into consideration the energy load of the building. Glazing and its structure or frame is the weakest point of a wall assembly from a thermal standpoint. For example a double-glazed aluminum curtain wall window with argon's U-factor (i.e. thermal transmittance) is typically around 3.5 W/(m^2 K). How then to improve the thermal performance of glazing systems in commercial buildings?

One solution would be to incorporate operable exterior shutter systems to provide additional thermal insulation. The current study investigated the possibility of designing an optimal exterior insulated shutter system for a four-storey medical centre located in Mississauga, Ontario. The five objectives set for the shutter system are: to obtain a maximum U-value of 0.5 W/K•m^2, to create a thermally integrated exterior shutter system, to minimize heat gains and losses, to maximize light penetration while reducing glare, and to create an aesthetically pleasing design.

Investigation

Simple two-dimensional simulation studies were applied to investigate the thermal performance of the curtain wall system insulated with exterior shutters. Three different shutter systems were analyzed to evaluate their thermal impact on the base curtain wall glazing system. The details of the base glazing system were provided by ATA Architects of Oakville, Ontario [2]. The following three main criteria were used to rank the various design iterations:– U-value of the assembly, ease of installation, and condensation potential of the assembly. The shutter options were: a) Horizontally sliding panel with operable arms, b) Vacuum insulated panel (vip) vertically sliding shutter system, and c) Insulated horizontal louver system. Each of the three main options had different variations within that were included in the investigation. The parametric description of the investigation is presented in Table 1 below. The complete details of the investigation are contained in the Reference 3.

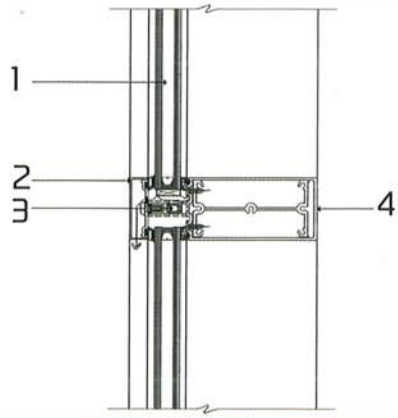
Table 1. The design options of exterior shutters

Design Option Number	1	2	3
Basic assembly	Horizontally sliding panel with operable arms	Vacuum insulated panel (vip) vertically sliding shutter system	Insulated horizontal louver system
Variation 1	aluminum frame/siding and aerogel insulation	10 mm thick panel and 220 mm air cavity	aluminum louver and aerogel insulation
Variation 2	aluminum frame, wood siding and polyurethane insulation	20 mm thick panel and 22 mm air cavity	aluminum louver and polyurethane insulation
Variation 3	wood frame/siding and polyurethane insulation	-NA -	vinyl louver with polyurethane insulation- Best
Variation 4	-NA -	-NA -	wood louver with aerogel insulation
Variation 5	-NA -	-NA -	wood louver with polyurethane insulation

Simulation software THERM and WINDOW were applied for the investigation [4]. THERM program is a two-dimensional (2-D) finite element program for calculating heat transfer in fenestration systems and other building envelope constructions. In addition to conduction heat transfer, the program also handles detailed radiation heat transfer, based on view factors. It also incorporates convection heat transfer modeling in glazing cavities [4]. WINDOW program serves two purposes. To calculate "center of glass" one dimensional (1-D) heat transfer and solar optical properties of glazing systems. Glazing configurations can be arbitrary constructed and can have up to 6 glazing layers, consisting of either glass or plastic. The other purpose of WINDOW program is to be a "collection point", where the complete window is assembled. Results are imported from THERM program for frame and "edge-of-glass" components, which are combined with glazing layers into complete fenestration system (window, skylight, curtain wall, etc.) [4]. Note: The overall U-factor can be evaluated in section, or in plan or at a corner.

The basic glazing system consisted of a double glazed unit with argon fill. The details are shown in Figure 1 below.

Figure 1. Details of the base curtain wall system - 1) doubled glazed unit with argon fill; 2) exterior mullion cap, 3) thermally broken mullion (PVC), and 4) interior mullion section.

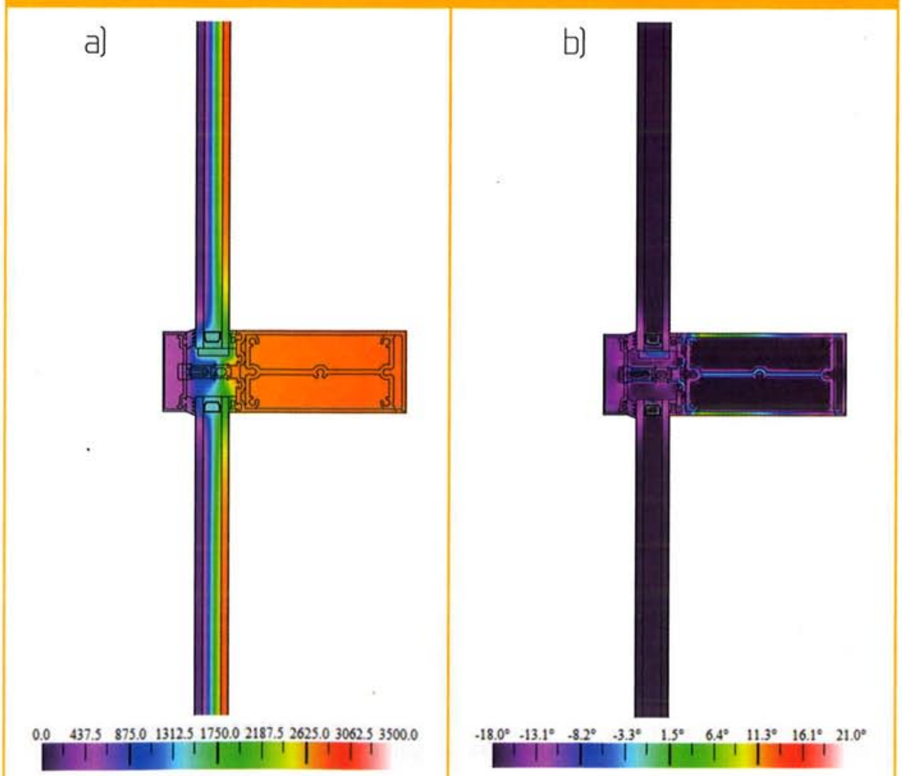


Frame: Consists of anodized aluminium (237 W/(m² K)); Special Bolt (1.03 W/(m² K)); Butyl Rubber (0.25 W/(m² K)); and Silicone (0.35 W/(m² K).

IGU: consists of 5.7 mm thick pane; 14 mm of Argon gas and 5.7 mm thick pane. The Centre of Glass U-factor is (1.34 W/(m² K));

The base glazing system was modeled in Window and Therm. The results of the simulation, in section, are shown in Figure 2 below.

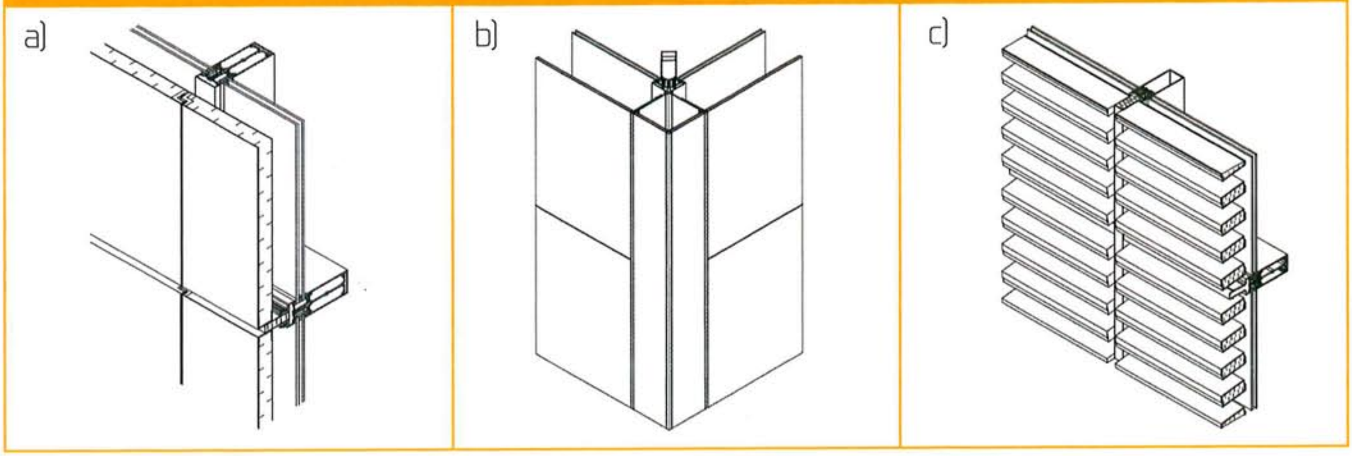
Figure 2. The results of THERM modelling. a) Temperature variation, °C, and b) Heat flux variation, W/m2



The overall U-factor for the base glazing system is 1.71 W/(m² K). It can be seen that the main deficient part of the glazing system is the mullion connection. In addition, most of the heat flow is seen to be through the aluminum portion of the connecting frame. The glass surface on the interior is cool with temperature in the range of 2 to 5 °C. The condensation potential can be deduced from the simulation results. For the base glazing system, condensation is possible at the mullion connecting points. The U-factor of the base system is seen to be around four times the design goal set for the current investigation. It must be pointed out that the base system performed better than the system used in Reference 2. The main reason is due to the fact the base system had more rubber than metal components in the framing system.

The main focus was to evaluate the improvement potential of the adding exterior shutter systems to the base glazing system. Three interior shutter systems were investigated. The basic configuration details of the three interior systems are presented in **Figure 3** below.

Figure 3. Details of the exterior shutter systems.



This exterior insulated shutter design consists of sliding panels with operable arms. The connection of the panels is at the mullion and center of glass. The arms extend and pull the panels towards the mullion (See **Figure 3a**). The design shown in **Figure 3b** consists of vertical sliding panels with operable arms. The arms are controlled by the building automation system. The panels are attached at the mullions extending to the center of glass and open on wheels when natural light is needed. The shutters are made of aluminum metal with vacuum insulated panels. **Figure 3c** presents a design consisting of an operable system of insulated horizontal louvers. The louvers are mounted on a frame system which sits outside of the curtain wall and are mechanically attached to the building structure. The louvers in each mounted panel are sealed via tongue and groove connection to facilitate air tightness in a closed position.

The results of the exterior shutter systems are described below.

Results and Discussion

Seven different shutter system options, as described in **Table 1**, were investigated. In addition to evaluating the improved U-factor, i.e., reduced heat transfer capability, other parameters such as ease of implementation, cost, condensation potential, drying capacity and aesthetics were also considered in the investigation. The performance of the different options is summarized in **Table 2** below.

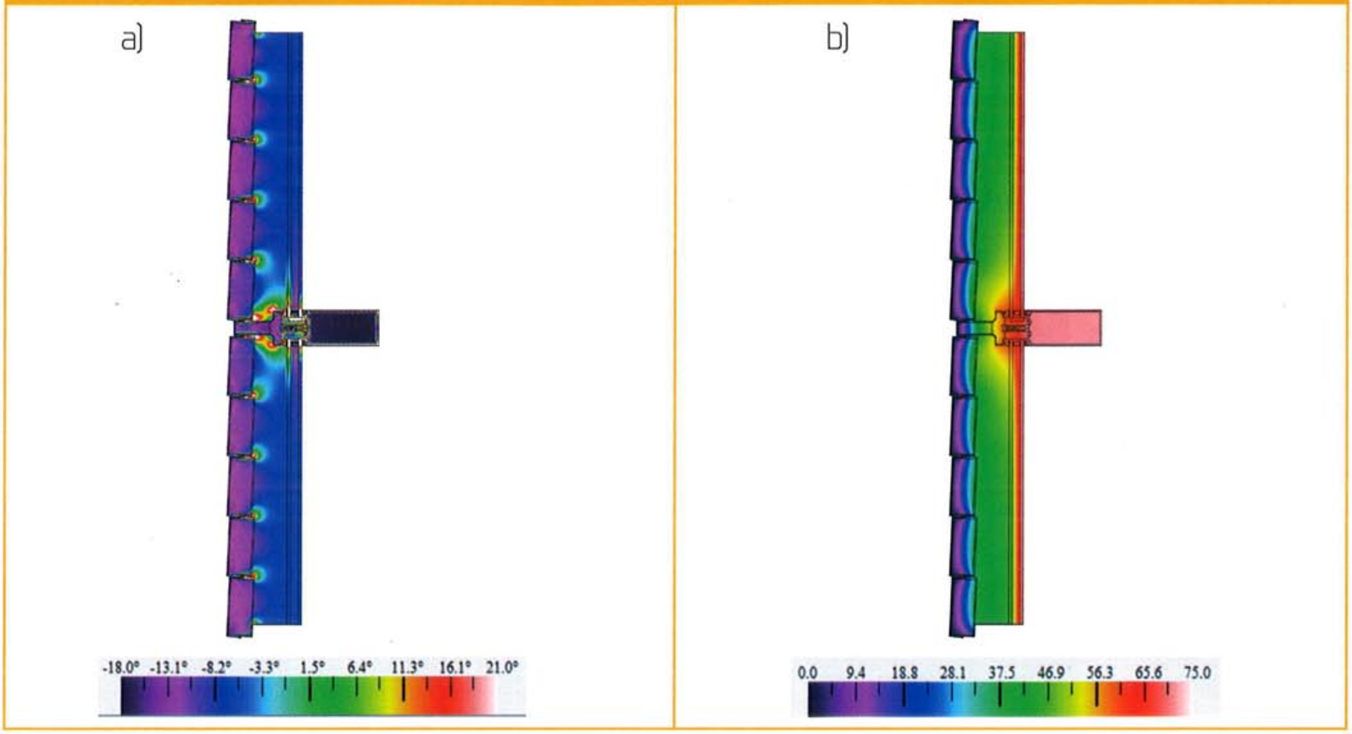
The temperature on the glass is a clear indication of potential condensation within the new glazing system. The simulated interior environment in THERM is: Temperature of 21°C and relative humidity of 50%. The dew point temperature for the interior is 10.2°C. The issue of condensation is discussed later on.

Table 2. Results summary of exterior shutters systems.

Conditions	Horizontal sliding Panels			Vertical vacuum sliding Panels	Horizontal Louvers		
	Aerogel	Wood & Alumimum	Wood		Aluminum & Poly-Urethane	Wood & Aerogel	Vinyl & Poly-Urethane
Costs	High	Low	Low	High	Low	High	Low
Transparency	Yes	No	No	No	No	No	No
Life Span/ Durability	Medium to High	Medium	Medium	Low	Medium to High	Medium	High
Thermal Performance	Low	Medium	Medium to High	High	Low	High	Medium to High
Renewable/ Recyclable	No	Yes	Yes	No	Partial	Partial	Partial
Constructability/ Repairs	Easy	Easy	Easy	Difficult	Easy	Easy	Easy
Condensation Potential	Yes, on exterior glass in air space	Yes, on shutter interior in air space	Yes, on shutter interior in air space	Yes, inside shutter	Yes, on glass exterior in air space	Yes, glass exterior in air space	Yes, near shutter interior in air space
Best U-Value (W/K•M2)	0.60 @ Corner	0.44 @ Corner	0.35 @ Corner	0.70 @ Corner	1.1 @ Corner	0.33 @ Corner	0.42 @ Corner

Finally the THERM simulations were evaluated for all the options. However, the results for only one of the interior shutter systems are shown in this article. The simulations results for the louver window system with vinyl and polyurethane are shown in Figure 4 below.

Figure 4. The results of THERM for Louvers, with vinyl and polyurethane: a) Temperature variation, °C, and b) Heat flux variation, W/m2



The various results were summarized in Table 2 and in Figure 4. It can be seen that the goal of achieving a U-Value of 0.5 W/(m2K) was fulfilled by the exterior shutter systems. The best value achieved was a U-value of 0.33 W/(m2K) by the louver system with wood and aerogel. It is also seen that the louver system with vinyl and polyurethane also performed with a U-value of 0.42 W/(m2K). The louver system with vinyl and polyurethane is the preferred option as it is economical, widely available and long lasting. The wood and aerogel system has to be treated for exterior weather conditions. One of the major advantages of the louver system is its ability to be operable as multiple units rather than a single system.

Condensation was found to be a critical problem for the interior shutter systems[1]. Condensation is also possible for the exterior systems, but drying potential is strong. Hence, condensation for exterior shutter systems may not be a major issue.

Conclusions

Glass curtain wall systems for high rise buildings is not the best envelope solution for a cold climate, the aesthetic appeal of glazing notwithstanding. The heat transmission coefficient (U-value) of conventional curtain wall system can exceed 3 W/(m^{2}K). The current study investigated the impact of exterior shutter systems for its potential to reduce the U-value to 0.5 W/(m^{2}K). Seven different designs were investigated. The designs were modeled in THERM. The results showed that exterior shutter systems with louvers would be able to achieve the design goal. In addition, the results also showed that condensation for exterior systems may not be an issue because of drying potential.

References

1. Doug Belanger, Anastasija Dudnykova, Matthew Gelowitz, Anusha Ramesh, Newton Xian , Yi Fan (Helen) Xie, Ramani Ramakrishnan and Mark Dreidger, "Impact of Interior Shutter Systems," *Sustainable Building & Design*, May 2014.
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Images courtesy of Ramani Ramakrishnan