SITumbra – Energy Efficient Structurally Integrated Transparent Shaded Façade System

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ABSTRACT

SITumbra is an Environmental Protection Agency (EPA) P3 award winning product [1] comprising a multi-use transparent structural window system made from a customizable fixed inner structural core compositely connected to outer transparent window materials. It can be configured to meet multiple material and design specifications and reduce maximum heating and cooling demands based on building location and orientation. SITumbra is expected to perform highly in the market place because of its unique product characteristics, specifically green building development applications. Ongoing full scale prototype thermal testing has been conducted resulting in improved energy efficiencies of 25% compared to an aluminum framed low e double glazed window system.

Keywords: energy, windows, buildings, materials, sustainability

1 INTRODUCTION

Buildings are large consumers of energy. In the United States; they consume nearly 40% of the country's total annual energy use and attribute 40% to landfill wastes [2]. It is essential that we find ways to save on energy and minimize waste in buildings. To address this need, the author has developed an innovative new window system as depicted in Figure 1, called SITumbra, which is energy efficient and made from sustainable materials. Various ongoing simulations and laboratory experiments are being conducted on this new product towards continuing improvements in product performance and future market acceptability. Much of the background behind this product development and associated research areas are described in a previous paper [3], that provides a more comprehensive background on the technical context of the product. Energy conservation in buildings is an important and pressing factor that can dramatically contribute towards reducing carbon emissions, pollutants and resource depletion. SITumbra out-performs the traditional double glazed low e window system in most areas as shown in Figure 2, and is therefore poised to become an effective and economic alternative sustainable façade system.

Figure 1. Concept application of the SITumbra façade system in a commercial office development.

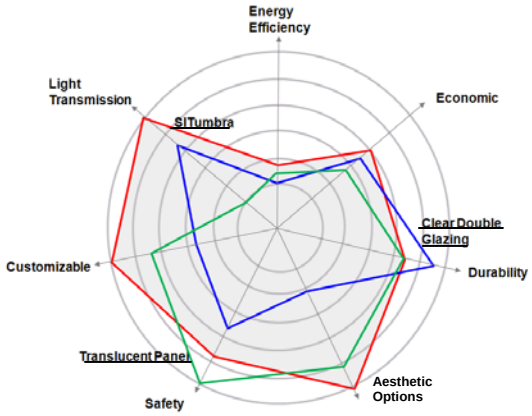

Figure 2. Qualitative assessment of SITumbra performance attributes compared to alternative window materials.

2 NEW ASPECTS

2.1 Solving the solar heat gain dilemma

In an assessment of the dilemma faced by the fenestration industry [4], in relation to the thermal performance of facades with low e coatings, it was observed that technologies that increase the R-value is always accompanied by a reduction in the SHGC value. This means that reducing the heat lost from the window is accompanied by a reduction in the heat gained from the sun which can mean that the window is less energy efficient. This conflicting relationship is noted in the graph in Figure 3, where the performance of coatings is shown.

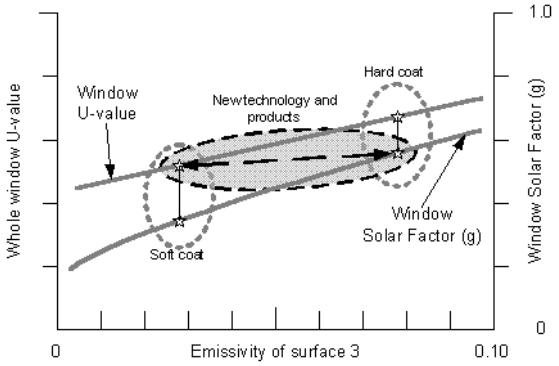

Figure 3. Relationship between U value (inverse of R value) and SHGC (g) comparing current low e coatings (dotted area) and required new technology products (dashed area) Source reference [4]

These studies concluded that what is needed to improve the energy efficiency of domestic windows is a new type of glass that increases the R-value of the glass and at the same time, retains a high solar factor. Key to the success of the SITumbra composite façade system is its ability to perform 'passively' between summer and winter conditions within an integrated skin/shading system. As can be seen from Table 1, the SITumbra composite panel performs with a variable SHGC as desired in the above assessment compared to the double glazed low e coating window tested.

Performance value	U	SHGC
Double glazing with low e coating	3.5	0.5
Biocomposite panel clear polymer skins and biocomposite grid core	2.5	0.2 – 0.6 summer to winter

Table 1 – Performance assessment comparison for double glazing and composite window system.
(U value units: W/K.m2)

2.2 The SITumbra product

SITumbra is a unique product that comprises alternative typologies of transparent and translucent load-bearing materials geometrically configured as a customizable and transparent layered skin and core window system. It can be used in a multiplicity of building applications. The window is essentially a transparent structural system made from a customizable fixed inner structural core compositely connected to outer transparent window materials. It can be configured to meet multiple material and design specifications and reduce maximum heating and cooling demands based on building location and orientation. The widow system performs differently from season to season as a mediator of solar energy, as shown in Figure 4. SITumbra is expected to perform highly in the market place because of its unique product characteristics, infinite opportunities for product variations and its applicability as a green building application. The product demonstrates innovation through the development of a highly energy efficient window system that uses sustainable materials, is configured with recyclable polymers or glass together with crop grown bio-composite materials, a renewable natural resource.

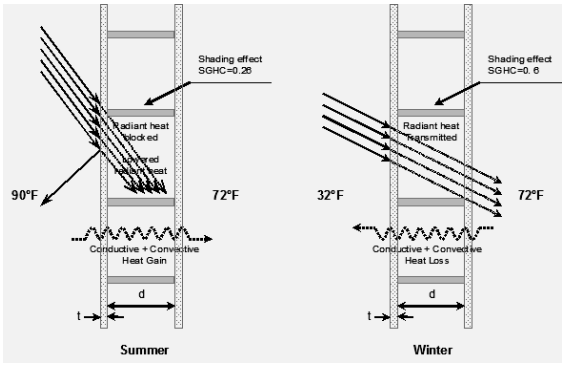

Fig 4 Composite panel performance characteristics between summer and winter conditions respectively.

2.3 The sustainability imperative

A whole building lifecycle can be categorized into five stages of raw material processing, manufacturing, construction, building-use and end-of-life as noted in Figure 5. Among these phases, building-use is the dominant phase due to heating, cooling, and lighting energy. Comparative environmental impacts associated with the building-use phase energy for a 10-story office building was made using eQUEST [5] software, applied to a particular configuration and location. A simple environmental impact parametric study was carried out on a base window model using a double glazing curtain wall system compared to the SITumbra composite panel system. The result of this analysis

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demonstrated that the composite system outperforms the double glazing system in relation to cooling, lighting and energy consumption and generates less pollutant emissions. In addition to analyzing the building-use phase, an initial estimate shows that the total embodied energies for both systems are quite similar.

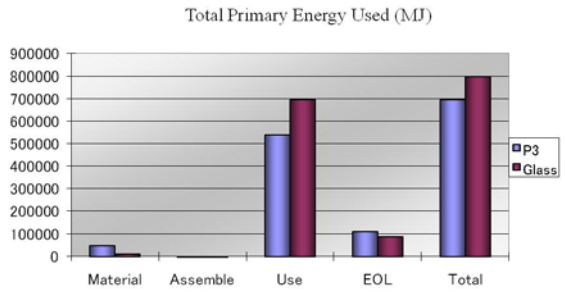

Figure 5. Life cycle analysis primary energy used comparison in a standard double glazed window project and SITumbra

3 MAIN RESULTS

3.1 A scalable prototype

Through full scale prototype manufacturing and testing, we have demonstrated that the product is scalable from smaller domestic to larger commercial building applications. The author has developed a unique prototype manufacturing and assembly system based on an integrated 3 axis CNC production machine, developed specifically for the purpose of making this product. The façade system is lightweight (approximately ½ the weight of a conventional glass façade system) and can be economically customized for mass production.

3.2 Thermal performance

Previous work using parametric tests and simulations on various configurations compared to conventional double glazed arrangements showed at least a 25% increase in energy efficiency. Ongoing full scale prototype thermal testing has been conducted on the SITumbra product and demonstrates superior energy efficiencies when compared to an aluminum framed low e double glazed window system. Thermal performance testing was carried using thermal chambers designed and constructed according to the National Fenestration Council of the United States [6] guidelines as shown in Figure 6 and data over the course of a full year has been obtained. Thermal tests were conducted during solar conditions only, measuring the effect of the SHGC factor and comparing this between seasons, during winter as shown in Figure 7 and during summer as shown in Figure 8.

Figure 6. Full scale thermal chambers showing the typical double glazed low e coating window on the left and the SITumbra composite panel on the right.

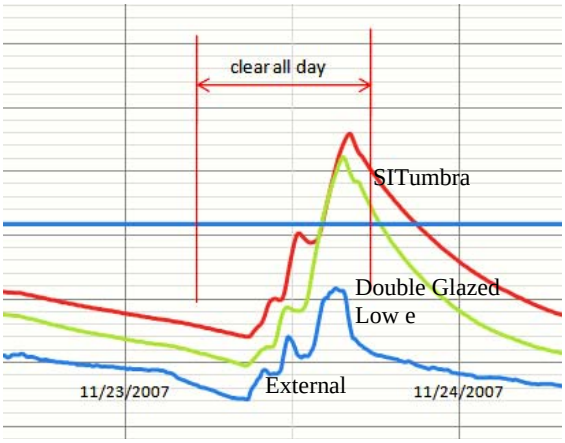

Figure 7. Typical temperature distribution with time comparison - cold day November 23, 2007 (note greater heat gain benefit in favor of SITumbra – red line)

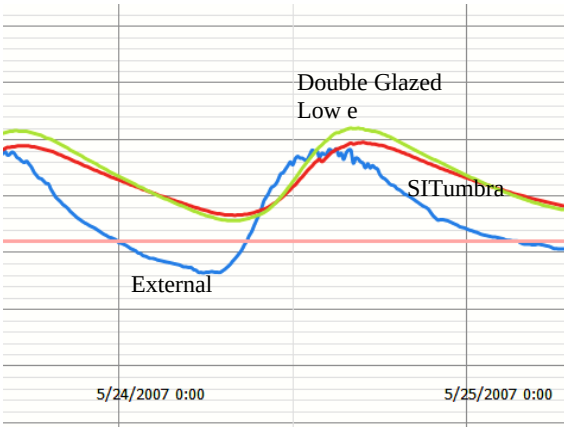

Figure 8. Typical temperature distribution with time comparison – hot day May 24, 2007 (note lower temperature shading benefit of SITumbra – red line)

Further internal heating tests were also conducted where the power used to heat the interior of the thermal chamber was measured and integrated over time. Again it was shown that SITumbra provided approximately 25% greater efficiency, since it took less energy to maintain a constant temperature between the dual chambers as noted in Figure 9 and

10. From these results it can be seen that the SITumbra product provides approximately 25% increased energy efficiency.

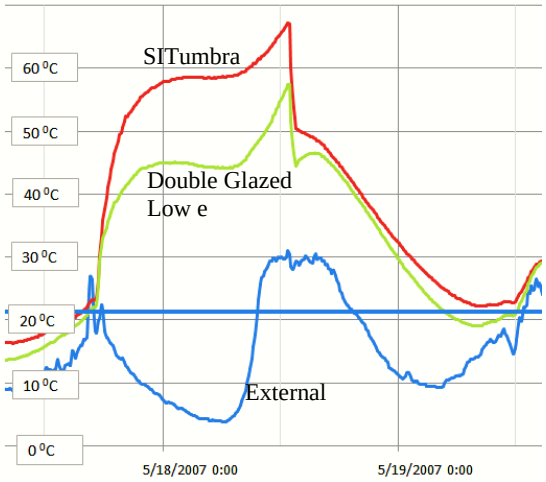

Figure 9. Controlled internal heating over steady temperature distribution with time

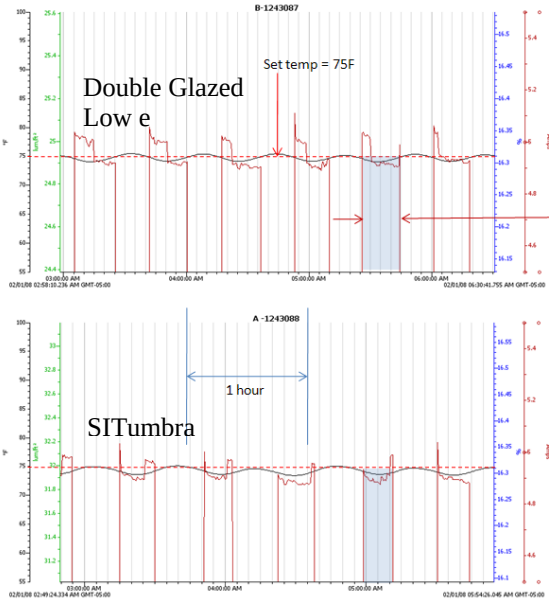

Figure 10. Controlled thermal chamber heating experimental results showing a 25% higher heating energy demand from a double glazed low e coated aluminum framed window. (Horizontal axis is time and vertical axis is heating amps measured – total energy is sum of area below the power curve).

3.3 Building design opportunities

As mentioned earlier, energy use performance of a building is the key parameter that dominates the sustainability life cycle and this relates directly to the thermal efficiency of its windows. The SITumbra product demonstrates high performance as a 'passive' moderator that optimizes the range of properties that come into play during an annual cycle between hot and cold seasons. Energy simulations also revealed that the shading effect of SITumbra favored buildings that maximize a south facing elevation, consistent with passive solar strategies with a narrow footprint. This plan shape offers the greatest benefits from winter heat gains and improved natural day lighting. Further research is being conducted to determine a time based function for the SHGC of the composite façade panel in order to make more accurate determinations, which are expected to lower energy consumption figures even further on the SITumbra product.

4 CONCLUSIONS

The goal is to provide a customizable mass product alternative to existing window systems that is both highly energy efficient and economically competitive.

The significance for emerging clean technologies is that the product is targeting windows as a major component of the primary life cycle energy use phase in buildings.

Energy conservation has a key role to play in the realm of clean technologies, as buildings being one of the key culprits in wasting energy.

SITumbra is expected to impact on the window systems market and be cost competitive due to its energy efficiency and sustainable materials component and light weight characteristics.

REFERENCES

[1] National Award Winner - Environmental Protection Agency /People Prosperity Planet (EPA/P3), 2006 National Academy of Science, Washington, DC http://es.epa.gov/ncer/p3/press/june_9_2006um.html,

[2] Energy Information Administration, (2004), "Annual Energy Review" EPA, 2003

[3] Giles H, Kim KH, "Transparent Façade Panel Typologies Based on Hybrid Bio-Composite and Recyclable Polymer Materials", ARCC/EAAE International Architectural Research Conference Philadelphia USA, 2006

[4] Robin Kent, "Changing an Industry" British Fenestration Rating Council, from http://www.bfrc.org/General_Publications-Fenestra50.htm , 2005.

[5] eQUEST Quick Energy Simulation Tool, James J Hirsh. Trademark. 1998-2004

[6] NRFC 102 "Procedure for Measuring the Steady-State Thermal Transmittance of Fenestration Systems", 2004