eBriefing

Glass Buildings: The Energy Challenge

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Posted April 06, 2009

Overview Media Resources Speakers **Meeting Report**

The vitreous high-rise tower is an icon of contemporary urban architecture. Glass-skinned buildings are often viewed as works of art by passers-by, and provide a coveted window on the world for those who work or live within. From a sustainability perspective, however, building experts and climate advocates are raising concerns about the energy performance of glassy transparent façades. New York City is weighing greener building code recommendations as the city—and the world—reconsider the built environment in the face of climate change. A study conducted for the Mayor's office concluded that 79% of New York City's total greenhouse gas emissions are attributable to energy consumption by buildings. Mayor Bloomberg's plan for a sustainable city aims to reduce these emissions by more than 30% by 2030.

On March 3, 2009, architects and engineers gathered at the New York Academy of Sciences to examine further the energy aspect of glass buildings. **Scott Frank** of Jaros, Baum and Bolles provided background on current energy codes and standards, and how recent glass designs have been able to meet them; **Adrian Tuluca** of Viridian Energy & Environmental discussed energy modeling for code compliance and how well modeling reflects reality; and **Chris Benedict**, an architect experienced in designing energy-efficient building envelopes, demonstrated calculations used to quantify a design's projected energy performance.

To set the stage for the discussion, **Nancy E. Anderson** of the Sallan Foundation asked participants to envision the arcades of 19th century Paris. Walter Benjamin, the German social historian, argued that the arcades, with their glass roofs and plate glass windows, were "the most important architecture of the 19th century." The arcades embodied two diverse faces, existing as "a primordial landscape of consumption," while at the same time reflecting and inspiring a utopian image of a new world. And where do we stand today in 21st century New York? Are fashion and consumer demand overshadowing more sustainable new building design and renovation of existing structures? Are glass-skinned buildings iconic symbols of modernity, or have they become ironic?

Behind the glass curtain

A low-e coating allows light through the glass but reflects heat.

One justification for using glass in curtain walls is the view that it adds value from a "biophilic" standpoint, Frank said. Humans have an innate affinity for the natural environment, and glass allows them to feel closer to the outdoors. As a thermal barrier however, glass is 26 times poorer than standard cellulose-based insulation. Aluminum is the material of choice for framing curtain walls due to its lightweight durability, strength, and appearance. Unfortunately, aluminum is also a very poor insulator (4800 times worse than insulation), acting as a thermal bridge through the envelope.

Curtain walls are often constructed with double-pane glass, consisting of two layers of glass with air space in between for increased insulation and energy efficiency. Transparent coatings can be chemically applied to the glass surface, acting as a mirror to reflect longwave radiation (i.e., heat), while allowing shortwave radiation (i.e., light) to pass. These low emissivity or "low-e" coatings keep heat inside in the winter and outside in the summer, without impairing visual qualities. Filling the gap between the panes with an inert gas such as argon, also reduces heat transfer without impairing visibility. Ceramic etchings on the surface of glass decrease solar gain, and therefore reduce the cooling load.

To enhance the energy efficiency of the aluminum frames, spacers or "thermal breaks" made of plastic or other materials are inserted to eliminate the direct path of the aluminum to the outside. Other technological advances for improving curtain walls include an assembly with thin transparent plastic film suspended between the interior and exterior panes, triple-pane glass, or double-skin walls (two curtain walls hung together, often with blinds in between). These glazing types are more expensive and not often used in commercial buildings.

Standards and tradeoffs

ASHRE 90.1-2004 is the predominant national standard that governs building energy performance in general, and curtain walls in particular. The standard is the basis of the Leadership in Energy and Environmental Design (LEED) Green Building Rating System. The recent federal economic stimulus package requires states that receive federal funding to implement building energy codes that are at least as strict as the latest version of this standard: ASHRAE 90.1-2007.

The ASHRAE standard includes three compliance paths:

1. The Prescriptive option lists building envelope requirements by climate zone. For New York City for example, the amount of glass in a curtain wall is limited to 40%;

2. The Envelope Trade-off option is performance based, allowing the improved energy efficiency of one envelope component to compensate for another that is below standard; and
3. The Energy Cost Budget Method is a detailed modeling approach that compares the annual energy cost of the proposed design with a hypothetical budget building prescribed by the standard. It allows tradeoffs between the façade and building systems. A non-compliant façade could be offset by daylighting to reduce electric lighting, passive solar heating from winter sun, natural ventilation, and efficient HVAC, as long as total energy cost of the proposed design is lower than that of the hypothetical code building.

Models versus reality

As previously described, energy codes allow for compliance via modeling. As examples, Tuluca highlighted the DOE-2 and EnergyPlus building energy use and cost analysis tools. Testing of DOE-2 in the laboratory, and through extensive monitoring of select buildings, indicates accuracy of ± 5% to 10%, respectively. When comparing modeling data against real-world performance, where not all information about the buildings is available, an accuracy of about 15% is reasonable. While EnergyPlus can be more accurate, Tuluca said, it is not yet ready for widespread commercial use.

Modeling performed for Code compliance assumes idealized conditions and is not appropriate for predicting actual energy use. Actual costs are over 25% higher than those than can be extracted from a model performed for Code compliance. There are several reasons for this. The Code and design models assume perfection, Tuluca explained—all equipment, insulation, and windows are manufactured exactly to standard, are perfectly installed and operated, and that there is no degradation over time. If a computer model is intended for predicting actual energy cost, all these inefficiencies need to be taken into account. There are other drawbacks of modeling for compliance. For example when including trade-offs, façades have a lifespan of 20–100 years, but lighting and HVAC controls have life spans of only 10–25 years. On the positive side, as noted earlier, modeling provides flexibility for high-performance applications (e.g., daylight harvesting, exterior shading, passive solar strategies). Tuluca noted that some requirements of the ASHRAE 90.1 standard are very stringent, but Appendix G addresses this to some extent, providing credit for advanced design strategies.

Keeping your cool in this culture of glass

In our culture, Benedict said, building a skyscraper of material other than glass is almost unheard of. Glass buildings convey a sense of power and dominance. Glass can be a metaphor for transparency, suggesting that the people and activities inside are accessible to us. People inside are delighted by the ability to see so much, so clearly, from behind a nearly invisible protection, she said. But are we getting everything we want from glass?

In an office building, solar heat gain is typically a significant problem, more so than heat loss (unless a desk is right next to the window, where despite the temperature of the room, it often "feels cold" to sit next to a 40° F surface).

Cooling load (or heat gain) is heat that must be removed by some mechanism, such as air conditioning. Calculations take into account thermal transmission through materials (from the outside in), solar radiant heat gain, ventilation, air infiltration, heat-making devices (which are substantial in an office building), and living things. Heat load (or heat loss) is the opposite, with thermal transmission occurring from inside to outside.

Using the NYAS headquarters at 7 World Trade Center as an example, Benedict demonstrated cooling load calculations using the Radiant Time Series (RTS) method load calculation spreadsheet software available from ASHRAE. Assessing one square foot of glass, she compared peak loads for the east-, west-, northeast-, and northwest-facing façades. The "U-value" (thermal resistance) of the curtain wall material, and the solar heat gain coefficient (SHGC, the fraction of heat from sunlight that enters the window), needed for calculations are available from the manufacturers.

Thermal transmission (BTU/hour) for a given area is calculated as the product of the U-value of the curtain wall material, the area, and the temperature difference between inside and outside. The situation is more complex for a glass curtain. The closer to 90° that the sun's rays hit the glass, the more solar radiation transmits through the glass. As such, in the winter, when the sun is lower in the sky, transmission is greatest.

In summer, light and heat come in through the glass curtain; in winter, though more solar energy is received than in summer, there is net energy loss through the façade.

In Benedict's examples, the peak cooling loads for the east and northeast façades occur in June and July respectively, in the mornings. For the west and southwest façades, the peaks occur in July and October, respectively, in the late afternoons. (Not unexpected, as the sun rises in the east and sets in the west). The ASHRAE spreadsheet is also useful for assessing the impact of different materials or shading on heat and cooling loads. While glass has improved over the years, shaded glass is significantly better at reducing peak cooling loads, and solid material with insulation backup reduces peaks by 90% over even very good glass.

A common approach to managing increased cooling load is air conditioning, but it is not without drawbacks, Benedict said. Air conditioning and fans consume significant energy, systems are vulnerable to mechanical failure, and may be unable to keep up with constantly changing conditions.

Other solutions to dealing with solar heat gain, in addition to low-e glass described earlier, include alterations to space and shape of the glass. Instead of vertical panes, Tuluca explained, glass can be tilted in the façade, or the building can be self-shading. Light shelves and fixed or movable shading are also useful. Benedict's examples showed significant reductions in peak loads, and more uniform loads throughout the day, when shading is introduced. While all of these solutions help address solar heat gain, they do not impact heat loss.

Glare can also be an issue, making it difficult to see computer screens and causing eye strain. People close interior blinds over the course of the day, and often fail to open them again, defeating attempts to reduce the use of electricity by relying on daylight. Light shelves can reduce glare to some extent, increasing the number of hours when shades are not needed.

Through the looking glass into the future

To close the session, moderator Michael Bobker of CUNY observed that glass skyscrapers seem to be able to meet current energy codes, albeit often as a result of tradeoffs and offsets. What then should we be addressing going forward?

> "We can't just add more glass ... Conservation has to be a main theme of the built environment. All of these materials come at a cost."

A significant problem, Benedict responded, is the daily and seasonal unevenness in the amount of solar heat gain affecting a building, which requires very sophisticated equipment to keep occupants comfortable. The best intentions of architects and engineers are often overridden by the way mechanical systems are actually used to ensure comfort.

Tuluca noted that there are geographic areas where glass façades make a lot of sense, and others where they do not. Proper application of curtain wall technology can impact energy efficiency, but usefulness varies by region and climate.

Frank stressed the need for more balanced awareness about façade choices. Simply adding more glass (e.g., triple glazing or double skin) is not the answer. Conservation must be a priority in the built environment. All of these materials come at a cost. Smelting aluminum, for example, is not an environmentally friendly process, Frank said.

Two experts in the audience suggested that not all glass covering a skyscraper needs to be transparent vision glass. In general, the more vision glass used, the more energy the building consumes, although employing daylight responsive lighting controls can counter this, if lights are subsequently used less. They recommended targeted use of vision glass in the curtain wall, employing non-vision glass that can be insulated inboard of the façade in other areas.

Benedict challenged designers to create office buildings that both provide delight and use very little energy, and to change public perception by developing new positive metaphors for non-glass envelope materials. Our iconic glass towers are at risk of becoming ironic. As New York addresses the energy challenges presented by glass-skinned buildings, Anderson said, our successes or our stumbles will be duly noted and emulated worldwide.

Open Questions

- Do we focus on the façade as a single element, or do we look at the whole building in terms of optimization?
- What happens to a curtain wall as it ages? What do we have to consider in addressing aging curtain walls? How will code requirements effect decisions about re-cladding buildings?
- How climate sensitive are new façade systems? Can advances in façade systems used in other geographic regions, such as double walls and operable windows, be applied in New York City?