Solar Reflectivity Studies
Lotte World Tower – Case Study

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Recent skyscraper designs have extensive exterior glass paneling that may cause hazardous glare to neighboring buildings or nearby traffic. Most building codes do not explicitly limit solar reflectivity in the architectural design criteria. However, for large projects or iconic structures it is prudent to evaluate the potential risk of negative affects of solar reflectivity from a proposed design.

Examples of recent problem designs include the Disney Concert Hall in Los Angeles, CA where curved metal panels reflected intense solar radiation onto an adjacent building façade. Remediation required a significant change in reflectivity of the surface finish. The Vdara Hotel in Las Vegas, NV was reported in local newspapers to produce a “death ray” due to intense solar reflections from the concave curtain wall geometry. And works of art are sensitive to solar reflectivity as noted in Texas Architect magazine. James Turrell’s Tending (Blue) at the Nasher Sculpture Garden has been closed and the bespoke skylight features tailored to filter indirect daylight to the art galleries are now subject to direct solar reflections from a new curved tower with a metallic coated glass facade.

Current tools to study the affects of solar reflectivity are limited to single ray tracing computations that do not account for accumulation nor for intensity of light. Not only are building codes silent on requirements or limits for reflectivity, but neither is any industry metric available for defining acceptable performance.

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CDC has developed a method to advance the current state of the art for solar reflectivity studies. Computational fluid dynamics (CFD) are used to emit a large number of rays and trace their trajectories inside a computational domain. The analysis allows accumulation of rays on discrete elements thus compiling an intensity value at the unique element location (Figure 1).

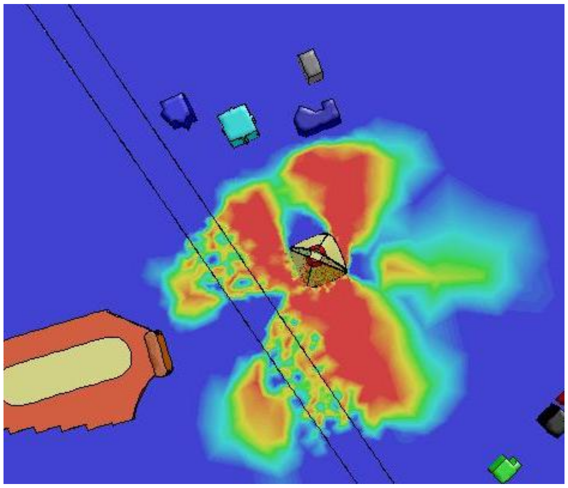

Figure 1

And, CDC has also proposed design criteria for a threshold of acceptable intensity based on comparison to common sources of light in concert with the project's environmental conditions. This information will allow the designer to make reasonable judgments regarding needed attenuation of the project glass's optical properties, or to the finishes on reflective surfaces.

To properly analyze sunlight, one must begin with a heliocentric model of the planet's movement. Important seasonal changes marked by equinox and solstice dates and solar declination will provide initial benchmarks for critical data points. Next a project-centric model is needed to begin sun tracking diagrams that illustrate exposure unique to the project location and orientation (Figure 2).

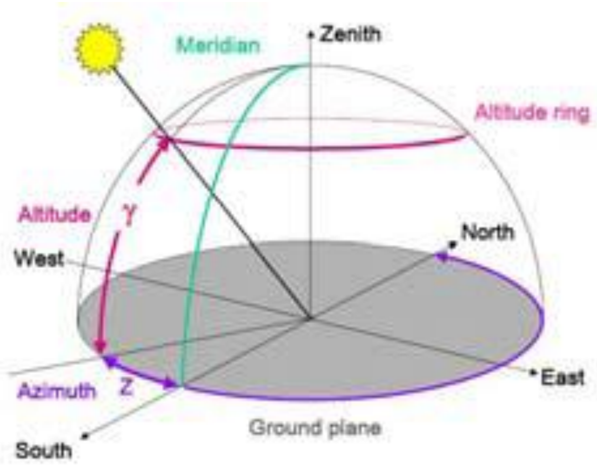

Figure 2

The model domain will require some level of accuracy with regard to surrounding environment. Adjacent buildings may shade the project at various times of daylight on certain days of the year. And conversely, roadways or neighboring facades may be sensitive to reflections bounced from the project's reflective surfaces. Engineering judgment will be needed to quantify the scope of the domain model and level of detail required to reasonably predict areas of concern.

The finite element analysis radiosity method uses a Monte Carlo ray tracing technique to inject sunlight into the model domain (Figure 3).

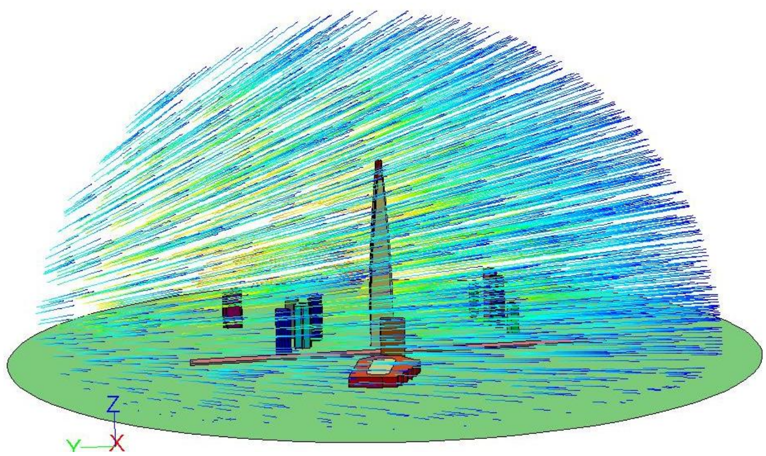

Figure 3

Only reflections from the project target are analyzed. Secondary reflection (rebound) is not included. And, only specular reflection is analyzed. Due to the enormous amount of data generated by the CFD routines, the studies will need to be guided by intuitive forecasting of critical days/times. And once hot spots are discovered, then fine tuning of the times examined can be specifically identified. Summary reporting of the voluminous data can be daunting, but compilation of salient conditions into a spreadsheet or matrix is recommended for presentation.

The next challenge is to establish some level of performance criteria to direct decisions as to acceptable behavior. Keep in mind that the overall goal is to avoid hazardous glare. Studies by David N.H. Hassall, have proposed limits particularly in regard to a cone of vision while driving a motor vehicle. And some municipalities have stated limits to exterior reflectivity of glass products. Also, the measurement of glare is subject to numerous variables, including age, eye color, eye ware, eye health, contrast, duration and weather. It is suggested here, as a base threshold, that the intensity of reflectivity measured at an individual location be limited to no more than one times the natural intensity at the project site (Figure 4).

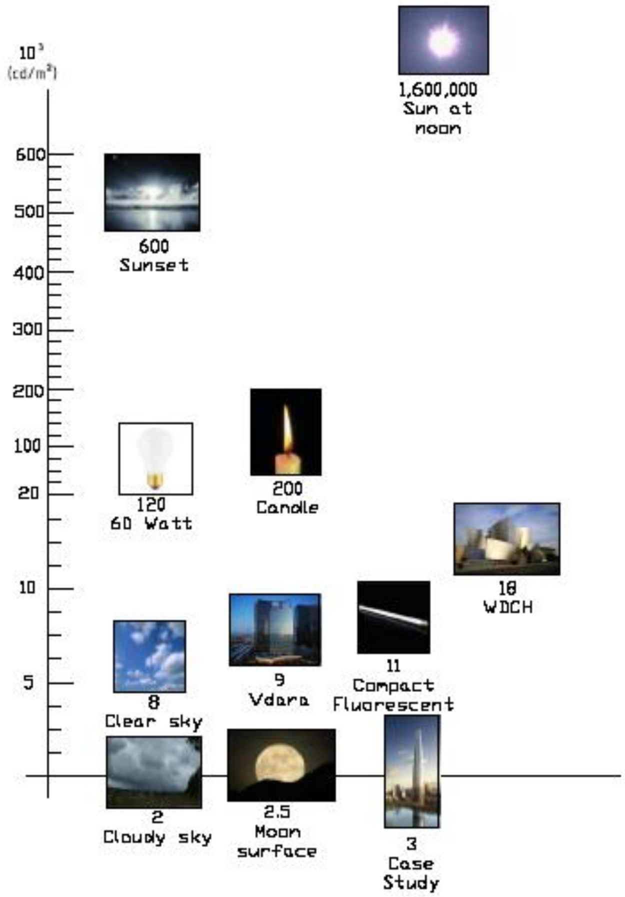

Figure 4

This threshold is reasonable because the project's areas are already receiving direct sunlight, hence setting such value as the maximum intensity limit is conservative. For example, if the glass product has a 33% exterior reflectance value and the CFD analysis results give an intensity of 1.0 at a particular location, then that area receives a reflective intensity that is only 33% of natural sunlight. And, if another location has an intensity result of 3.0, then that location is receiving a reflection equal to 100% of the sunlight.

This new CFD tool is valuable as orientation of the design can be easily rotated to search for optimum results with respect to mitigation of reflectivity. And the CFD's provision of a scale of intensity level is critical to judge the limit of primary surface reflectivity in regard to hazardous glare.

As architectural designs become increasingly complex in shape and geometry, the need for reflectivity studies is heightened. This new CFD tool is available to assist designers in making sound decisions and avoiding pitfalls of poor performance.