Urban Environmental Glare: the Secondary Consequence of Highly Reflective Materials

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ABSTRACT: This paper examines the impacts of the choice of building materials on the immediate surroundings by examining a case study, the Walt Disney Concert Hall by Frank Gehry, in downtown Los Angeles. The building apparently increased surrounding ground surface temperatures to 60 C and lightweight freestanding surfaces reached temperatures as high as 170 C (enough to melt some plastics.) Surrounding neighbors complained of increased temperatures within their buildings and visual glare. There was also visual glare in surrounding traffic intersections.
The building was studied and simulated. Several solutions were considered and two solutions were employed. The resulting changes in the building appear to have solved the problem without destroying the visual and conceptual aspects of the building. There are strong implications for future use of specular materials in downtown buildings, including negative effects offsetting the supposed benefit to the heat island effect.

Keywords: urban environment, glare, heat island, reflectance, microclimate

1. INTRODUCTION

We often examine the effect of building materials on the energy usage of our own building. We sometimes examine the impact of materials on the environment, as a whole. We rarely care about the impact of the choice of materials on our immediate neighbors. This is unacceptable, especially in urban environments.

The impact of reflective materials on surrounding buildings has been known for some time. One of the earliest cases was the Sun Valley Bank in Phoenix, AZ, which was only resolved when the bank (the new reflective building) bought the building which had become overheated by the reflections.

Furthermore, many architects believe that by reducing the thermal gain in their own building, they automatically reduce the heat island effect, without considering the impact that their building has on surrounding surfaces and buildings.

While changing the albedo or reflectance of the roof surfaces may reduce the heat island, the only demonstrable reduction has come from reducing the amount of exposed construction material, such as concrete and asphalt. Vegetation, which converts sunlight (short wave radiant gain) directly into plant mass, is the only alternative known to be effective, as long as there is sufficient moisture to keep the vegetation alive and allow evapotranspiration to limit sensible heat gain and temperature increase.[1] Similar buildings abound in most downtown areas. See figure 1.

Figure 1: Crocker Bank, Deutsche Bank and reflection of Deutsche Bank onto neighbouring building

2. THE CASE OF THE WALT DISNEY CONCERT HALL

The new Walt Disney Concert Hall provides an extreme example of this phenomenon. The initial environmental impact report was written when the building concept proposed white limestone as the finish material. When the building was changed to stainless steel, the report was simply modified by noting that the reflectance of the stainless steel was similar to that of the stone. Nothing was mentioned of the specularity. When the building was completed, it met with general approval and great excitement as a strong architectural statement. Frank Gehry was quoted as saying, “The building is frozen music.”

But shortly thereafter, difficulties began to emerge.

Figure 2: Reflection from REDCAT marquee

Surrounding buildings complained of significant temperature increases. One neighbour indicated that, "You couldn't even see and then the furniture would get really hot," said Jacqueline Lagrone, 42, who lives on the fourth floor of the Promenade Residences. "You would have to literally close the drapes and you'd still feel warmth in the house." [2]

The building is visibly reflective, especially in the area of the Founders Room and the Roy and Edna Disney California Arts Theater (REDCAT) marquee. See Figure 2.

Both of these portions of the building use a polished version of the stainless steel, which has a reflectance similar to the brushed stainless of the rest of the building, but a much greater specularity.

In addition, there were stories of melted traffic cones, trash bins set on fire and an obvious and immediate physical discomfort which could be felt when standing in the path of the direct beam sunlight converging from the concave reflective surfaces. It was also possible to observe that there was glare in at least two of the surrounding intersections which could easily interfere with traffic making a left turn through a pedestrian walkway. This was all unacceptable to the owner of the building, the County of Los Angeles. It became necessary to ascertain the real extent of the rumoured phenomena and take corrective action.

3. METHOD OF MEASUREMENT

To observe thermal behavior, Dallas/MAXIM iButton dataloggers were embedded in the surface of the concrete to the south of the building in areas where concentrated beams of reflected sunlight were observed to pass through. These recorded values every 30 minutes for two week periods around both solstices and equinoxes.

In addition, a piece of foamcore was painted dark green and suspended in midair in one of the moving beam focal points. After five minutes, the surface temperature of the foamcore was read with a RayTek infrared thermometer. This was done on several separate occasions.

To observe visual glare, photographs were taken and analyzed for glare and then computer simulations were performed for the remainder of the year, to anticipate similar glare in various locations around the building. See figures 4 and 5.

3.1 Datalogger data

The dataloggers showed that ground temperatures regularly attained 60 C (140 F). See Figure 3.

Other information became apparent, as well. The equinox values showed a different behaviour than the summer values. Upon further inspection of the site, it was found that there was a building which was shadowing the marquee at certain times of the day, during the equinox, which cut off the sun and thus also cut off the reflected and focused beams.

The temperature of the foamcore held aloft in the focal point was measured at 150C to 170 C (300F to 350F).

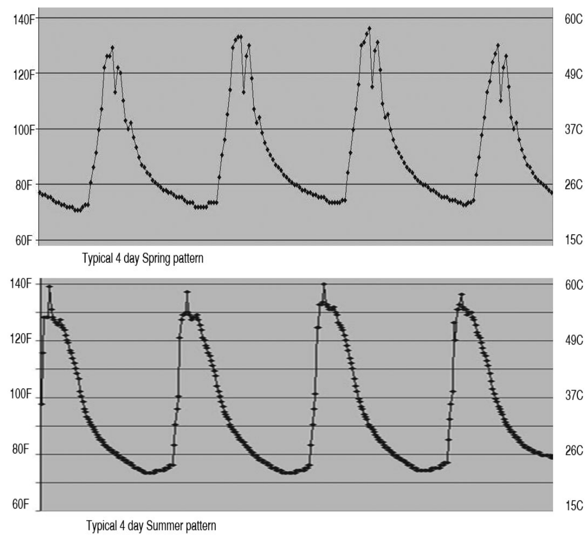

Figure 3: Four typical days in Spring and Summer

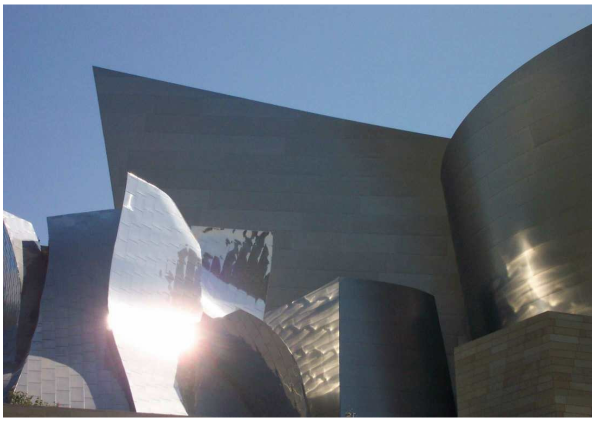

Figure 4: Photograph & Simulation of WDCH

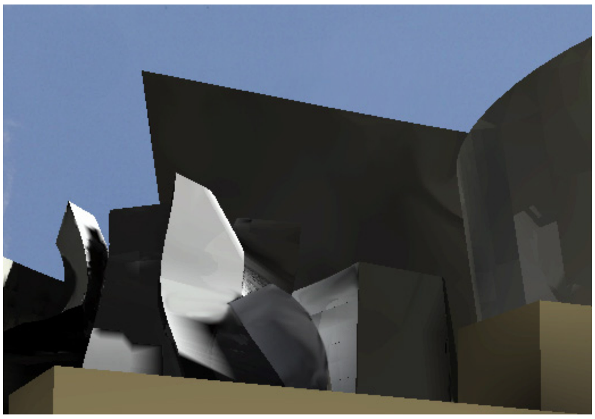

Figure 5: Simulation of WDCH

3.2 Glare data

In a new process developed by Schiler, Japee, Tedjakusuma and Culp the histograms of the photographs were analyzed to determine if the ratio of peak luminance to background (adaptation) luminances was indicative of glare.[3, 4, 5] See Figure 6. The analysis consistently showed that luminances in excess of 12,000 cd/m^2 were problematic.

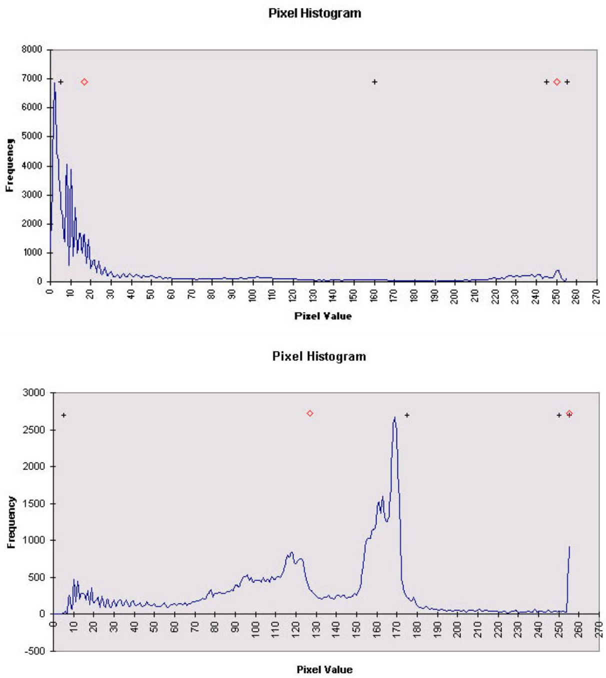

Figure 6: Histogram of relative pixel intensities distributions showing glare (above) and no glare (below) conditions.

The building was simulated from each intersection and three other critical locations at both solstices and equinox at half hourly intervals. See figures 4 & 5. Simulations were color coded. Absolute values in excess of 12,000 cd/m^2 were flagged in red so that they could be easily picked out in a visual survey and clearly delineated for corrective action. See Figure 7. Surfaces which resulted in focal points well above the ground in areas not occupied by buildings or traffic intersections were ignored.

Six surfaces on the Founders Room were deemed unacceptable. Most of the marquee proved to be unacceptable at one time or another. The other surfaces were either above the field of view or did not focus radiant energy in an occupiable area..

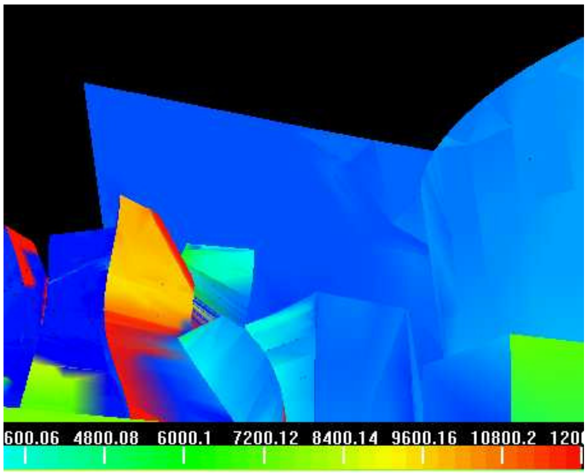

Figure 7: Isolux plot w/ 12,000 cd/m^2 flagged in red (in original)

4. SOLUTIONS

The very iconic nature of the building eliminated several possible solutions. Masking the areas of glare with billboards advertising upcoming concerts had been suggested. It would have been necessary to hide large portions of the (US$275,000,000) building. Using landscaping was suggested and considered, but there were indications that the building was killing the landscaping and several of the critical reflective surfaces were above reasonable tree height, and were reflecting across the street into even higher apartments and balconies. In this particular building, the only reasonable solution appeared to be surface treatment of one sort or another. Paint was rejected as substantially altering the character of the building, leaving only three possibilities: surface film,

Figure 8: Fabric wrapped over offending surfaces

draping fabric over the surface or treating the metal to reduce the specularity.

Three of the six surface films tested were found to be acceptable and one plastic fabric of approximately the same color as the steel was also acceptable. It was decided to use the fabric as a temporary solution, draped over the critical surfaces. This allowed verification that all critical surfaces had been accounted for, while further tests were conducted and the first season of the symphony commenced. See Figure 8.

The original polished stainless steel and the original brushed surface ("Angel Hair treatment") and four alternatives were tested using a Rhopoint gloss meter at a 60° degree angle from the surface and at a 20° angle from the surface. See Table 1. The greatest benefit in shallow angles came from the 220 Grit vibrator sanding and 100 Grit at steeper angles. The vibrator sanding was used as the base treatment. For aesthetic reasons, orbital sanding was done in addition to the vibrator treatment. The final treatment sanded all panels which had been determined to be sources of glare. See figure 9. Because of the geometries of the curved surfaces, it was often the case that only a portion of the surface needed to be sanded. In such cases, the cutoff for sanding was often a diagonal line, so the resulting sanding resulted in interesting stair-step patterns on the façade of the building, but resulting from naturally harmonic patterns instead of random placement. See Figure 10.

Figure 9: Fabric, sanded, brushed and polished surfaces against sky

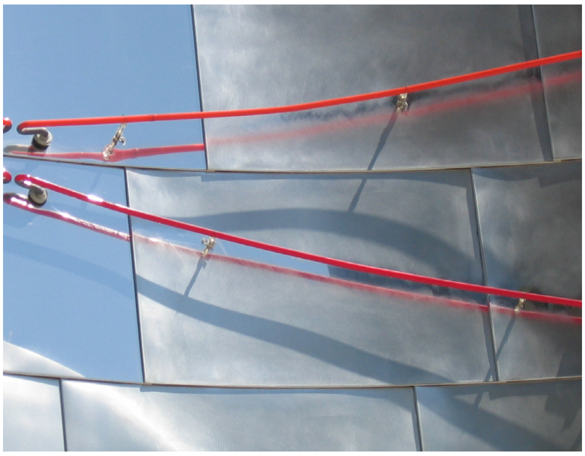

Figure 10: Sanded panels next to polished panels in diagonal stair step **pattern**

	polished	brushed	220 Orbital	100 Orbital	220 Vibrator	100 Vibrator
20°	**749 - 801**	**21 - 25**	**49 -78**	**35 – 42**	**34 – 37**	**43 – 45**
60°	**365 - 547**	**65 - 68**	**178 - 192**	**86 -132**	**100 - 113**	**81 - 85**

Table 1: Specularity of Alternative Surface Treatments in Gloss Units (GU)

5. CONCLUSION

Modern construction materials pose several kinds of difficulties for the environment despite the improvements in energy conservation they provide. This is true not only during their fabrication, or their deconstruction. Glare and heat gain from specular buildings can cause changes in the microclimate and other difficulties to public safety. It is clear that at specularity levels of 300 GU or greater, concave surfaces will be extremely problematic and even flat surfaces are questionable, depending on interference with traffic, etc. Vertical surfaces should be kept below 100 GU, when possible.

These difficulties can be avoided or remediated with proper analysis and design. [3, 4, 5]

Surface temperatures at ground level are the hardest to get rid of. This is what occurs when highly specular and reflective materials are used on vertical surfaces in an urban environment. The best solution is to use highly reflective surfaces primarily on roof surfaces, rather than creating reflective canyons which bring all the heat down to the ground plane.

Killing the landscaping is the worst possible problem with regards to the heat island effect. Reducing the internal gain at the expense of local hotspots and increased temperatures in other buildings is unacceptable. It is simply not an option to put reflective coatings on all older and historic buildings, nor is it reasonable to make them increase their HVAC in order to make up for the new buildings.

Specular surfaces must be used with great care, despite their current aesthetic popularity.

6. ACKNOWLEDGEMENT

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