

Overview of the Simulation of Non-Planar and Diffuse Fenestration Products:

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INTRODUCTION

For planar, specular transparent systems and products, simulation methodology had been developed and successfully used over the past 30 years. Program such as WINDOW and OPTICS are capable of simulating single and multiple layer glazing configurations with high accuracy. WINDOW program has been successfully used for certification of fenestration products incorporating planar, specular glazing systems, from the beginning days of NFRC. Its accuracy has been so well validated over the years that there is not even need to do any validation testing. OPTICS program has been in existence for many years, but its use in generating approved glazing layers has started only recently. Currently approved version of these software tools are WINDOW 5.2 and OPTICS 5.1.

Currently, it is not possible to simulate diffuse glazing systems with these tools, therefore, for certification, these products have to be tested. Next revision of WINDOW program 6.0, incorporate simulation methodology for diffuse glazing systems and shading devices. This is great step forward, since it will be possible to simulate these complex systems using easy to use WINDOW program. These new classes of transparent systems are being modeled using simplified methodologies (radiosity and view factor based) to approximate their complex behavior. Validation studies, conducted in the mean time indicate that they are very accurate and reliable and most likely WINDOW 6 will be approved for certified simulations in the near future.

However, simulation of the non-planar products and specular shading devices will not be possible with the WINDOW 6 program. It is not clear when in the near future it would be possible to upgrade WINDOW program to handle these systems. The geometric complexities and the lack of simplified methods are limiting factor and it appears that it will remain limiting factor for some time in the future. The redesign of the WINDOW program will have to take new directions, where the simple glazing library interface will have to be replaced with the advanced geometry editor, where exact 2-D and/or 3-D geometry can be generated and will have to be supplanted with the more sophisticated simulation engine that is closer to ray tracing methodology.

In a mean time, there is a need to provide reliable simulation of the solar-optical properties of non-planar transparent systems, namely T_{sol} , R_{sol_f} , R_{sol_b} , T_{vis} , R_{vis_f} , R_{vis_b} . At the present time, this can be accomplished by using proven ray tracing based computer programs. The two major programs are used by researchers in United States at present. Lawrence Berkeley National Laboratory (LBNL) researchers, Dr. Mike Rubin and Dr. Jacob Jonsson use TracePro (Lambda Research, <http://www.lambdares.com>). Dr. Ross McCluney from the Florida Solar Energy Center uses ASAP program (Breault Research Organization or BRO, www.breault.com). Both

organizations have used these programs to model diffuse and non-planar fenestration products with great success. These programs are commercial software tools and are sold on the market. They are quite expensive and they include appropriate user and technical support.

Another approach has been developed at the National Research Council of Canada (Laouadi and Atif 1998). Approximate equations were developed for domed, barrel vault and pyramid configurations. However, it appears that these models do not provide capability to specify exact geometry of the system and it also appears that they do not account for inter-reflections between glazing layers, being suitable for single layer system analysis. This methodology had been incorporated into the software tool SkyVision which is available at no cost from the NRC Canada web site. The applicability of this tool is more for the design and energy performance analysis and less for the rating of exact configurations.

The accompanying papers to this overview provide more details about the ways these programs have been used in the past, their methods as well as validation of these tools. The full listing of relevant papers is listed in References section.

PROPOSED SOLUTION

From these materials it can be concluded that with the proper setup and with the expertise of the simulator, both programs can be reliably used to model non-planar fenestration products. Because of the program's complexity, the simulator would need to have proper education and experience.

To minimize potential for errors, templates could be developed, which would simulate performance of the test apparatus. Geometry of the domain, detector placement, density of rays, specimen opening, and any other relevant details would be fixed in a template. We can call this template "Virtual Optical and Solar Test Apparatus" or VOSTA. Simulator would then prepare geometry of the non-planar system and material optical properties (measured separately) and would "insert" into the VOSTA template and run simulation. After the completion of simulations, results would be interpreted in a standardized way, which would also be incorporated into VOSTA. In other words, the post-processing unit would be developed that would produce bi-directional matrices for the transmittance, and front and back reflectance in solar and visible portion of spectrum, as well as normal incidence values.

SHGC and VT from these results can be obtained by incorporating these results into WINDOW program and applying thermal algorithms to calculate SHGC. The thermal algorithms for domed skylights and other systems incorporating curved glazing have been developed in a separate NFRC research project.

The question remains who would accredit laboratories and simulators to perform these kind of simulations. Naturally, this would be done under the auspices of the APC. Because of the high level of expertise, NFRC APC can rely on highly qualified experts, such as Dr. Rubin, Dr. Jonsson, Dr. McCluney, etc. to run train the trainers workshops and to assist in accrediting other individuals that may want to become certified simulators for Non-Planar solar-optical properties.

REFERENCES

- Andersen, M.; Rubin, M.D.; Powles, R.; and Scartezzini, J-L. 2005. „Bi-directional transmission properties of Venetian blinds: experimental assessment compared to ray-tracing calculations.” *Solar Energy*. Vol. 78, pp 187-198.
- Andersen, M.; Rubin, M.D.; and Scartezzini, J-L. 2003. “Comparison between ray-tracing simulations and bi-directional transmission measurements on prismatic glazing” *Solar Energy*. Vol. 74, pp 157-173.
- Laouadi, A. and Atif, M.R. 1998. “Transparent domed skylights: optical model for predicting transmittance, absorptance and reflectance”. *International Journal of Lighting Research and Technology*, V. 30, no. 3, pp. 111-118.
- McCluney, W.R. 2001. “Test/Measurement Procedure Concept Paper: Tubular Daylighting Devices”. *FSEC Report for NFRC*.
- McCluney, W.R. 2007. “Overview of Ross McCluney’s Ray Tracing Work”. Summary prepared for NFRC Non-Planar TG.
- Rubin, M.D.; Jonsson, J.K.; Kohler, J.C.; Klems, J.; Curcija, D.C.; and Stojanovic, N. 2007. “Bidirectional Optical Properties of Slat Shading: Comparison Between Raytracing and Radiosity Methods” *Solar Energy*. Submitted for Publication.