IEA SHC Task 27: SkyVision: A Software Tool to predict Skylight Performance

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Introduction

Skylights can offer useful benefits in reducing building energy consumption, and improving building occupants satisfaction. Skylights can also offer interesting features in increasing building market values by giving aesthetic look to buildings, admitting natural light indoors and connecting building occupants to the outside world. While skylight features are fully exploited, their benefits are still not fully understood and accounted for in currently available computer tools. Research has shown that skylights may result in high-energy consumption if not properly designed. The SkyVision software aims to assist skylight manufacturers and building designers to come up with an appropriate skylight design for a given building and use. The software analyses the optical characteristics of skylights of various shapes and types, and calculates their daylighting and energy performance. Skylight manufacturers are able to precisely specify, build and rate skylight products. Building designers, architects, or engineers are able to select skylight products that meet a given design requirement. The benefits of skylights may be maximized by accounting for the skylight shape and glazing, lighting and shading controls, curb/well geometry, building location and orientation, and prevailing climate.

About the SkyVision Software

SkyVision is an easy-to-use, Microsoft Windows™-based computer program developed by the National Research Council Canada in partnership with Natural Resources Canada and Public Works and Government Services Canada. The software calculates for a given design day, the overall optical characteristics (transmittance, absorptance, reflectance and Solar Heat Gain Coefficient) of various skylight types, performance indicators of skylight/room interfaces (well efficiency and coefficient of utilization), indoor daylight availability (daylight factor and illuminance) and lighting energy savings. It is intended for use by skylight and curb manufacturers, building designers, architects, engineers, fenestration councils, and research institutions.

Features

The SkyVision software features the following:

- Detailed calculation of skylight optical characteristics and indoor illuminance.
- Uses state-of-the-art glazing optics calculation models.
- Uses ray-tracing-based modelling to compute the skylight optical and daylighting performance.
- Automatically tracks changes in the design inputs and compares corresponding design output performance.

- Present results in graphical or tabular formats that can be used as inputs for third-party software such as building thermal simulation software.
- The choice of working in two unit systems: English (IP), or International (SI).
- Uses an attached glass product database to build skylight products.
- Uses a climate file database to simulate scenarios with real, dynamic sky conditions.
- On-line hep.
- Incorporates automatic lighting and shading controls.

Calculation Engine

SkyVision's calculation engine is composed of four sets of modules: glazing optics modules that compute the optical characteristics of a composite glazing pane (substrate with/without coating) and glazing assembly (set of composite panes separated by an air/gas space) at a given incidence angle; skylight optics modules that compute the overall skylight optical characteristics; daylighting modules that compute indoor illuminance distribution and related quantities; and sky models that compute sky luminance distribution. These modules feature the following:

- The monolithic and one-layer, thin-film coating models are used to compute the optical properties of a composite pane at oblique incidence angles for each light polarization component.
- Ray-tracing based models to compute the overall optical characteristics of representative skylight shapes.
- The newly-developed concept of the Shape Parameter is used to compute the optical characteristics of skylight shapes other than representatives.
- The newly-developed zonal model, in which the space below the skylight is split into a number of vertical, four-surface (floor, walls, ceiling and opening) zones, is used to calculate the diffuse and inter-reflected components of surface light fluxes. Ray-tracing technique is used to compute the direct component of surface light fluxes.
- CIE/IES standard sky condition and the climate-based (Perez et al.) models are implemented.

Inputs

The input parameters include the site location, sky conditions, skylight shape and glazing, indoor space geometry and surface characteristics, and control strategies of the lighting system and shading devices.

Site Location

The user specifies the site latitude, longitude, and time zone (or, choose from a database of major Canadian and US cities), and the ground/surroundings reflectance values.

Sky Conditions

Two sets of sky condition models are implemented - luminance-based and illuminance-based models. In the luminance-based models, the sky relative luminance pattern is known. However, in the illuminance-based models, the illuminance on a horizontal surface is known. Luminance-based models are more accurate and computationally expensive. For both sets of models, the user may specify standard skies that are site-independent, or dynamic real skies that change with daytime. Standard sky conditions may be uniform overcast, CIE overcast, CIE intermediate, IES partly cloudy, CIE clear with polluted air, CIE clear with clean air, or dynamic (Perez et al. model).

Skylight Shape and Glazing

Users may specify various skylight shapes found today in the market. Skylight shapes are classified into five categories: dome-like, cone-like, vault-like, light pipe and flat. Under each category, one can simulate a number of shapes. For example, for dome-like skylights, one can simulate circular domes, segmented domes, square-based bubbles, or any other similar shape. Skylight glazing may be multi-pane transparent or translucent. An attached glass database allows users to build skylight products from certified manufacturer glass products. Users may also add their own glass products to the database.

Indoor Space Geometry and Surface Characteristics

The indoor space is composed of the curb (space between skylight and roof), well (space between roof and ceiling) and room (space below ceiling). The user specifies the dimensions of the curb, well, and room spaces, the indoor surface reflectance values, the building orientation, and the skylight position layouts.

Lighting and Shading Controls

Users specify the lighting control strategy (on/off auto, or continuous dimming), the type and position of the shading devices (fixed or movable), and the shading control strategy (time clock, on/off auto, or adaptive).

Outputs

For a given set of design parameters identified in the input process, the software calculates the following quantities:

- The skylight overall optical characteristics (transmittance, absorptance, reflectance and Solar Heat Gain Coefficient) as a function of the incidence angle and daytime hour. The hemispherical values of the skylight optical characteristics are also calculated under a given sky luminance distribution pattern.
- The daylight factor at room floor, ceiling and wall surfaces under a given sky condition.
- Total illuminance from sun beam and sky diffuse light at room floor, ceiling and wall surfaces.
- The well efficiency and coefficient of utilization.
- Percent of the room floor surface under adequate illumination levels at a given daytime hour.
- Percent of daily lighting energy savings.

Typical Results

Figure 1 shows the main screen of the software. It is composed of three sections: the left section encompasses the tools to specify the inputs; the middle section displays the skylight optical characteristics; and the right section displays the daylighting and energy performance. The results displayed in the main screen are for a given daytime hour. Users can also use the graph facility to plot the results and get more details on a given output parameter. Figures 2 and 3 show typical plots of the skylight optical characteristics and indoor illuminance.

Comparing Skylight Designs

Beside the detailed analysis of the optical characteristics of skylights and the resulting room illuminance distribution, the software provides users with a useful feature that allows them to compare different design options based on built-in criteria. Figures 4 and 5 shows typical skylight product and performance comparisons.

Beta Release V1.0

The fist beta version of the software is to be released in the Fall of 2002. A web site (www.nrc.ca/irc/light) will be created for downloading the software and for more information on future releases.

Contact and Feedback

Comments and suggestions are appreciated, and may be directed to the address below. All mails received will be read, though you may not always receive a personal reply. The benefit of having sent such a message will be improved software that will benefit all.

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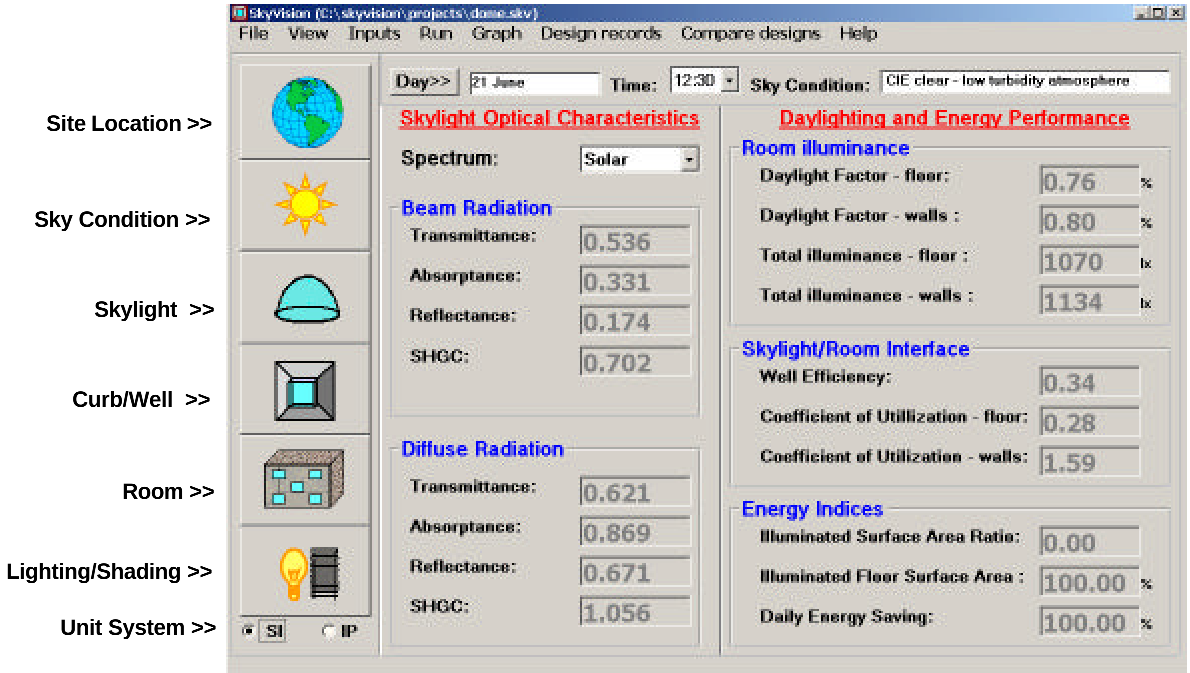

Fig. 1: The main screen of the software. The results are shown at noontime hour of a typical summer, sunny day (21 June) in Ottawa (latitude 45° north), Ontario Canada. The skylight is double clear dome with a fixed diffuser placed at ceiling level (transmittance = 0.8). The building is 3m (width) x 3m (length) x 4m (height) with curb/well height of 1.2m and a skylight opening area of 1m^2. The skylight optical characteristics are based on the incident flux on the horizontally projected surface area of the skylight. At low sun altitudes, for example, the transmittance or SHGC may be higher than unity as the incident flux on a horizontal surface tends to zero. The energy indices indicate the degree of daylighting saturation (through the percent of the illuminated floor surface area) and the lighting energy savings, and consequently the cost effectiveness of the lighting control system. The shown energy savings are based on a set point illuminance of 200 lux at room floor level.

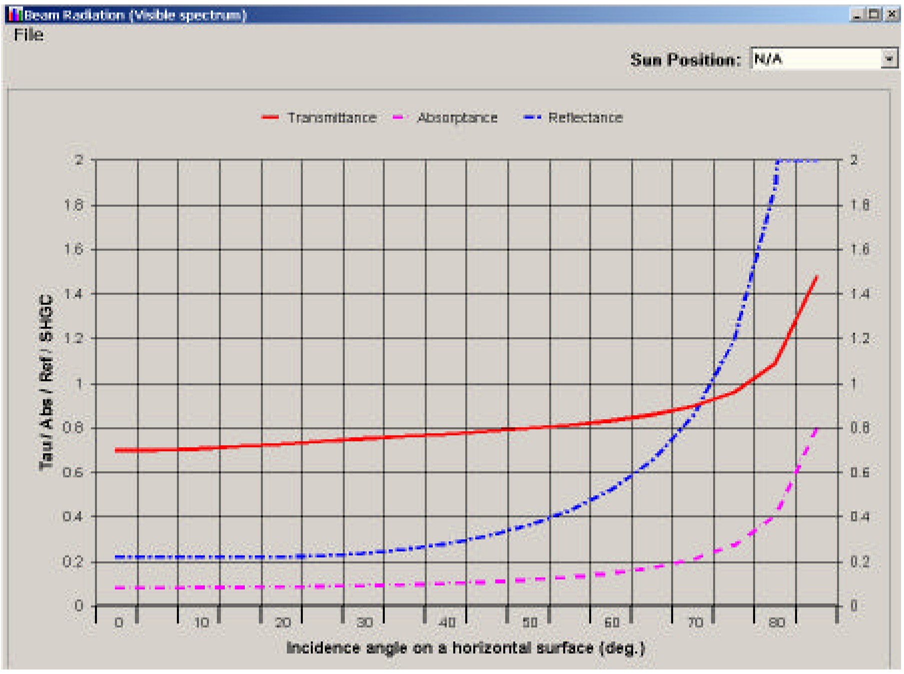

Fig. 2: Optical characteristics of a double clear hemispheric dome. Domes have an interesting feature of increasing the light transmittance as the sun moves from high to low altitude angles. For example, at noontime in the Ottawa city, clear domes transmit about 22% more daylight in winter than in summer days.

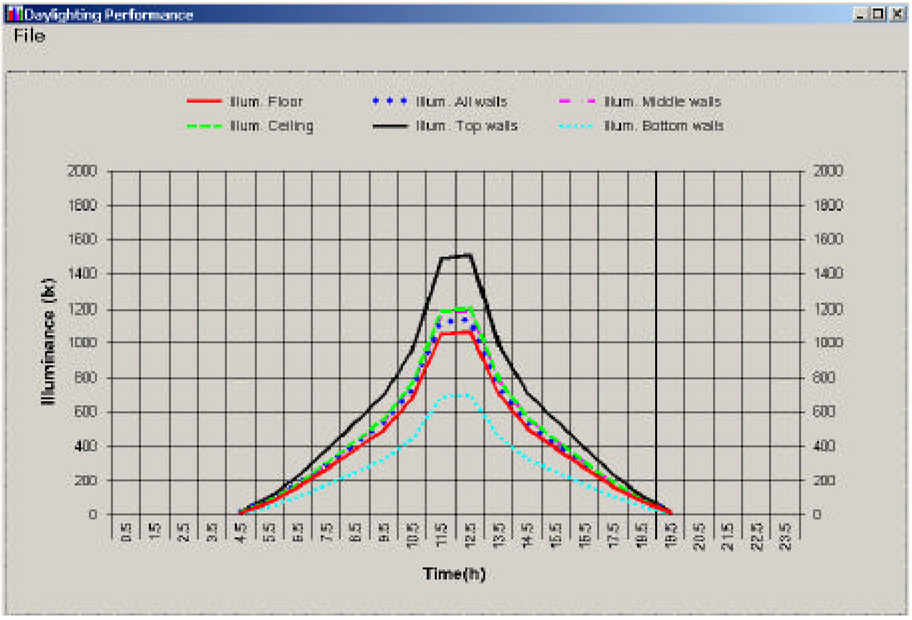

Fig. 3: Indoor total illuminance (from sky diffuse and direct sun light) variations with daytime resulting from a double clear domed skylight with a fixed diffuser placed at ceiling level. The results are for a typical summer, sunny day (21 June) in the Ottawa city. The building is 3m (width) x 3m (length) x 4m (height) with curb/well height of 1.2m and a skylight opening area of 1m^2 in the roof center. The graph shows the illumination levels available at the room floor surface and at different heights normal to the room walls, which are useful for daylighting design of the adjacent spaces. Similar graph for the Daylight Factor (for diffuse light only) may also be obtained.

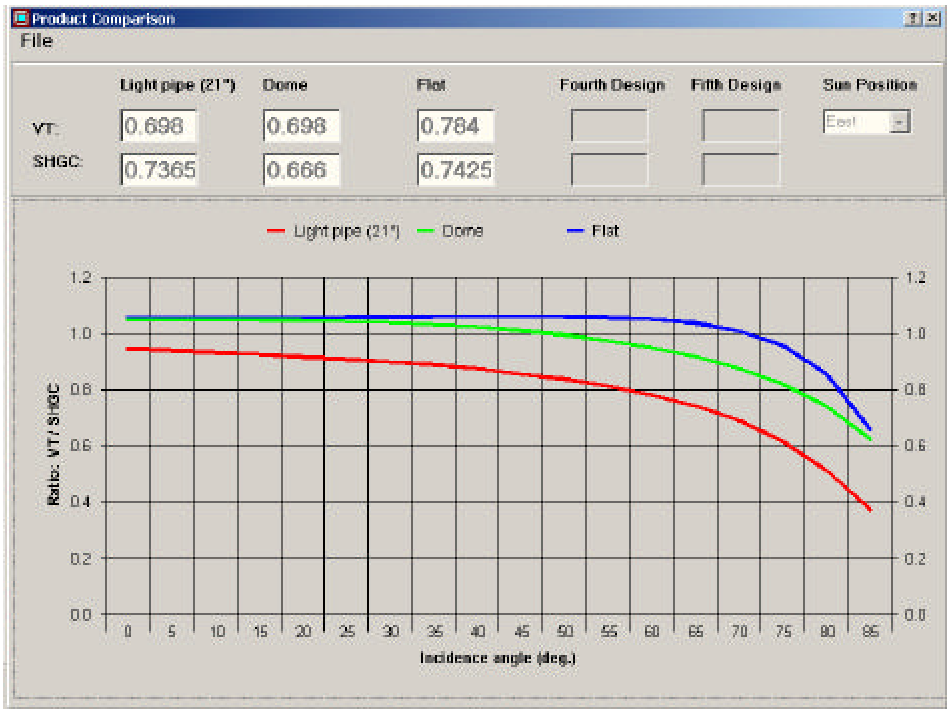

Fig. 4: Comparing skylight products based on the visible transmittance (VT) and solar heat gain coefficient (SHGC): double clear flat skylight, double clear hemispheric dome, and light pipe (21" diameter and 4' length). Domes offer an additional feature of admitting more solar heat gains at low sun altitudes (typical winter days) compared to similar fat skylights.

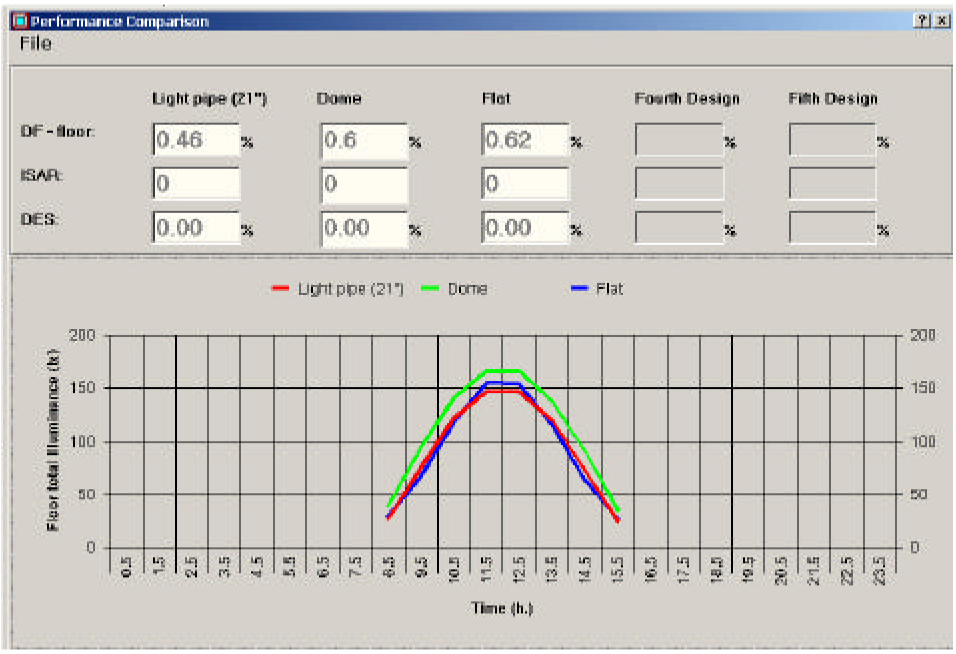

Fig. 5: Comparing skylight performance based on the daylight factor on the room floor surface and the illuminated surface area ratio (ISAR) calculated at noontime hour for diffuse light (direct sun beam light is excluded), the daily profile of the total floor illuminance from sky diffuse and direct sun beam light, and daily lighting energy savings (DES). The results are for a typical winter, sunny day (21 December) in the Ottawa city. The building is 3m (width) x 3m (length) x 4m (height) with curb/well height of 1.2m and a skylight opening area of $1m^2$ in the roof center, except for the light pipe (opening area = $0.22m^2$). A diffuser (transmittance = 0.8) similar to that of the light pipe is used with the flat and domed skylights. Light pipes with about 4.5 times smaller opening surface area provide approximately the same illumination levels as conventional skylights when the latter are used with a similar light diffuser placed at ceiling level.