USE OF IEA-SHC TASK 21 C BENCHMARKS TO ASSESS PERFORMANCE OF LIGHTSCAPE 3.2 IN DAYLIGHTING CALCULATIONS,

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ABSTRACT

In this paper, we use the validation test cases initialized within the subtask C, "Daylight design tools", of IEA SHC Task 21, "Daylight in buildings" to assess the accuracy of a commercial lighting software, Lightscape 3.2.
We first analyzed the applicability and the limitations of the IEA 21 test cases, and we concluded some directives for validation test cases in order to guaranty its applicability to assess any lighting software.
Then we compared the results obtained with Lightscape 3.2 to the IEA 21 benchmarks in order to assess its performance in daylighting analysis and to position it among the other tested softwares. This comparison showed that Lightscape is in most cases within an acceptable range of accuracy compared to the other tested software programs, with a tendency to increase illuminances resulting of façade openings and to decrease illuminances resulting of roof openings. Results also showed that Lightscape has a remarkable limitation to simulate correctly the contribution of external ground to internal lighting.

KEYWORDS

Lighting, simulation, software, validation, benchmarks, Lightscape.

INTRODUCTION

An important international validation work have been conducted within the subtask C, "Daylight design tools", of the IEA Task 21, "Daylight in buildings", between 1995 and 1999. This work included a set of benchmarks between experimental measurements in scale models placed in artificial skies and computer simulation results from the following daylight computer programs: Radiance, Superlite, Genelux, Adeline and LESO-Dial.(Fontoynont, 1999). Results showed that lighting simulations are very sensitive to the input file parameters including light source description, material photometry and building geometry.

The importance of this work is mainly due to the lake of similar validation references, what makes it useful to verify its applicability to other lighting softwares. Therefore, we decided to test the IEA test cases with a certain lighting software, Lightscape 3.2 (Maamari, 2000).

Lightscape is a lighting and visualization application that uses both radiosity and ray tracing algorithms where only the radiosity solution is considered for the quantitative results. It is also important to note that Lightscape has a remarkable friendly user interface, which makes it largely used in the fields of architecture, artificial lighting calculations and 3D renderings (Autodesk, 1999) (Maamari, 2000).

COMPARISON OF LIGHTSCAPE TO THE IEA 21 BENCHMARKS

Preparation of Lightscape simulations

In order to apply the IEA 21 test cases on Lightscape, we started by constructing the geometry as per the description in (Fontoynont, 1999, Laforgue, 1997) and with reference to the original working documents for some missing or confusing details. The reference sky luminance distribution is the CIE overcast sky (CIE, 1990), and it was represented in the Lightscape simulations by a cloudy sky with 0 Lx for sun illuminance (Maamari, 2000, Pezzana, 2002). Surfaces are supposed to be ideal diffusive. Further details on parameters used, on calculation time and on complete results are available in (Maamari, 2000). The comparison is based on the Daylight factor values at a certain number of measurement points.

BRE simple atrium scale model

The BRE simple atrium is a square room (12.125 x 12.125 m) with 24.5m height. Different tests were defined by changing the floor position over 7 different levels, with 3.5m difference. A full opening (12.125 x 12.125 m) was left on the top (Figure 1). The scale model used for measurements was build at a scale of 1/25. Four different surface reflectance were used simultaneously: 4% (black), 30% (dark gray), 48% (light gray) and 85% (white). The sensor was placed in the center at 75cm height from the tested level floor. To represent the sky luminance distribution, the scale model was placed in a square mirror room of 4.5 x 4.5 m dim. with lamps placed over a diffusing ceiling. The different software programs of the IEA report simulated a CIE standard overcast sky.

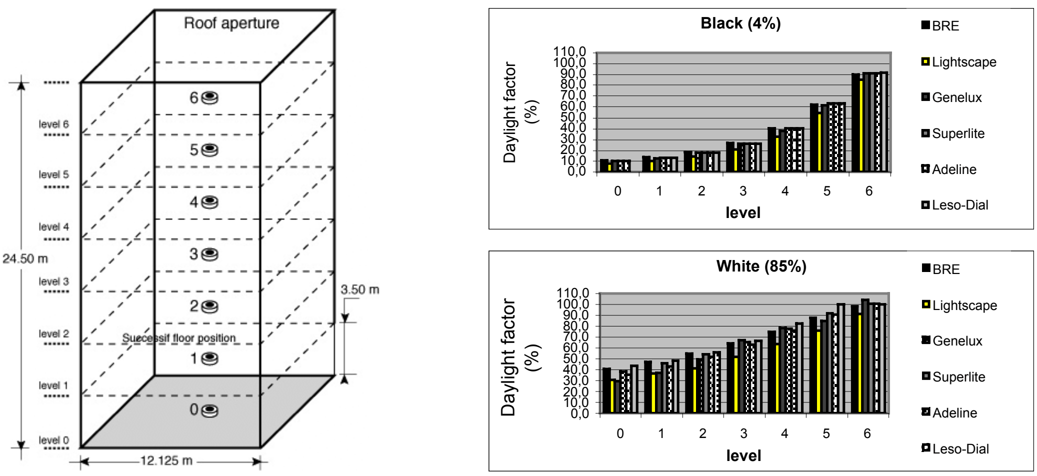

Figure 1: Geometry description and Benchmark results for the black (4%) and the white (85%) atriums (compared to measurements in BRE scale model)

Results show that the difference in percentage between Lightscape simulation and the scale model measurements increases with the deepness of the atrium (with lower daylight factors). This difference is always negative and varies from – 6% to – 40%.

Compared to other computer programs, Lightscape results present higher differences with the scale model measurements. Despite the extreme simplicity of the geometry, remarkable differences are sometimes observed between simulation results of other tested tools.

The test case is useful to assess computer simulation in regard to diffuse inter-reflections, but it represents the following limitations: Assuming surfaces to be ideal diffuse in computer simulations represents an error source of about 5% for direct lighting (Fontoynont, 1999), The uncertainty in measuring the surface reflectance can also be an important source of errors for indirect lighting. Another limitation for similar test cases is that the artificial sky luminance distribution is rarely 100% equivalent to CIE standard overcast sky. Face to these limitations, and in the case of simple geometries, defining validation test cases with analytical references can be a more reliable solution (Maamari, 2002a).

BRE complex atrium scale model

In the BRE complex atrium, adjacent rooms, (10.16 x 11.26 x 3.15 m), were added at each level of the simple atrium, and the atrium floor was fixed at level 0. Openings were added to the rooms from the atrium side. Movable separation partitions were placed in the middle of each room (Figure 2). For the atrium walls and floor two different surface reflectance were used: 4% (black) or 82% (white). The side room surfaces were 82% white for the ceiling and walls, 13% for the floor, 32% gray for the front of the partition, 82% white for the back of the partition and 4% black for the back wall. Six sensors were placed at levels 4 and 6 on the room floor (0cm height), three from each side of the partition, and at a distance of 2.88 m from the side wall. The sky luminance distribution used is the same as for the simple atrium.

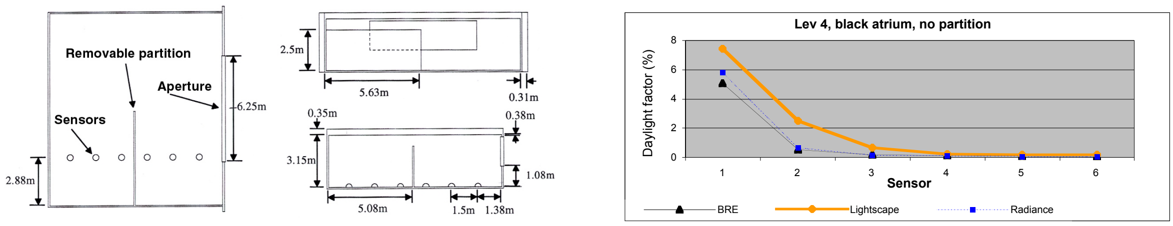

Figure 2: Geometry description and Benchmark results for level 4, black atrium, no partition

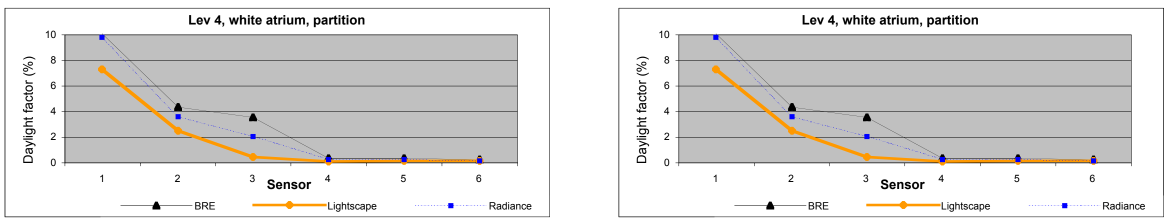

Figure 3: Benchmark results for level 4 with white atrium with and without partition

In most simulated cases Lightscape results represent high differences compared to both scale model measurements and Radiance simulations. Note that Radiance is a scientific computer program known by its capacity to simulate accurately complex scenarios, but also known to require long experience and complex preparations as well as high time consumption.

In addition to the uncertainty in defining the surfaces photometry and the sensors position and height, the simulation of this test case is faced by multiple error sources as it requires to take into consideration the following different aspects of light propagation: Daylight entry to the atrium, indirect reflections in the atrium and from the atrium walls into the room surfaces through the aperture, the inter-reflections inside the room and the internal obstruction influence; What limits the reliability of the test case to be used with other computer programs.

ECAD/CSTB scale model

The ECAD scale model represents, at a 1/10 scale, a square room (9 x 9 x 3 m). Three different opening's combinations were tested: with side opening only, with roof opening only or with both side and roof openings. Surface reflectance used in the room: 30% for the floor, 50% for the walls and 70% for the ceiling. Ten sensors were placed in the room as shown in the figure 4. The artificial sky at the CSTB lab is a square mirror room of 4.5 x 4.5 x 1.95 m dim, with nine sets of lamps over a diffusing ceiling. The different software of the IEA report simulated a CIE standard overcast sky.

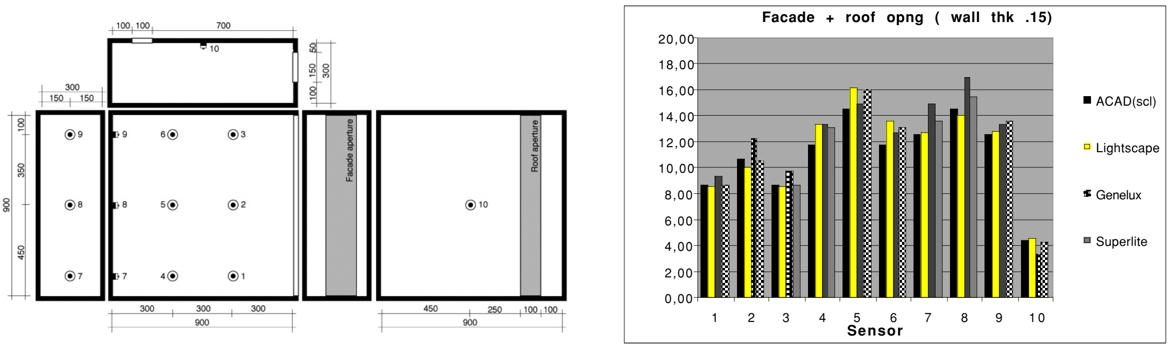

Figure 4: Geometry description and Benchmark results for simulations with both roof and facade openings including wall and roof thickness (compared to measurements)

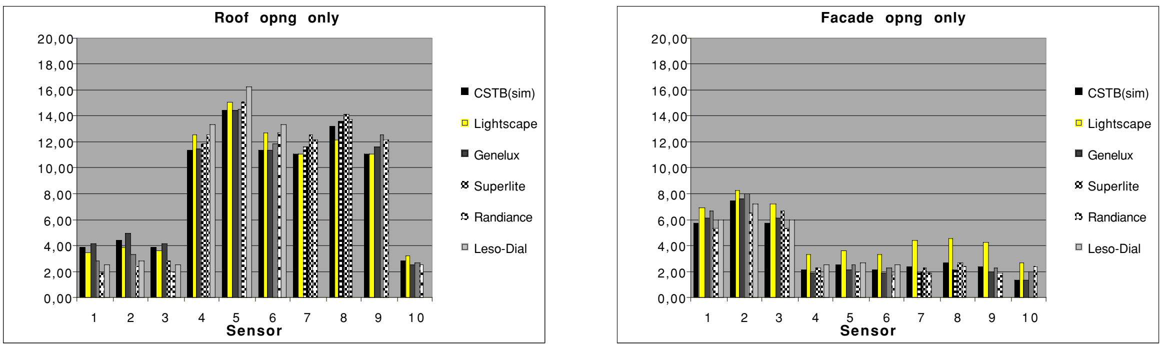

Figure 5: Benchmark results for simulations with roof opening only and with facade opening only (compared to CSTB simulations)

The last two benchmarks are not reliable to assess the accuracy of Lightscape or any other tools except based on the known accuracy of one or more of the tested computer programs and supposing that the reference simulation is conducted by an experienced user in order to obtain the maximum accuracy that the software can give.

In our case, if we take the Radiance results as a reference, it appears that Lightscape tends to decrease daylight factors under roof openings and to increase them under wall openings, which meets the conclusions obtained from the BRE test case and from (Maamari, 2002a).

In the first Benchmark comparing computer programs to scale model measurements, Lightscape is very well positioned among other tested tools despite the above mentioned conclusions. Most probably, the fact of having both openings makes that positive errors due to wall opening compensates negative errors due to the roof opening; What proves that for validation purposes, it is recommended to minimize interfering error sources. Note that in this test case, the limitations of scale model measurements might be majored by not taking external ground into consideration.

LESO/EPFL scale model 2

The LESO-2 scale model represents a simple rectangular room (6.5 x 3.05 x 3.05 m), with a full side opening (3.05 x 3.05m). An external ground was considered with a surface reflectance of 1% or 30%. The surface reflectance used in the room is 28% for the floor, 60% for the walls and 83% for the ceiling. Nine sensors were placed in the room as shown in the figure 6. The artificial sky at the LESO laboratory represents 1 / 8th of a sky dome. Experimental measurements are obtained by addition of illuminance obtained simultaneously from eight rotations of the scale model. Both isotropic and CIE overcast sky were simulated, in this report we will expose only the last one.

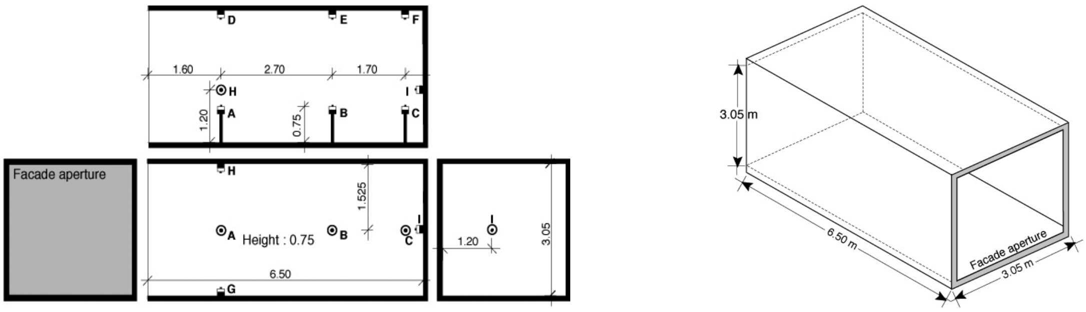

Figure 6: Geometry description

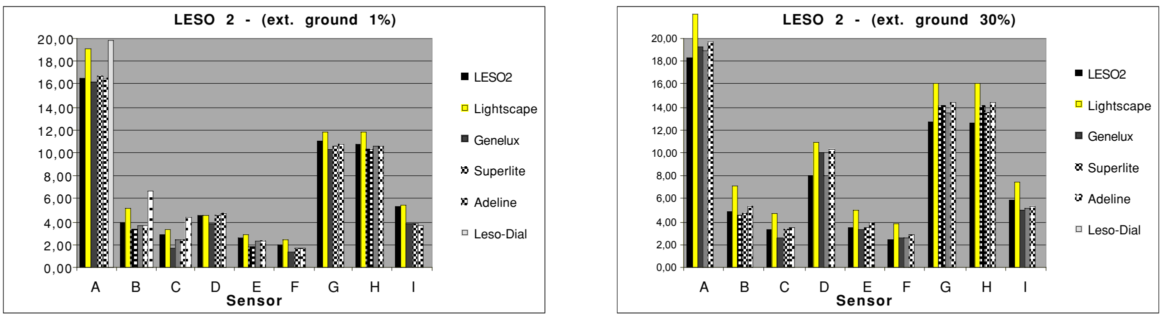

Figure 7: Benchmark results for external ground of 1% and 30% refection

The above benchmark results (Figure 7) show again that Lightscape tends to increase direct lighting due to wall openings (points A, B, C G and H), and show that it has a major limitation to simulate correctly indirect reflections from external ground (larger range of errors for points D, E, F, G and H with 30% external ground)

Also for this test case, and face to the limitations of the scale model measurements including the uncertainty in the accuracy of the sky luminance distribution and the external ground description, it is recommended to replace the scale model measurements by analytical references, what we have done in (Maamari, 2002b).

CONCLUSIONS

The IEA 21 benchmarks helped us to verify Lightscape 3.2 limitations in simulating daylight entry through apertures: it reduces the luminous flux entering through roof openings, and increases the luminous flux entering through wall openings. We observed another Lightscape limitation in simulating external ground influence on internal lighting.

Since it is usually costly to realize new experimentations, it is important, when defining validation test cases, to guaranty its usability at any time by any user of any lighting software. Therefore, and based on the limitations we identified in the IEA 21 test cases, we concluded the following directives for defining reliable validation test cases:

1. Test cases should include a minimum of interfering error sources, and should use analytical references when possible. 2. The description of a test case should be accurate and complete including geometry description, position of sensors surface photometry in addition to the experimental procedure and its estimated accuracy (i.e. Method and instruments used to define surface reflectance, to take measurements…). 3. The external luminance distribution should be described accurately, potentially by using calibrated fisheye photos (Dumortier, 2001) (Roy, 1998). 4. References should avoid low levels of illuminances. 5. Test cases descriptions should be made available for potential testers with DXF files if possible (through a website…). 6. It is also important to join to the results of simulations with different tested tools the parameters used, the users experience, the date of tests and the version of the computer program used….

These directives are being discussed and elaborated within the CIE Technical committee 3.33.

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