ESL-HH-85-09-03

DAYLIGHTING ANALYSIS THROUGH SCALE MODEL, FULL SCALE MEASUREMENTS AND COMPUTER ANALYSIS FOR A TEXAS A&M UNIVERSITY CAMPUS BUILDING

Kang-Soo Kim
Doctoral Student of Architecture
Texas A&M University
College Station, Texas

Dr. Lester L. Boyer, P.E.
Professor of Architecture
Texas A&M University
College Station, Texas

Larry O. Degelman, P.E.
Professor of Architecture
Texas A&M University
College Station, Texas

ABSTRACT

In the first part of this study, daylighting levels in an actual classroom are compared to scale model measurements and to computer program predictions.

Secondly, the daylighting effects in the building atrium are examined through the studies of an actual building and of a scale model. Results are reported about how these data compare to each other.

INTRODUCTION

In office and classroom buildings the lighting systems can account for over half of the annual energy consumption for the building. With increasing energy awareness, daylighting has received a great deal of attention in terms of building design. This has resulted in a strong demand for accurate information concerning the relative benefits in terms of energy conservation and the quality of illumination that can be achieved with various methods of incorporating the daylighting potential.

However, designers still lack the tools to use in the lighting design process. Traditional-

computerized design aids have begun to provide designers with the ability to model numerous alternatives quickly, and to see the effects of each change (1).

The purpose of this research is to compare daylighting data from a computer program, a scale model of a building, and a constructed full-scale building to illustrate the potential of using daylighting design methods to reliably predict actual building daylighting performance.

PART I

DAYLIGHT ANALYSIS OF THE CLASSROOM AT TEXAS A&M UNIVERSITY (TAMU)

Actual daylight levels of the classroom at TAMU were measured at 20 interior locations in the classroom (Figs. 1 and 2). The measurements started 3 ft from the exterior wall and proceeded at 6 ft intervals to the opposite wall (30 ft). After daylight levels (in foot candles) were recorded, daylight factors were calculated. For the Daylight Factor (DF), the interior measurements were divided by the exterior horizontal illumination at a point away from the building (2). All measurements were done under the overcast sky condition.

Design Conditions

1. Sky Condition; Overcast sky
2. Latitude, Longitude, Time meridian; 30°, 96°, 90° (College Station, Texas)
3. Window Direction; North (0°)
4. Month, Day; May 15
5. Room Width, Depth; 40', 30'
6. Ceiling Height; 10.5'
7. Ceiling Reflectance (%); 80
8. Wall Reflectance (%); 70
9. Floor Reflectance (%); 30
10. Measurement Height; 2.5'
11. Window Type; Double Clear
12. Transmission (%); 80
13. Reflectance (%); 20
14. Window Width; 3.5'
15. Window Height; 6'

DAYLIGHT ANALYSIS USING A SCALE MODEL

The daylight effects of architectural elements were examined through the use of scale model studies. Model studies are effective methods for estimating interior light levels and

The scale model was built from opaque cardboard and painted foam board to prevent light transmission through the walls and ceiling (Scale: 1/2" = 1'-0"). Colors were selected to be typical of a normal room. The reflectances used in the test were; floors - 30%, walls - 70%, ceiling - 80%, and ground (concrete) - 55%. Daylight levels were measured at 5 interior locations, 2.5 ft above the floor.

DAYLIGHT ANALYSIS USING A COMPUTER PROGRAM

The daylight factors were calculated through the use of a computer program. The computer program that was used for predicting the amount of daylight is called MICROLITE (4). It evaluates daylighting design in the early stages of the design process. The MICROLITE computer program was developed by Harvey J. Bryan at MIT and is available through the Designers Software Exchange (DSE). The output from the program gives several formats in the familiar architectural representation of plan, section, and paralled projection.

Table 1 Daylight levels (Daylight Factors) of the classroom

Actual Data (DF)	Computer Data (DF)	Scale Model Data (DF)
0.3	1.0	
0.5	1.0	
0.5	1.0	1.3
0.6	1.0	
0.5	1.1	
0.6	1.1	
0.6	1.1	1.6
0.6	1.1	
0.75	1.5	
1.0	1.6	
1.1	1.6	3.3
0.9	1.5	
0.9	2.0	
1.8	2.6	
2.8	3.5	6
2.1	3.0	
0.6	1.4	
2.25	4.1	
5	9.1	10
4.4	8.5	

RESULTS & CONCLUSIONS

Results show that the computer generated daylight levels in the classroom were highly correlated to the measured daylight levels, but they were almost twice the measured levels. The difference was due to the low and uneven reflectances of actual classroom surfaces. The classroom had many pieces of furniture such as chairs, desk, blackboard, venetian blinds; exposed structural columns; doors; and surface texture characteristics which may have influenced the measured daylight levels, and were not accounted for in the computer program.

Additional differences between the computer generated daylight levels and the measured daylight levels occurred near the window area because this area of the classroom was especially sensitive to the outside sky conditions.

Scale model data were higher than the measured and the computer generated daylight levels because of the high surface reflectances of the model's wall and roof material (cardboard). This model did not contain furnishings, nor did it have the texture and detailed construction features of the actual building.

PART II

DAYLIGHT ANALYSIS OF THE ATRIUM OF A BUILDING AT TAMU

The daylighting effects of several architectural elements from the scale model building were compared with the data from the atrium of the Animal Science Building at TAMU (5). This illustrated both the inconsistencies and the relationships between the data from the scale model and the information obtained from the existing building.

First, actual measurements were made at 34 interior locations in the Animal Science Building atrium. The measurements started at 2 ft from the wall and proceeded at 10 ft intervals to the opposite wall (60 ft). After daylight levels (in foot candles) were recorded, daylight factors were calculated. All measurements were done under the overcast sky condition.

Second, a scale model was built with opaque cardboard and thick foam board to prevent light transmission through the wall and ceiling (scale: 1/2" = 1'-0"). Colors were selected to be comparable to the actual building. Measurements were made in the doctoral studio of the Architecture Department at TAMU.

Actual daylight levels were compared with the scale model data (Table 2). Fig. 13 shows the actual daylight distribution of the Animal Science Building and Fig. 14 shows the daylight distribution (Daylight Factor) of the scale model building.

Table 2 Daylight levels (DF) of the atrium

OBS	Actual Data (DF)	Model Data (DF)	OBS	Actual Data (DF)	Model Data (DF)
1	4.1	6.5	18	4.1	7.6
2	3.1	5.3	19	6.9	9.4
3	4.1	5.9	20	7.2	10.6
4	5.2	8.2	21	6.9	10.0
5	5.5	8.2	22	5.5	8.2
6	5.5	8.2	23	3.4	6.5
7	5.2	8.2	24	4.8	8.2
8	7.6	10.0	25	6.2	8.2
9	7.2	10.6	26	4.1	6.5
10	6.2	10.6	27	2.5	4.7
11	4.8	9.4	28	3.3	5.3
12	5.5	8.2	29	2.8	4.7
13	7.6	10.6	30	3.3	7.0
14	9.7	11.8	31	2.3	5.9
15	7.6	10.6	32	3.0	6.5
16	5.9	9.4	33	2.2	5.9
17	4.1	7.0	34	6.2	7.0

In order to find the relationship between the actual data and the model data, statistical regression tests were executed using the Statistical Analysis Simulation (SAS) program.

$Y = 0.869X - 1.819$
$N = 34$
$R^2 = 0.84$
$F = 170.38$
$P < 0.001$
Y = Dependent variable (actual data)
X = Independent variable (model data)
N = Sample size, number of measured points
R^2 = Coefficient of determination (portion of the total variation of Y explained by the linear regression of Y on X)
F = The value of F statistic for the data
P = Probability (probability of obtaining a tabulated F value more extreme than the computed F value)

The values of the regression coefficients provided an estimate of the change in Y (Actual

Proceedings of the Second Symposium on Improving Building Systems in Hot and Humid Climates, College Station, TX, September 24-26, 1985

data) associated with a one-unit change of the independent variable X (Model data), holding constant the effect of all other variables. The coefficient of determination, identified by the symbol R^2, indicates that the regression explains 84 percent of the changes in the dependent variable.

Also, the F-test statistic is used to estimate whether there is a significant relationship between the dependent variable (Y) and the independent variable (X). The hypothesis that there is no relationship between the data is rejected when the computed F value exceeds the tabulated F value. Since the computed F value of 170.38 is larger than the tabulated F value of 7.56 (6), we would conclude that there is a high relationship between the data at the 0.01 level of significance.

CONCLUSIONS

Table 2 shows that the scale model daylight levels in the atrium are overestimated by about 30%. The most likely cause of the discrepancies between the actual measurements and the scale model measurements is high reflectances of scale model materials compared to the average reflectances in the actual building (7).

In the statistical test, the hypothesis that there is no relationship between the actual data and the model data is rejected at .01 level of significance and it is concluded that there is a significant linear regression of Y on X. With $R^2 = 0.84$, approximatly 84% of variability is explained by the regression on X. It would appear, therefore, that model measurements could be useful tools to predict actual daylighting performance.

In future studies, actual measurements will be made in the office area of each floor of the building and will be compared with the model measurements (8). Also, several types of atriums will be studied to develop a computer program.

BIBLIOGRAPHIC REFERENCES

1. Lindsey, L., and W. Hallagan, "Solving the Mysteries of Natural Lighting," Solar Age J., September 1983, pp. 27-33.

2. Mcguinness, W. J., B. Stein, and J. S. Reynolds, Mechanical and Electrical Equipment for Buildings, 6th edition, John Wiley & Sons, New York, New York, 1980, pp. 783.

3. Evans, B. H., Daylight in Architecture, McGraw-Hill Book Co., New York, New York, 1981, pp. 107-128.

4. Bryan, H. J. and D. L. Krinkel, "Microlite I: A Microcomputer Program for Daylighting Design," Proceedings of the 7th National Passive Solar Conference, Knoxville, Tennessee, August 30 - Sept. 1, 1982, pp. 405-410.

5. Boyer L. L., "Evaluation of Energy Savings due to Daylighting," Proceedings of the International Passive and Hybrid Cooling Conference, Miami Beach, FL, November, 1981, pp. 343-347.

6. Ott, L., An Introduction to Statistical Methods and Data Analysis, Second Edition, Duxbury Press, Boston, MA, 1984, pp. 700-701.

7. Boyer, L. L., and R. W. Roush, "Daylight Analysis for an Earth Covered Office Building in Sacramento, CA.," Proceedings of the 8th National Passive Solar Conference, Santa Fe, NM, September, 1983, pp. 163-167.

8. Oretskin, B. L., "Studying the Efficacy of Light Wells by Means of Model under an Artificial Sky," Proceedings of the 7th Passive Solar Conference, Knoxville, Tennessee, August 30 - Sept. 1, 1982, pp. 459-463.

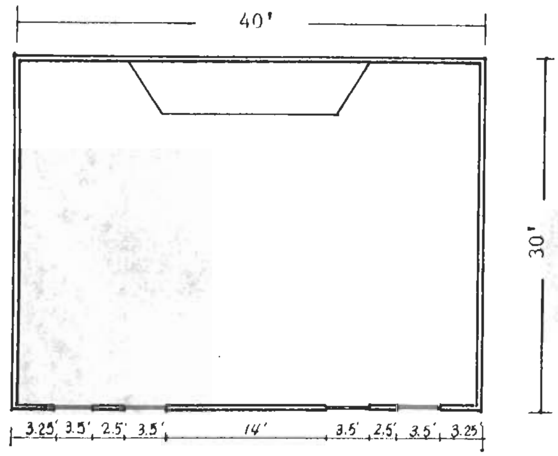

Fig. 1 Floor plan of the classroom

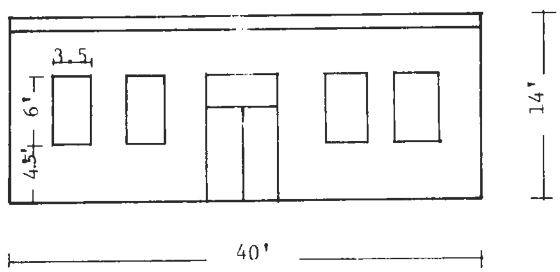

Fig. 2 Elevation

Fig. 3 Exterior view of the classroom

Fig. 4 Interior view of the classroom

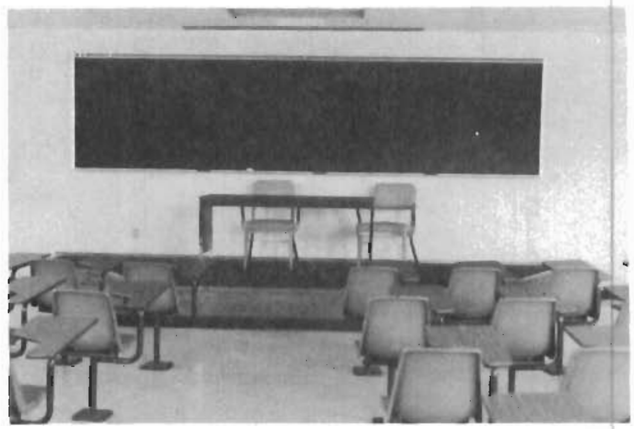

Fig. 5 Interior view

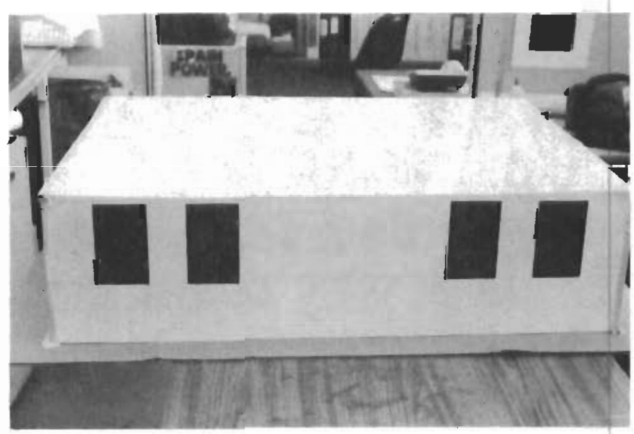

Fig. 6 Scale model of the classroom

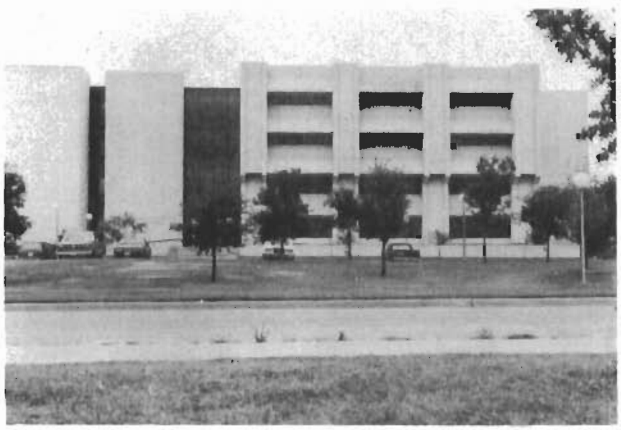

Fig. 7 Exterior view of the Animal Science Building

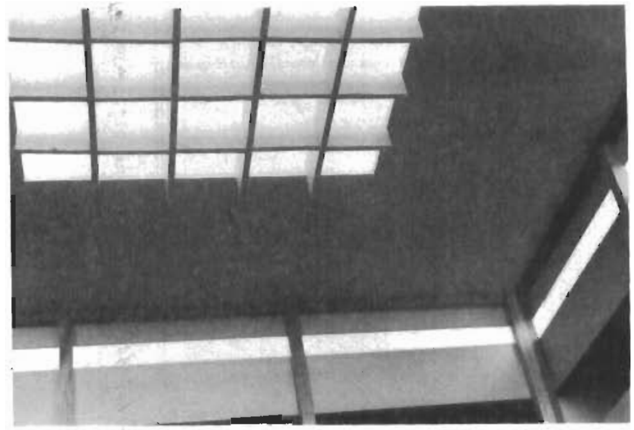

Fig. 10 Skylight(model)

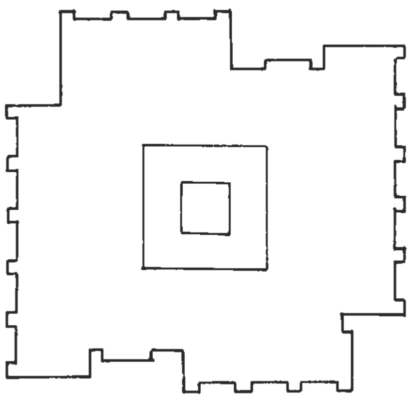

Fig. 8 Roof plan

Fig. 11 Sitting area

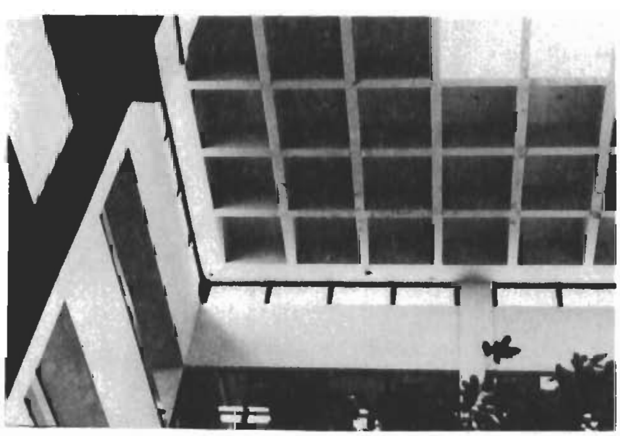

Fig. 9 Skylight(actual)

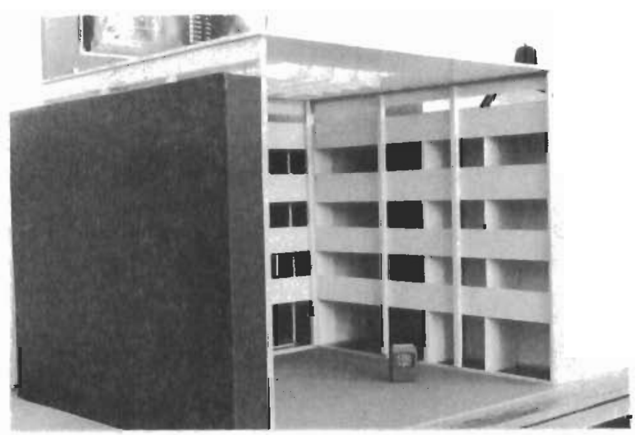

Fig. 12 Scale model

Proceedings of the Second Symposium on Improving Building Systems in Hot and Humid Climates, College Station, TX, September 24-26, 1985

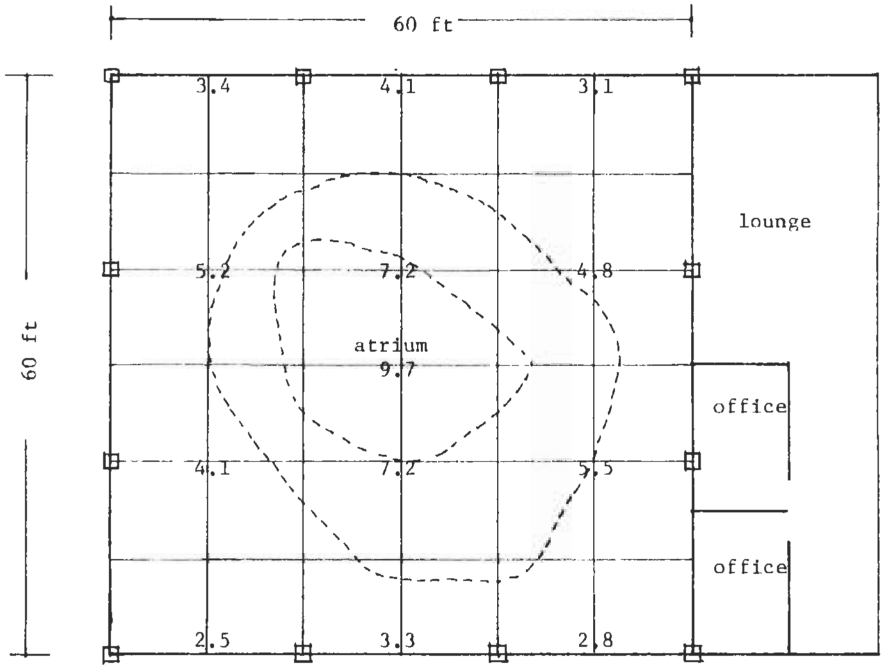

Fig. 13 Daylight distribution in the Animal Science Building atrium

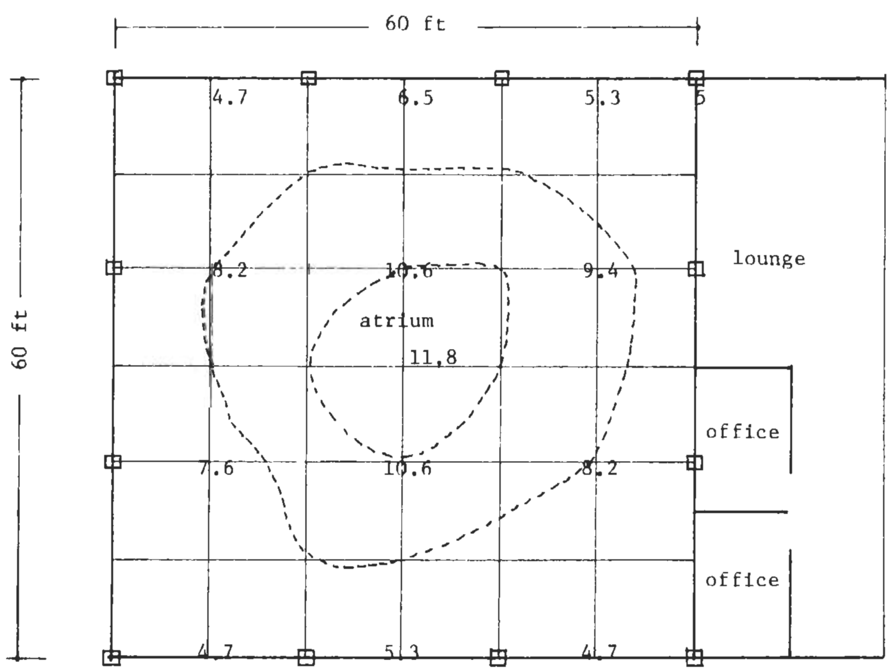

Fig. 14 Daylight distribution in the scale model building atrium(DF)

Proceedings of the Second Symposium on Improving Building Systems in Hot and Humid Climates, College Station, TX, September 24-26, 1985