A NEW METHOD TO DETERMINATE INDOOR DAYLIGTHING THE BUILDING: IMPROVING " LUMEN MODELS "

Fakra Ali, Harry Boyer, Eddy Laffosse, Philippe Lauret

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Fakra Ali Hamada
Laboratoire de Physique du Bâtiment et des Systèmes
Faculté des Sciences de l'Homme et de l'Environnement
117 rue du général Ailleret 97430, Tampon
Université de La Réunion (Françe)
fakra@univ-reunion.fr

Harry Boyer
Laboratoire de Physique du Bâtiment et des Systèmes
Faculté des Sciences de l'Homme et de l'Environnement
117 rue du général Ailleret 97430, Tampon
Université de La Réunion (Françe)

Eddy Lafosse
Laboratoire de Physique du Bâtiment et des Systèmes
Faculté des Sciences de l'Homme et de l'Environnement
117 rue du général Ailleret 97430, Tampon
Université de La Réunion (Françe)

Philippe LAURET
Laboratoire de Physique du Bâtiment et des Systèmes
Faculté des Sciences de l'Homme et de l'Environnement
117 rue du général Ailleret 97430, Tampon
Université de La Réunion (Françe)

ABSTRACT

Many researches were undertaken in order to set up models which enable us to calculate indoor dayligthing [4], [5] and [6]. There are three method types to calculate the daylight luminance through windows and large openings inside the building. Among others, 'simplified methods' (''Lumen method'', ''Split Flux System method''…), 'numerical simulation method' (''Radiosity'', ''Ray Tracing''…) and finally 'experimental method' (''scale model'', ''building experimental ''…) are described in literature. We put some specific interest in the 'simplified methods' because they are easy to use and don't need a lot of data base for simulating. The big disadvantage for most of these models is these models depend on restricted conditions. For example, if we considered ''Split Flux System method'', we see that the models used only to overcast condition. Another example, the ''lumen method'' applied for any skies but the models take only five values in the space. Therefore they can only work under precise and limited circumstances. In this present paper, we purpose to see how we can circumvent these difficulties by improving the ''Lumen Model''. Indeed, we are going for introduce the notion of ''Equivalent Deep'' (E_D) (''profondeur fictive'' in French) into the ''Lumen method''. This ''Equivalent Deep'' will calculate any values and any types of skies contrary to the original ''Lumen method''. The original ''lumen method'' can only calculate indoors dayligthing in five values.

1. INTRODUCTION

We will present the methodology set up in order to improve the "Lumen model". The dayligthing within room is given by this model (*). In "Lumen method", the only parameters used for determinate the dayligthing within the room are the distance between a point enlightened and the window (the Depth from the room (D)), the coefficient of utilization from sky luminance (CU) which we will see more in detail, the net transmittance of the window factor (TL), the exterior vertical illuminance from the half sky, and finally the exterior horizontal illuminance from the ground. This method calculates dayligthing from five points on the workplane (a ratio of 10, 30, 50, 70 and 90 to 100 of the Depth of the room) for a depth D given (which represents either the length or the width of the room depending on the position of the window). The "lumen method" applied in every sky (cloudy, cloudless or intermediate sky), but we have not calculate for any points. In this works, we introduce a new concept who allows us to calculate the dayligthing on any points of workplane from "Lumen method".

Indeed, the depth (D) of a point in workplane is absolutely essential to determine the coefficient CU ([1] and [2]). This fixed depth limits (D) us the numbers of points on which one can calculate dayligthing in only five positions. Into our study we propose to introduce the “Equivalent Deep” to solve this problem. By definition, the “Equivalent Deep” will be the distance between window and an imaginary wall that would move along the real depth of the room. This imaginary wall will reduce the real depth of the room and will make it possible to recalculate dayligthing in five other points.

We will compare the results between the “Lumen method” and the new “improving Lumen method” developed.

2. CALCULATION PROCEDURE AND LIMIT FOR “LUMEN METHOD”

The “Lumen method” as adopted by the IES Committee on Calculation Procedure, (1989) is a procedure used to predict interior daylight illuminance under predetermined conditions [7]. Most of the time, this method is used in the United States [2].

2.1 Principal of calculation

The prediction of interior daylight illumination from side lighting is simplified by using standard configuration shown in (Fig. 1). The floor cavity extends from the window sill to the floor and is assumed to have a reflectance of 30 %. The ceiling cavity extends from the top of the windows to the ceiling and is assumed to have a reflectance of 70 %. The room cavity extends in height (H) from the top of the floor cavity to the bottom of the ceiling cavity, in width (W) along the window wall, in depth (D) from the window wall to the rear wall, and its reflectance is assumed 50 %. The lumen method assumes 5 sky luminance distribution models, each with succeeding higher ratio of luminance of zenith to that of the horizon. The total interior daylight component is calculated for a few points 10%, 30%, 50%, 70% and 90% distance from the window. The sky models used and the inability to distinguish illuminance values of points at equal distance from window but unequal distance from wall are main deficiencies of the “Lumen method”. The parameters used in this method are primarily the geometrical properties (width, height, positioning…) and physics (coefficient of luminous transmission, constituting pane…) of the glazed opening, (the date, the hour considered, the locality (longitude and latitude of the place) and) the weather conditions of illumination (light intensity provided by a weather file) and especially the depth of the room with respect to the position of the window. This method applies for any types of sky. The geometrical model used in the Lumen method for lighting in frontage ([7] and [3] is given by figure (Fig. 1):

*

$$E_i = E_{xv} \times \tau \times CU$$

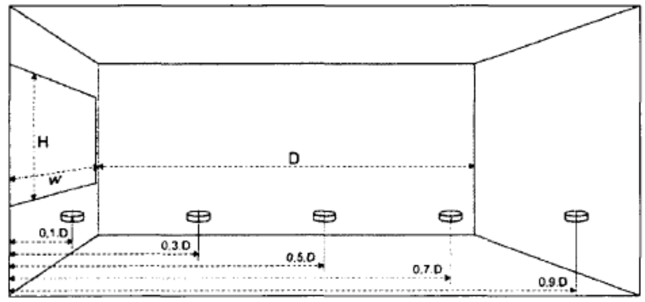


Fig. 1: Standard configuration in a room for calculating sidelighting (Lumen method) [7]

2.2 Limit for the method

The “Lumen method” applied for any type of sky (clear, cloudy and intermediate sky), but he give only illumination values of five points of the workspace. Thus, we could not calculate the values of illumination everywhere on the workspace. In this paper, we has improved the “Lumen method” in order to calculate the dayligthing values for several points in workspace.

3. IMPROVING LUMEN METHOD

In this paragraph, we will present the step to be followed for “Improving Lumen method” and the calculation algorithm used. The programming language used is the C.

3.1 Approach of the proceeding

The new idea is to consider an “Imaginary moving wall” which would enable us to calculate illumination in any point of the room by using the “Lumen method ''. Indeed, starting from our "Imaginary moving wall", we can recalculate the illumination on 5 other points of the room by keeping the same principle of calculation as the original ‘‘Lumen method'. The only notorious difference will reside on the new points of calculations which different from those given by the real depth of the room. Let us take as example, the case where we want to know the value of illumination on a point which is on the perpendicular axis of the window at a distance from 3 meter. The room has 6 meters deep. The direct calculation of the “Lumen method” starting from the real depth of the room will not give us the value of illumination on this point. In order to be able to give the approximate value on this point (distant of *3m*); we are thus to take a imaginary depth $D_{virtuel}$ = 3/0,9 for example (one could also choose $D_{virtuel}$ = 3/0,7 or divided by 0,5 or 0,3 or 0,1 this depth following the need) and to make calculations by the "Lumen method". That way, we would have the value of desired illumination at the distance (i.e. *3m*). Note that in this example, we consider that the imaginary wall has a imaginary depth of 3,33 m instead of the real depth (of 6 m). we are not interested in the values of illumination beyond 3 metres deep. Calculates them remain true As long as $D_{virtuel} \leq D_{réel}$ (what will be always the case as long as we seek to know illumination inside the room).

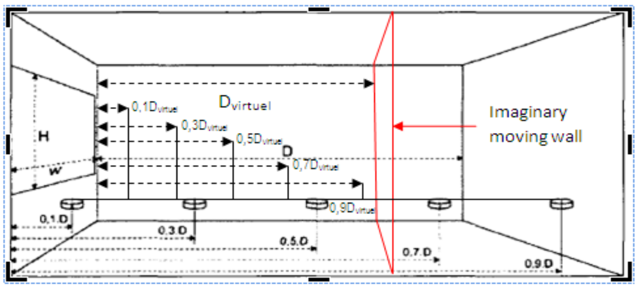


Fig. 2: proceeding for calculating sidelighting with improving “Lumen method”

3.2 Calculation algorithm of new method

We will see here how make algorithm code which allowed to Improving “Lumen method” (Fig. 3).

4. APPLICATIONS

4.1 Case study and suppositions of the simulation

In order to compare the results "Lumen method" and “improving lumen method”, we will study the case from one simple room that has only one window. In this study, we consider only the dimension of the window (length and width of the window) and the depth from the room. The dimensions of the room (length and width of the room) are not necessary because the "Lumen method" don’t use these characteristics. The dimensions of the window are 3 meters length 2 meters width. 20 meters depths zone.

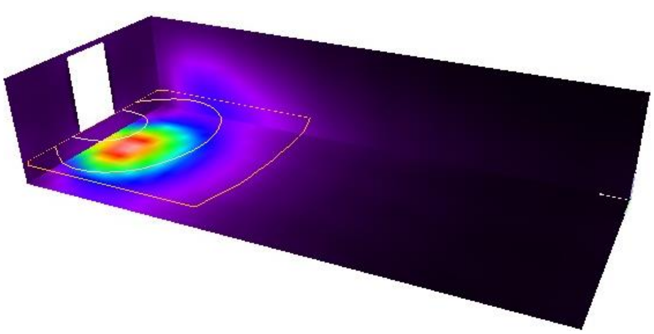
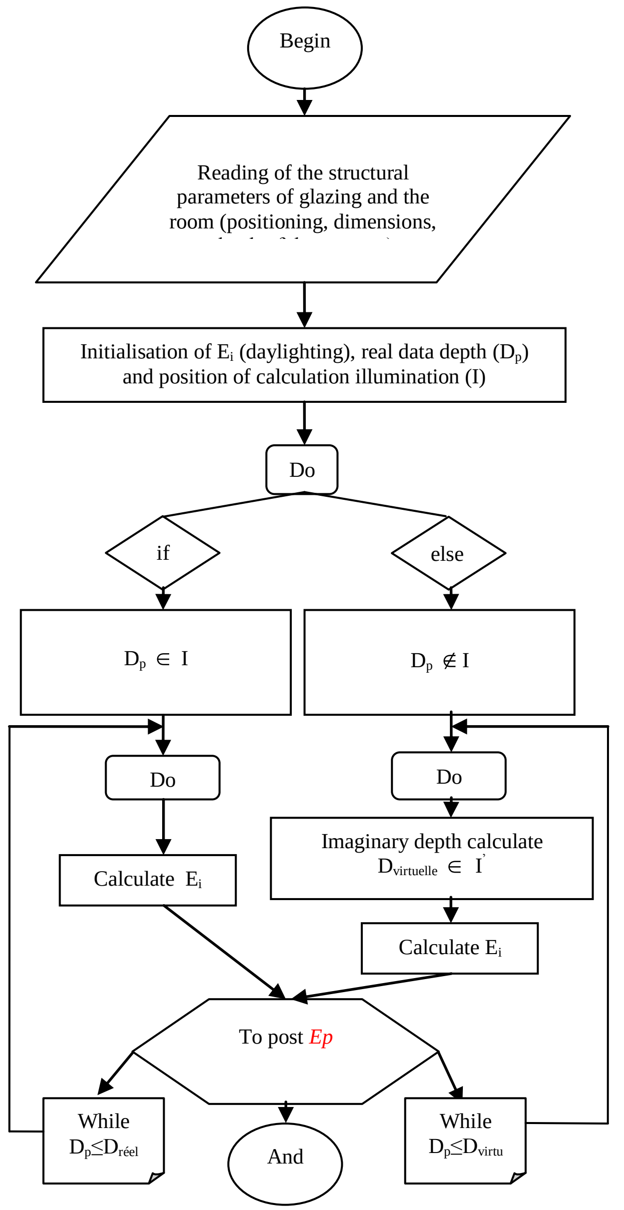


Fig. 4: Case study (use DIALUX software for the picture): an simple room of various depths and one window



I = 0,1 ; 0,3 ; 0,5 ; 0,7 and 0,9 once $D_{réel}$
$I^{`}$ = 0,1 ; 0,3 ; 0,5 ; 0,7 and 0,9 once $D_{virtuelle}$

Fig. 3: Algorithm for ‘’Improving Lumen Method”

The suppositions of the simulation are:

- The net transmittance of window factor (TL): 90 percents.
- The exterior vertical illuminance from the half sky: 3100 lux.

- Total exterior horizontal illuminance: 5200 lux.
- The transmittance of exterior ground: 20 percents.

4.2 Results and comparisons

We varied our depth from 0 to 20 meters. We then classified the values of illuminations obtained following these variations, according to five categories (Table 1). The model used to calculate these illuminations is well on the traditional ‘’Lumen method’’.

We could note that the values remain the same ones for each category of depth: one thus has values of illuminations which do not change when one passes from 1 to 2 meters depth (Category A) and so on.

This illustration (Fig. 4 and Fig. 5) shows us the values of illuminations according to our depths categories.

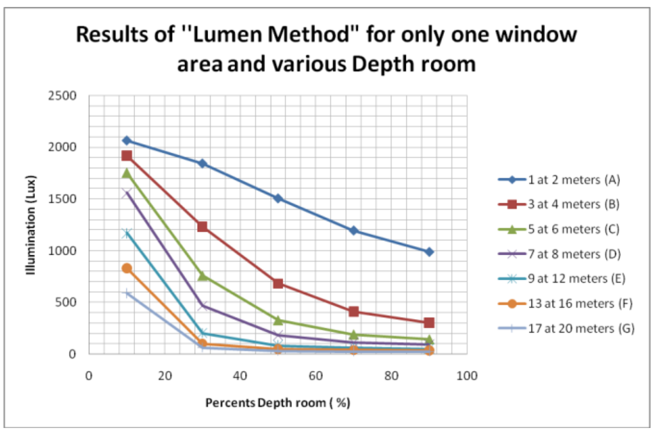


Fig. 4: Results of ‘’Lumen Method’’ for only one window are and various depth room

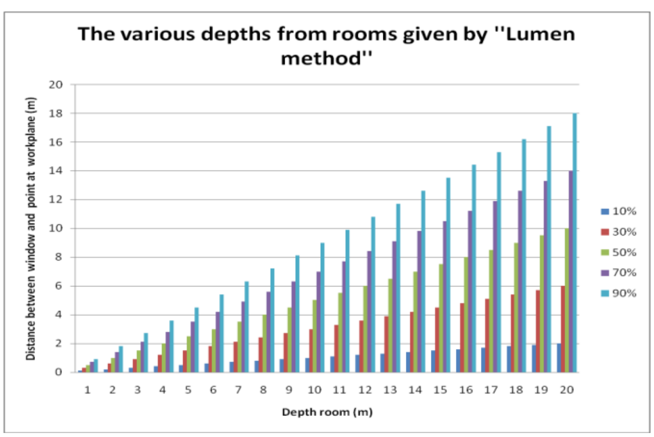


Fig. 5: The various depths from rooms given by ‘’Lumen method’’

The (Table 2) recapitulates the values of illuminations obtained according to the five points well defined by the Lumen method. These five points are calculated according to the various depths of the room.

TABLE 1: CATEGORY OF ILLUMINATIONS IN FIVE POINTS STARTING FROM THE LUMEN METHOD AND ACCORDING TO THE VARIOUS DEPTHS OF THE ROOM

A	B	C
1 at 2 meters	3 at 4 meters	5 at 6 meters

D	E	F
7 at 8 meters	9 at 12 meters	13 at 16 meters

G
17 at 20 meters

TABLE 2: ILLUMINATIONS VALUES IN VARIOUS POINTS OF THE ROOM TEST

Local points (m)	First values (lux)	Second values (lux)	Beetwen
0,3	2063	1918	A and B
0,5	1506	1752	A and C
0,6	1842	1752	A and C
0,7	1197	1560	A and D
0,9	991	1171	A and E
1	1506	1171	A and E
1,2	1230	1171	B and E
1,4	1197	834	A and F
1,5	680	758	B and C
1,8	991	758	A and C
2	680	588	B and G
2,1	410	467	B and D
2,7	301	203	B and E
3	329	203	C and E
3,5	191	184	C and D
3,6	301	203	B and E
4,2	191	101	C and F
4,5	144	101	C and F
5,4	144	61	C and G
6	84	61	E and G
6,3	93	63	D and E

7	63	49	E and F
9	52	33	E and G
12,6	34	28	F and G

The curve (Fig. 6) gives us the results of the values of illumination for given local points and various depths. We observed that with this method we can calculate values of illuminations in any point. This approach took into account each enlightened position points in comparison to windows of the room. Thus, we did not limit ourselves to the calculation of illumination into five point of the room only .

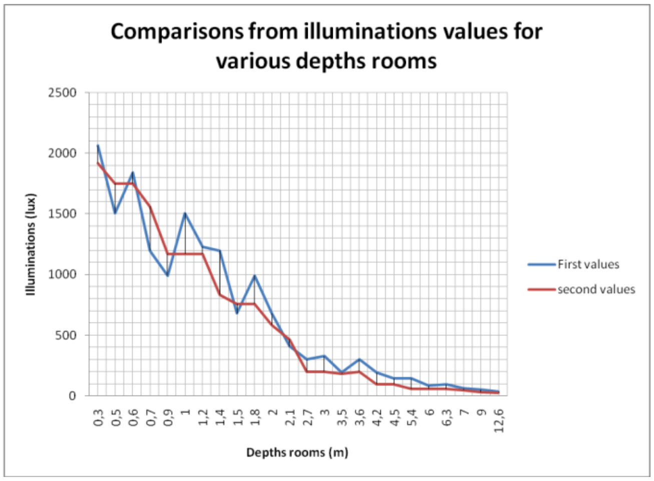


Fig. 6: Comparison from illuminations values for various depths rooms

The curve (Fig. 7) illustrate the correlation of various values.

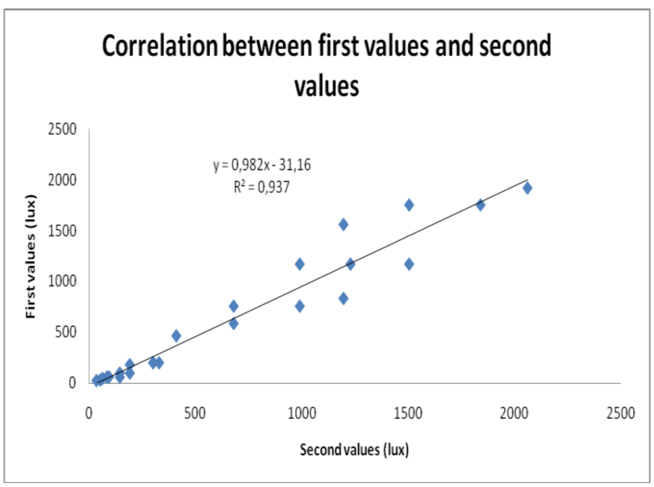


Fig. 7: Correlation between first values and second values

We note that, certains values of points near the window are not taken correctly because in the reality, the physical phenomenon is more complex and like we use a simplified model, it is obvious that these values will not be taken with accuracy.

The linear line shows the correlation between illuminations values given by two depths rooms different for the same point.

5. CONCLUSIONS

The method lumen is a method simplified and efficacious to calculate illumination at the interior of a room according to any type of sky. The big defect of this method is that the calculations are limited in five positions of the room only. We saw here how one could improve the model so that it can calculate any point of the room. The ''Improving method Lumen'' results obtained are promising.

7. REFERENCES

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