OPTIMIZATION OF A SUN-BREAKER ENVELOPE FROM AN CAD SOFTWARE INVERSE APPROACH.

V. Meunier[1], S. Houpert[1] and R. Brec[2]

[1] *Laboratoire CERMA, Ecole d'Architecture de Nantes, Rue Massenet, BP 81931, 44319, Nantes cedex, France*
[2] *IMN, Laboratoire de Chimie des Solides, 2 rue de la Houssinière, BP 32229, 44322, Nantes cedex, France*

ABSTRACT

People employed in building offices have new needs in terms of comfort at the working place. To satisfy these needs, it is necessary that architects check carefully the efficiency of the corresponding new systems that they conceive in order to improve these people working conditions. This study shows that it is possible to optimize the sizing up of the different elements of an office cell front (envelope) containing, in addition to the glass wall, sun-breaker strips and an electrochromic protection. For that purpose, the inverse simulation technique was used thanks to several programs. The thermal performances of the office cell envelope were determined with solar tools. It is shown that the various architectural elements of the envelope improve meaningfully the thermal comfort of the cell. Since there is a unilateral relationship between constraint and optimization, each optimization of the sizing up of the envelope elements makes sense.

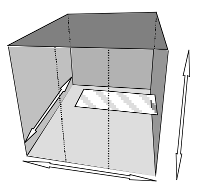
KEYWORDS

Inverse simulation, optimization, sun-breaker, electrochromic, luminous and thermal comfort.

INTRODUCTION

Comfort is a notion which is continuously changing. It is the result of regulations requirements and personal needs. New requirements of comfort correspond to obtaining a global answering to several surrounding parameters. In spite of this trend, architects do not systematically use modern tools to check the performances of the architectural elements that they conceive. In this article, we propose an optimization of the size of the different parts of a sun-breaker envelope of an office room in order to obtain a luminous and thermal comfort. After a presentation of the object under study, we will explain the various methods used to evaluate the performances of the envelope and the results of these size optimizations.

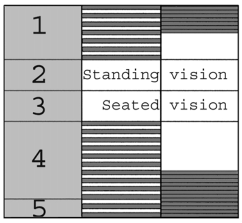
1. OBJECT UNDER STUDY : ENVELOPE OF THE OFFICE CELL.



Hypotheses :

- Location : Nantes (France)
- Single orientation cell
- Orientation : West
- Cell located in the middle of a building

Figure 1 : Perspective view of the office cell under study.



Five parts :

- 1 : Upper part
- 2 : Transparent area, vision when standing
- 3 : Transparent area, vision when seated
- 4 : Middle lower area
- 5 : Lower area

Figure 2 : Front view of the office cell under study.

Figure 1 shows a perspective view of the office cell to be studied with its dimensions. The sun-breaker envelope (Figure 2) is a glass wall in front of which is located a particular system acting as a sun-breaker (in the following text, “envelope” will refer to the cell glass front with its various elements). The cutting out of this element follows the official regulations concerning luminous comfort for working spaces (R.235-2-1 articlbernard@lif.co.uke of the French work code and C.11.04.1984 circular [1]).

2. EXPERIMENTAL : METHOD OF EVALUATION OF THE ENVELOPE PERFORMANCES.

Quite often, the conception procedure of architects does not include the checking of the performances expected through accurate calculations means. This situation happens all too often, although very simple and fast checking tools exist (solar diagrams, Gnomon, Girasol).

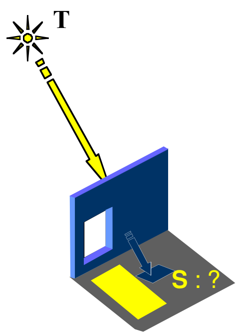


Figure 3 : Direct Simulation.

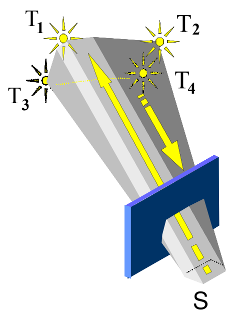


Figure 4 : Inverse Simulation.

Most tools used for solar simulation on the market at the moment consider the so-called direct simulation of the solar constraints (Figure 3). This means that, to answer to the solar constraint of the type : "To be protected from the sun at the moment T from the D1 to D2 day" or for instance : "To have some sunshine at the moments T1, T2, T3 and T4… etc..", the architect must in fact use a trials and errors procedure of direct simulations with CAD tools. We here suggest to use the inverse simulation method and, to reach the optimization of our envelope, to use the SVR interface software (Sun, Visibility & Reflection) developed at the CERMA laboratory [2]. This interface can be used from AutoCAD 2000. This inverse approach consists in a first step to visualize all the sun rays in a volume (Figure 4) for a given architectural constraint. In a second step, the use of this volume allows to size up the openings and the solar screens. We start from an initial surface (work or play-ground surface for instance), an area where comfort will be provided, to go back towards a target corresponding to the surface of the sky-vault. Let us notice that only the direct solar rays component will be taken into account.

3. SIMULATIONS FOR THE OPTIMIZATION OF THE SUN-BREAKER SIZE.

3.1. Strips optimal shape.

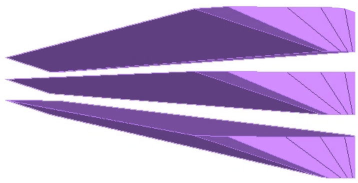


Figure 5 : A set of strips with optimized shape.

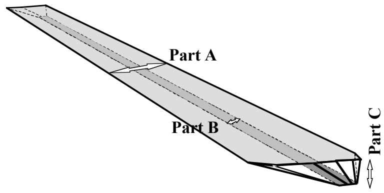


Figure 6 : Strip optimal shape having a given thickness C.

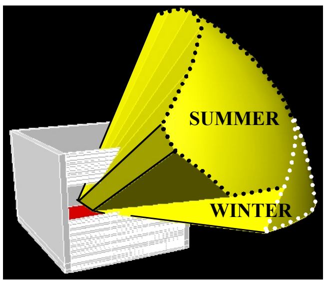
The optimization of the strip size takes place in all the set directions (Figure 5). The A portion (upper part) of the strip alone gives the same protection than the B (lower part) and C (thickness) portions together (Figure 6).

3.2. Choice of the strips features with respect to their industrial fabrication.

The sizing up of the strips is made by considering essentially their width since this one has a considerable influence on the visibility constraint. Simulations carried out for winter showed that the strips width become much too important at certain hours (Table 1). Consequently, we reduced the fall/winter and spring/summer simulation periods (Figure 7).

TABLE 1
Determination of the optimal strip widths (in cm) for one-hour periods.

	21 Dec.	21Jan./Nov.	21Feb./Oct.	21Mar./Sep.	21Apr./Au.	21May/Jul.	21 June
12.30-1pm	1.18	1.0	0.78	0.61	0.5	0.43	0.41
1pm-2pm	2.86	2.86	1.72	1.3	1.04	0.89	0.84
2pm-3pm	6.85	6.85	3.21	2.24	1.73	1.43	1.35
3pm-4pm	91.13	18.97	6.85	3.91	2.74	2.18	2.0
4pm-5pm			54.63	8.57	4.65	3.35	3.27

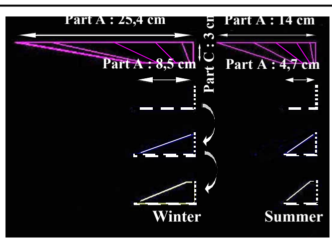


For fall/winter : in December from 12.30pm to 3pm, in January/November from 12.30pm to 3.30pm, in February/October from 12.30pm to 4pm and in March/September from 12.30pm to 5pm. For spring/summer : in March/September from 12.30pm to 4pm and in April/August, May/July and June from 12.30pm to 5pm. The choice of these simulation slots takes into account the daylight saving time.

Figure 7 : Constraint volume – office cell work plan protected for the whole year.

3.3. Strips optimal sizing up : two different configurations for the same protection.

We determined an optimal sizing up for two strip configurations.



The first one (A) corresponds to a thickness of 3cm and to a spacing between two strips of 1.5cm, while the second one (B) corresponds to a thickness of 3cm and an inter-strip space of 3cm.

Figure 8 : Strips optimal width and shape changes (configuration A).

Let us consider the lower portion of the strip : to insure a complete protection for the A configuration, its optimal width is 8.5cm in winter and 4.7cm in summer (Figure 8). For the B configuration we obtain a width of 19.6cm in winter and 9.3cm in summer. One configuration will be favored over the other as function of the constraints imposed for the fabrication of the envelope. For instance, if the use of a small amount of material is the driving factor, then configuration A will be chosen. In effect, for the same protection, this choice implies more strips (1/3 more for A than for B) but smaller ones (1/2 less volume for A than for B) which favors the saving of materials. If visibility is the major factor to take into account, then configuration B will be the option of choice.

3.4. From the optimal shape to the industrial object.

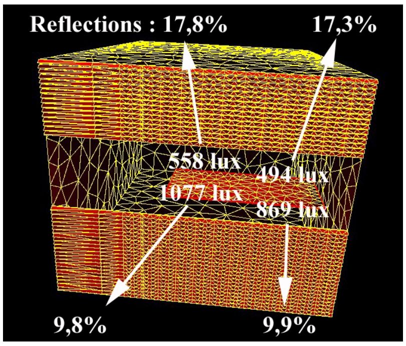
The shape of the strips is complex because the dimensions are different in all the directions of space. For industrial reasons, we propose to simplify their shape. In order to deliver a reasonable luminous comfort in the office cell, we chose triangular cross-sections for the strips, an industrial-friendly geometry bringing extra light into the room (Figure 8). To provide a proper mobility and stacking of the strips, we also suggest to cut out the upper angle of the strips.

4. EVALUATION OF THE PERFORMANCES OF THE ENVELOPE.

4.1. Luminous performances.

4.1.1.The set of strips.

In order to evaluate the influence of the strips shape on the lighting of the work surface, the Solene software developed at CERMA (checking through direct simulation) was used. The simulation was done for the configuration A with summer industrial-friendly strips.



Three hypotheses were made. The first corresponded to a model with a normalized sky for which the energy (10 000 lux) hitting the horizontal plane comes from all directions and is three times more intense at the top of the solar vault than on the horizon. In the second hypothesis, we neglected the transmission reduction due to the presence of the glasses. The third hypothesis concerns the choice of the reflection coefficient of the strips (0.8) and of the envelope (0.7).

Figure 9 : Lighting of the office cell working plan considering the walls and the strips reflections.

The strips reflections represent between 9.8 and 17.8 % of the whole lighting on the working plan (Figure 9). The lighting values on the work plan after reflection on the walls and on the strips are rather high. Because the inter-strip width is more important in the B case, there is no need to determine the lighting values in this latter case since they will be necessarily higher.

4.1.2. The transparent part of the envelope.

The transparent part of the envelope without the strips which allows an outside view gives a sun spot on the work plan. To counter this inconvenience and avoid any dazzling discomfort, we suggest to use, for this part of the glass wall, a sun-controlled electrochromic display [5]. We propose to split up the electrochromic area into several smaller surfaces in order to darken only these regions needed to the protection of the work plan. The optimal colored zones of the electrochromic area were determined with the SVR interface (Figure 10 and 11). Indeed, the importance of the electrochromic area in the colored state allowing a proper protection of the office work plan induces a meaningful decrease of the lighting level. The value of the light absorption coefficient being rather high in the colored state, we have made some simulations allowing the precise determination of the electrochromic colored zones for one hour for different months of the year. Notice that these simulations take into account only the direct sun rays. Since the positioning of the electrochromic protection changes with time, we can envision to monitor the protection through the use of an adapted software working all over the year. The results show that, for example, the whole electrochromic device is uncolored on December 21 from 12pm to 1pm (Figure 10). The electrochromic display will shift from an uncolored state to a colored one on June 21 from 3pm to 5pm. For the other hour slots, no colored electrochromic protection is necessary (Figure 11).

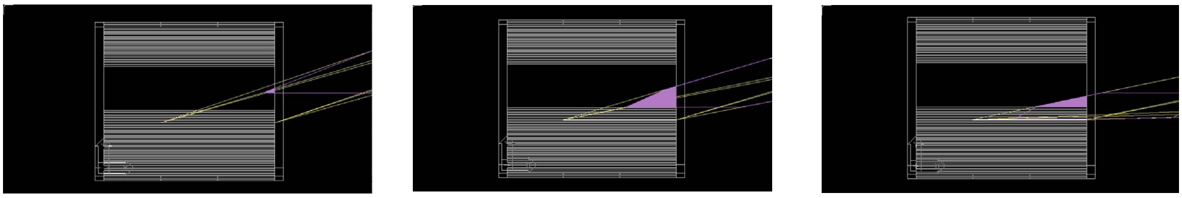


Figure 10 : Electrochromic protection (colored state) – work plan protected on December 21 from 1pm to 4pm.

Figure 11 : Electrochromic protection (colored state) – work plan protected on June 21 from 3pm to 4pm.

4.2. Thermal performances.

The thermal study dealt with the portion of the envelope void of strips, because the optimization of the strip size allows, as seen above, a complete protection at the strips location. The "Solar Tools" software developed at CERMA were used to evaluate the thermal performances of the envelope by considering the global solar emission (direct and diffuse). The first simulations were made with a standard double glass (CLIMALIT 4/12/4) presenting a solar transmission factor of 75% [4]. In a second step, we substituted it for an electrochromic display whose solar factor was 15% in the colored state and 39% in the transparent state.

TABLE 2
Transmitted solar energy through the envelope of the office cell in Wh/m_.

	P1	P2	P3	P4	P1	P2	P3	P4	P1	P2	P3	P4	P1	P2	P3	P4
	21_December				21_Jan./Nov.				21_Feb./Oct.				21_Mar./Sep.			
12.30-1pm	829	135	122	122	937	153	138	138	1155	188	170	170	1351	220	199	199
1pm-2pm	1511	246	223	223	1763	287	260	259	2217	361	327	323	2571	419	379	379
2pm-3pm	1637	267	242	230	2095	341	309	290	2890	471	427	383	3458	563	511	461
3pm-4pm	799	130	118	115	1435	232	210	198	2807	457	414	344	3778	615	558	443
4pm-5pm													3130	510	462	360

	P1	P2	P3	P4	P1	P2	P3	P4	P1	P2	P3	P4
	21_Apr./Aug.				21_May/Jul.				21_June			
12.30-1pm	1508	246	223	223	1582	258	233	233	1600	261	236	236
1pm-2pm	2789	454	412	412	2844	463	420	420	2844	463	420	420
2pm-3pm	3781	616	558	531	3845	626	568	568	3839	625	567	567
3pm-4pm	4312	702	637	513	4450	725	657	557	4453	725	658	574
4pm-5pm	4177	680	617	415	4515	735	667	463	4570	744	675	484

P1 : without protection
P2 : with strips
P3 : strips + electro. 39%
P4 : strips + electro. 15%

The strips reduce the amount of energy transmitted through the envelope by 83,7% of what it is when there is no strips at all and with the standard double glass (Table 2). The replacement of the standard double CLIMALIT 4/12/4 glass by the electrochromic device in its uncolored state allows an extra decrease of 10% of the transmitted energy over the entire year and for all time slots (Table 2). On the other hand, the change of state of the electrochromic device during winter time does not modify substantially the transmitted energy. In that case, the main interest to use such device is to avoid dazzling phenomenon that may happen in winter, although it is the intake of energy which is sought. The colored electrochromic surfaces allow to reduce the transmitted energy by about 25% in spring and fall (that is between March and September) for the 3pm/5pm time slot (Table 2).

CONCLUSION.

The SVR interface allowed us to optimize the sizing up of the different architectural elements of the envelope of a glass office cell front, that is the shape of the strips and the electrochromic protection located in that area which is devoid of strips. We have shown that the inverse simulation tool used to study the sun lighting allows to take into account specific and a priori space constraints. We can conclude that the optimal shape of the strips can be somewhat modified according to extra constraints such as those originating either from industrial processing requirements or from visibility constraints. It was shown that this can be made without little performance loss. We also found that the amount of energy transmitted through the envelope can be reduced from 7 to 10 times according to the time of the year when going from an envelope made of an only standard double glass to the same envelope but equipped with a sun-breaker made of strips combined to an electrochromic protective layer. Therefore, we substantially improved the luminous and thermal comfort of the office cell under study.

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