HOW CURRENT TRENDS IN THE DESIGN OF FACADES INFLUENCE THE FUNCTIONAL QUALITY OF INTERIOR SPACES

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ABSTRACT

During the last decade, all construction standards evolved rapidly and became increasingly demanding in terms of energy performance. The joint reduction of heating and cooling loads resulted in a rise of the relative importance of electricity consumption due to indoor lighting. As a result, the question of daylight is getting more and more important and has to be addressed carefuly in the design process.

In this context we can see the emergence of a dominant trend in the design of facades of non-residential buildings, which results in an alternating composition of glass and opaque vertical stripes. Beyond the aesthetic implications, we do not allow ourselves to judge, we can imagine that this type of system can be advantageous in terms of building rationality.

However, this paper shows that this design trend have some negative implications in terms of thermal behaviour without bringing any decisive advantage with respect to visual comfort and natural lighting. We evaluated the performance of three variants of this particular typology and compared them with a classical horizontal opening fitted with a 95 cm sill height. The results show that, when applied to the case of an individual office, this trend is far from optimal.

This study leads to clearly point out the main advantages and drawbacks of these typologies and we believe that the outcomes of this work could be useful to designers and contribute to promote efficient design solutions regarding both architectural quality and energy performance.

Keywords: Window, daylighting, overheating risks, heating loads, energy demand.

INTRODUCTION

In the early twentieth century, the window strip proposed by Le Corbusier was the subject of controversy in the architectural environment. Beyond academic considerations, the arguments to defend this new form of opening were the benefits associated with the use of daylight:

" It illuminates better: in fact, its shape allows him to gather all its light at the height useful which is that of the eyes of the inhabitant" [1].

Nearly a century later, curtain wall facades offer complete freedom in the façade composition between glazed and opaque parts. This freedom can be exploited to optimize all functions performed by the window, namely, daylighting, ventilation, contribution to solar gain and thermal insulation in winter and control of the overheating risks in summer.

Figure 1: View of the strip window of the « petite maison » in Corseaux (CH). Photography published by Le Corbusier in his Almanac of Modern Architecture, Paris, 1926, with the caption: «La fenêtre a 10,75 m de long. En hiver, le site "est là" comme si l'on était au jardin. Alors les jours ne sont plus tristes; de l'aube à la nuit, la nature déploie ses métamorphoses».

In our daily practice as a consulting firm in building physics, we see more and more projects whose facades are composed of vertical stripes, fitted with glazed parts from the floor to the ceiling (see Figure 2). Although this observation is not based on statistical data, we thought it was interesting to compare the overall performance of these types with the horizontal band mentioned above.

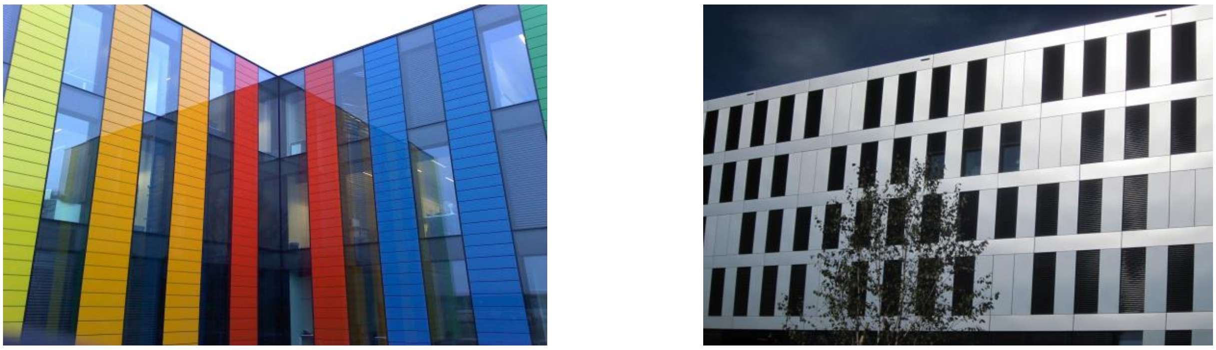


Figure 2: Office buildings in the Lausanne areas,
Left: D. Perrault architect, Right: CCHE architecture; photos Estia SA.

METHODOLOGY

We concentrate on an individual south oriented office room (depth = 5.50m, width = 3.50m, height = 2.70m) and we analysed the four typologies presented in Table 1 (WFR = total glazed area/floor area). The glazing characteristics are as follow: $T_v = 0.80$, g= 0.62, $U_g = 1.1$ W/m^2°K. The reflection coefficients are as follow: ρ_{floor}=0.3, ρ_{walls}=0.5, $\rho_{ceiling}$=0.7. The south facade is the only one in contact with outdoors (U_{value} of opaque part = 0.19 W/m^2°K). The occupancy scheme follows the Swiss regulation for office rooms: 7 am- 6 pm, 5 days per week, totaling 2871 hours of use per year. The required illumimance level is 500 lux on the work plane (height = 75 cm). The room is facing south.

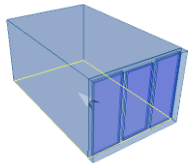
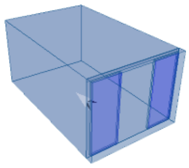
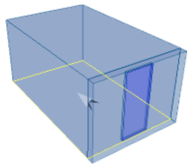
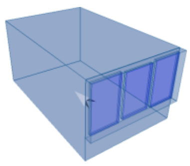
	Type 1	Type 2	Type 3	Type 4
Axonometric				
Window to floor ratio	39%	26%	12%	25%

Table 1: Schematic description of the four typologies that were analysed.

The following topics are addressed:

- Daylight contribution (Daylight factor, Diffuse Daylight autonomy)
- Heating loads
- Cooling loads
- Visual appraisal

The comparisons were made by means of numerical simulations with DIAL+ software [2]. The energy weighting factors follow the Minergie® recommendation [3], e.g. electricity : 2.0; fossil fuels (heating): 1.0, cooling : 0.5 (COP = 4).

RESULTS AND DISCUSSION

A) Daylighting

To compare the lighting performance of the different types, we calculated the diffuse daylight autonomy (DDA, [4]), on the basis of daylight factor values (DF). DDA represents the percentage of time during which the indoor illuminance exceeds a certain illuminance value (here 500 lux) only with the diffuse component of the sky. Table 1 summarizes the results of the lighting analysis of the 4 types. Obviously, Type 1 shows the best performance, Type 3 the lowest one, and Type 4 is very close to Type 1.

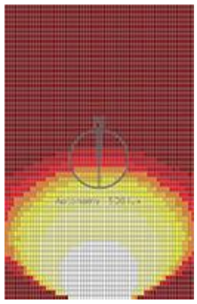
	Type 1	Type 2	Type 3	Type 4
Diffuse Daylighting Autonomy distribution (7am-6pm)				
Average DDA	56.7%	42.7	26.3%	53%
Average DF	6.0%	3.8%	2.1%	5.1%

Table 2: Daylighting contribution for the 4 types (simulations DIAL+Lighting).

B) Electric lighting

The electric lighting installation is composed of 4 downward luminaires Channel Office CLD 2x28W, with a total installed power of 246 W, e.g. 12.8 W/m^2. Switching of the luminaires is automated (ON if average illuminance < 500 lux & OFF if average illuminance > 500 lux). To estimate the energy consumption due to electric lighting, we applied the Swiss standard calculation procedure (SIA 380/4, [5]). Table 3 shows the results for each of the types.

	Type 1	Type 2	Type 3	Type 4
Full charge hours (7-18h) SIA	832 h	1185 h	2303 h	1205 h
Lighting demand SIA (7-18h)	10.7 kWh/m^2	15.3 kWh/m^2	29.7 kWh/m^2	15.5 kWh/m^2
Weighted energy SIA	21.4 kWh/m^2	30.6 kWh/m^2	59.4 kWh/m^2	31 kWh/m^2

Table 3: Energy consumption due to electric lighting according to SIA calculation.

We note that this calculation method clearly favors Type 1. Thus, the number of hours is reduced by about one third compared to type 4, while the difference in terms of autonomy is only 3.7% of the opening hours (56,7% vs 53%, see Table 2).

C) Heating / Cooling loads

To estimate the influence of each type on the heating loads, we performed dynamic thermal simulations with the thermal module of DIAL+[6,7,8,9]. In order to facilitate comparison, we decided to cool the room and to look at the specific cooling demand. Furthermore, in order to avoid bias related to users, we considered automated blinds.

The room characteristics follow the Swiss standard SIA 2024 for offices

- Room parameters: Floor: concrete slab + False floor; Outdoor Walls: Light wall, Insulation thickness: 20cm; Indoor walls: light walls; Ceiling: Concrete slab, no coating;
- Internal gains: Occupants: 5 W/m^2; Electric equipment: $7W/m^2$;
- Heating device: radiators, T_{min}: 21°C; P_{max}: 1,92 kW
- Cooling: Coil heater, T_{max} = 26.5°C, P_{max} = 3.85 kW (no openings)
- Ventilation: Air flow during room use: 49.5 m^3/h; Air flow when room not in use: $6m^3/h$
- Shading: Automated external venetian blinds,
  Blinds down when incident flow > $90W/m^2$ and Indoor Temp > 22°C

	Type 1	Type 2	Type 3	Type 4
Cooling demand	7.4 kWh/m^2	5.7 kWh/m^2	5.6 kWh/m^2	4.6 kWh/m^2
Weighted energy for Cooling	3.7 kWh/m^2	2.85 kWh/m^2	2.8 kWh/m^2	2.3 kWh/m^2
Heating demand	37.0 kWh/m^2	29.5 kWh/m^2	17.1 kWh/m^2	21.2 kWh/m^2
Weighted energy for Heating	37.0 kWh/m^2	29.5 kWh/m^2	17.1 kWh/m^2	21.2 kWh/m^2

Table 4: Energy consumption for heating and cooling according to SIA 380/4.

Type 1 is the one that shows the highest heating and cooling demands while Type 3 shows the lowest heating demand. Type 4 shows the lowest cooling demand which can be explained by the fact that, during summer, the glazing is better protected by the thickness of the facade. It is reasonable to think that the situation would have been worse with manual shading device, with a significant increase of the cooling demands due to a misuse of sunscreens [10].

D) Global energy consumption

The global energy consumption of the four types is calculated on the basis on the energy demand and, following the Swiss standard, is weighted by a factor 1 for gas or oil for heating, 2 for electricity and a ESEER value of 4 has been used to determine the electricity consumption required for cooling.

Figure 3 shows that Type 4 is the less energy intensive and that the three vertical stripes types show a lowest global efficacy. This figure also points out the fact that lighting has become a major area of consumption. We must emphasize here that the SIA calculation method for artificial lighting consumption does not take into account the actual geometry of the openings, which in this case, may favor Types 1 and 2 while penalizing the result of Type 4.

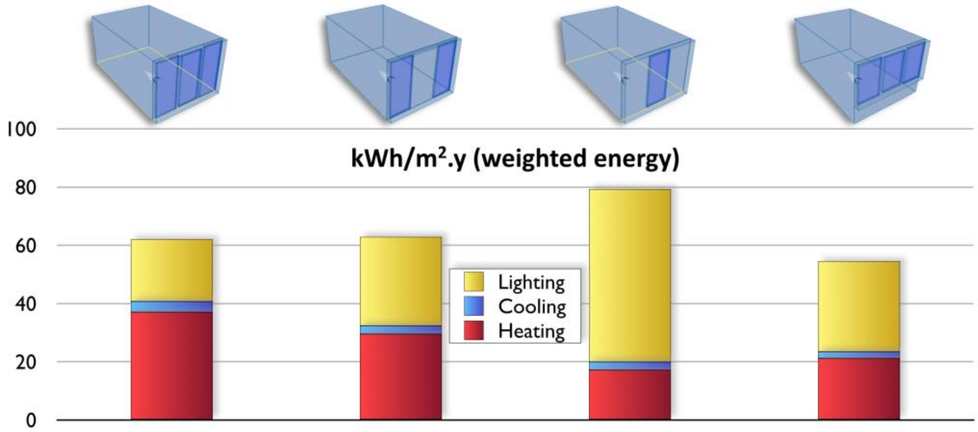


Figure 3: Comparison of the energy consumption of the 4 types according to SIA 380/4 and thermal dynamic simulations [5].

E) Visual appraisal

Figures 4 to 6 allow comparing the visual field of a "typical" user for each of the 3 vertical types with Type 4. The simulations conditions are as follow: Clear sky with sun, 21st of March 9 AM. The observer is looking towards the East and the sun is visible on the upper left corner of the window

The difference between type 1 and Type 4 is based solely on the cut-off of down vision due to the sill (fig.4). In type 2 (fig. 5), the outward view is almost completely cut off, but the sky portion that is still visible is very close to the computer screen and the potential for glare situations is still high. In Type 3 the view outside is partially maintained, but the daylight availability is significantly reduced (fig. 6). This comparison shows that type 4 represents a good compromise between the glass surface and the services offered to the user.

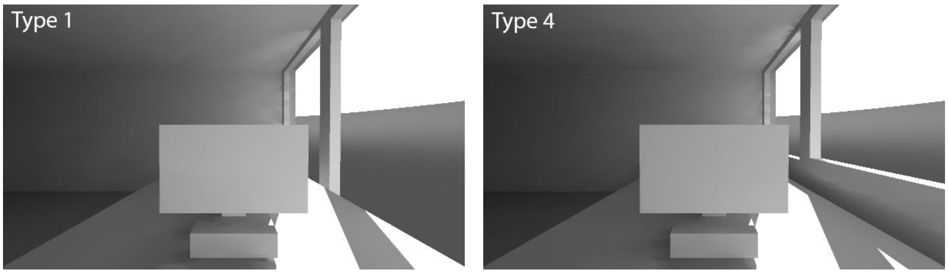


Figure 4: Type 1 / Type 4: Visual field of a typical user / clear sky with sun, march 21, 9 am. External view is completely free and glare is depending on movable shading device.

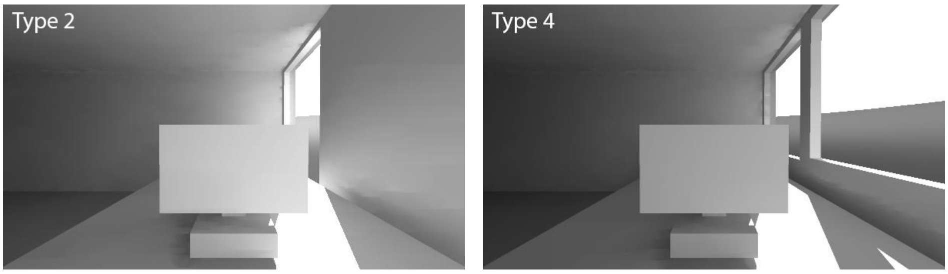


Figure 5: Type 2/ Visual field of a typical user / clear sky with sun, march 21, 9 am. External view is blocked but glare may still occur and depends on movable shading device.

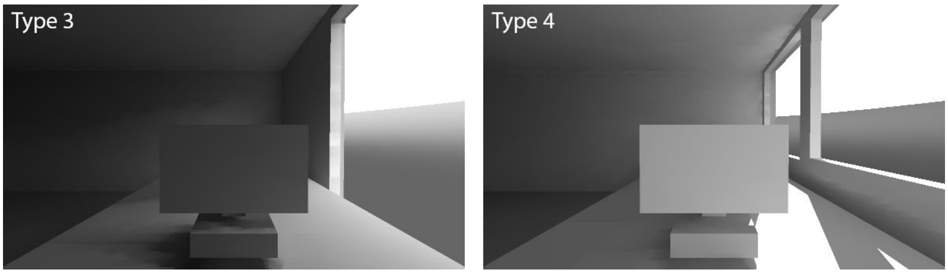


Figure 6: Type 3, / Visual field of a typical user / clear sky with sun, march 21, 9 am. External view is mainly maintained and glare is solved in this particular circumstance.

CONCLUSION

This study showed that the actual architectural trend, which consists in designing facades with vertical stripes of glazing from the floor to the ceiling, does not lead to improve the overall performance of the building. Compared with horizontal windows (type 4), each of the vertical type (1-3) we analyzed has a higher global energy demand (heating + cooling + lighting). Concerning Type 1 (fully glazed), it is reasonable to think that the situation would have been even worse with manual shading device, with a significant increase of the cooling demands. Type 2 (two vertical stripes) is less effective to let daylight penetrate deep into the room and reduces the outward visibility. Type 3 (one vertical stripe) does not allow activating the back part of the room with natural light and leads to a significant increase in lighting consumption.

This information is likely to call into question this architectural trend and should encourage architects to reconsider their approach to the design of buildings, especially if it comes to office buildings.

Finally, this study also confirms the fact that the weight of lighting in the overall building energy consumption becomes increasingly important. In the current context it is a major issue to change practices and regulations to be in line with the new targets regarding energy efficiency and sustainability.

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