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CHALLENGING SOLAR DESIGN CLICHÉS – SOLAR CONTROL STRATEGIES

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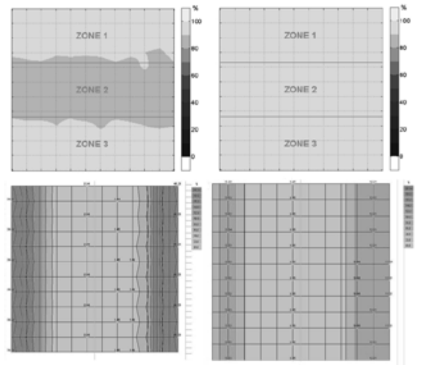

Fig 1: Comparative analysis of vertical vs horizontal louvres

WHICH ARE YOUR ARCHITECTURAL (R)SOLUTIONS TO THE SOCIAL, ENVIRONMENTAL AND ECONOMIC CHALLENGES OF TODAY?

Research summary

This paper challenges the clichés around solar control design and orientation. It proposes an analytical approach according to building typology, building geometry, orientation and location based on latitude. The approach considers not only solar control performance, but availability of external views, glare control and daylight availability with related lighting energy consumption. The variation in daylight availability, significant difference in sun path and the added performance indicators demonstrate that using the typical cliché's of vertical shading on East and West facades can send designers off on significant tangents. The paper compares vertical shading on an east and west facade with horizontal shading with the same shading surface area to demonstrate applicability and potential inapplicability with reasoning why the cliché is suited to certain conditions (or not) and not to others. The paper concludes with a summary of the results of the different strategies with quantified results in energy performance, daylight availability, access to views and duration of glare limitation as a starting point for designers to appreciate what should be considered in their projects.

Keywords: shading, daylight, energy, sun angle, insolation, orientation

1. Introduction

Solar control design is generally one of the first steps for many building designers. However, they often fall into the trap of solar control clichés without considering the various factors which affect the overall building strategy along with occupant comfort.

This paper takes a look at the solar control cliché of using vertical shading devices on the East and West facades of buildings as a solar control strategy. This design rule of thumb is challenged based on the argument that sun angles are different at different latitudes, for example Munich in the Northern Hemisphere with respect to Cape Town in the Southern Hemisphere, which can influence solar control design aspects. The argument is analysed based on added performance indicators such as shading performance, availability of external views, useful daylight availability, glare control, related lighting energy consumption and finally the corresponding cooling and heating requirement. The factors influencing a building solar design, such as shading devices, glazing ratio, building typology (with respect to usage and occupied hours), building orientation and geometry are discussed.

The objective is not to provide yet another design rule-of-thumb but to show that simple analysis can be considered in a project in its first stages to avoid going on significant tangents by following design clichés which do not necessarily apply anywhere and everywhere in the world.

2. Motivation

The original hypothesis that led to the writing of this paper was that vertical shading on the east and west facades were driven by higher latitude building design in the Northern Hemisphere where it would be appropriate due to a longer duration that sun occurs at low vertical sun angles. The authors of this paper have found through analysis of shading design in their projects in lower southern latitudes that this cliché is not appropriate to their projects. An investigation was made to compare the duration of occurrence of vertical and horizontal sun angles equivalent to fixed shading devices that are intended to have a forty five degree shading angle.

An hourly analysis of the duration of time for 365 days from sunrise to sunset was performed for: vertical sun angles of below forty five degrees (to represent exposure duration of simple horizontal shading) and the same for horizontal sun angles of between minus forty five and forty five degrees for simple vertical shading of the same surface area. This was performed for two locations – Cape Town (latitude of 33°55’31”South and longitude of 18°25’26”East) and Munich (latitude of 48°21’14”North and longitude of 011°47’10”East). The results are presented in the following graph.

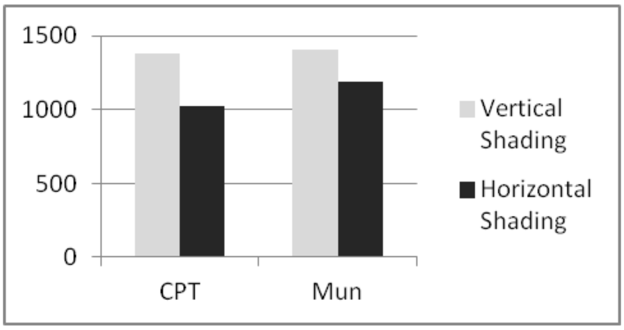

Fig 2: Hours of direct sunlight based on vertical and horizontal shading in Cape Town and Munich

Cape Town will experience a 26% reduction in hours that direct sunlight would be striking the glazing compared to only an 15% reduction in Munich. These results prove and disprove the hypothesis in the following manner:

Purely based on this simple quantification, in Munich, the horizontal shading should prove to be more effective in providing shading that vertical shading on the east facade and therefore at face value the cliché is not appropriate to that latitude either.

However the increase in shading performance when using horizontal shading on an East or West facing facade is more pronounced in Cape Town than in Munich. This still supports the statement that the cliché is not necessarily valid and should be further tested against a full set of performance indicators fully representing the function of the shading devices.

2.1 The Functions of Solar Control Devices

In order to analyse the requirements imposed on a building for solar control, the functions of solar control itself must be established. This paper proposes that solar control has two functions, mediation of solar gain and facilitation of fenestration to function optimally via assisting with glare control.

2.2 Solar Gain Mediation

Many designers focus on one particular aspect: the energy flow from the sun and how to use or exclude it throughout the year. However, by focusing on it, designers can often sideline other aspects of the overall building performance. On the other hand, simply following rule of thumbs do not necessarily provide the optimum solar control solution to the building.

Solar gain mediation allows solar radiation in the space when it is needed and excludes it when it is not needed - the rule of thumb of “solar radiation out” in summer and “solar radiation in” in winter is generally followed. However, summer and winter conditions are not necessarily a function of the month of the year only. For example, in a particular location, “winter” conditions may occur in some summer months for a few hours in the morning and a few hours in the evening. Furthermore, if a building typology and usage inherently generates a high internal thermal load through the year, it may be counter-productive to encourage solar radiation into the building in winter which could overheat the internal spaces and thus, extend the running hours of a mechanical cooling plant which would otherwise be switched off.

2.3 Fenestration facilitation through assistance with glare control

The function of windows and glazing is to allow in natural light and to allow external views from occupied space. Natural light availability assists with improving indoor environmental quality as well as potentially reducing energy consumption related to artificial light. These aspects need to be balanced against the mediation of solar gain and are interrelated through the potential problem of glare.

While an important source of daylight, glazed areas can contribute to glare. Glare can arise from: direct sunlight and high ambient daylight levels adjacent to the fenestration. Glare can cause occupants to close blinds, therefore reducing the duration of availability of external views and natural light. Solar control devices therefore have a role to play in glare control in order to meet the function of fenestration facilitation. The authors of the paper recognise that glare is in fact a more complex issue than what has been described, but propose that this simplification is adequate for the purposes of this paper .

In summary, the design of solar control devices is to consider: solar gain mediation, natural light for energy saving, natural light for indoor environmental quality, glare control of direct sunlight and glare control of diffuse light.

3. Quantifying and Measuring the Functions

From an understanding of the above functions, one has to ask the question: "What are the added *performance indicators of these functions and how are they measured?"*

3.1 Solar Gain Mediation – Annual cooling and heating energy

Solar radiation into a space can cause an increase in solar thermal gain in the internal heat loads. As a result, this will cause an increase in the cooling energy requirement of the building or a reduction in heating requirements if occurring during a heating period. To determine whether the solar mediation is effective or not, a comparison is made of the two shading options with regards to the required heating and cooling.

3.2 Natural light for indoor environmental quality – Daylight autonomy

Daylight autonomy defines the percentage of occupied hours per year when the minimum illuminance level can be maintained by daylight alone. [1] It characterises the daylighting potential of the indoor space and is measured by the Continuous Daylight Autonomy value in this paper.

3.3 Glare control of direct sunlight – Duration of direct sunlight striking the occupied areas of the space.

This is quantified in this paper through the percentage of hours per year that direct sunlight shines into the space on the analysis grid. During these hours it is assumed that occupants will draw the blinds which will have an impact on the availability of external views and natural light..

3.4 Glare control of diffuse light – Useful daylight index

Useful daylight index defines the percentage of occupied hours per year when the illuminance level is comfortable or useful to the occupants in the space. Although comfort ranges are subjective, 2000 lux is assumed to be the upper threshold of comfort with higher light levels becoming too uncomfortable, hence not useful for the occupants.

4. Evaluation against the performance indicators

In order to demonstrate the point an evaluation of a simple building in Cape Town is performed. A comparison is made between vertical shading and horizontal shading both having the same surface area in total. The same can be done for other potential shading strategies (movable screens, blinds in combination with shallower horizontal device etc.)

A simple model, representative of a typical building geometry for the chosen typology, was first setup using the Autodesk Ecotect software as shown in Figure 3 for the basis for the analysis.

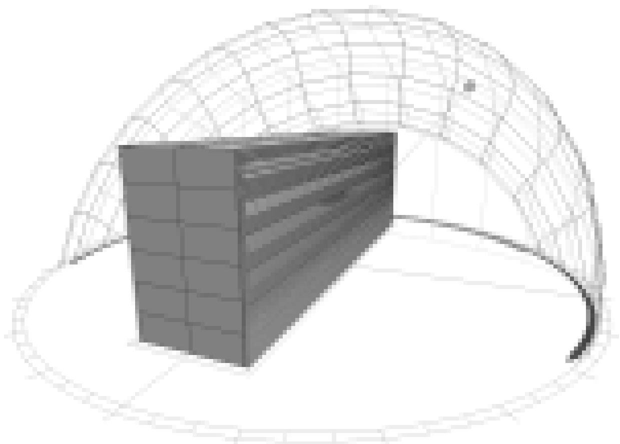

Fig 3: Simple base building model showing a typical sub path in the sky dome.

The shading devices are then added to the windows of the base building model. The glazing type and characteristics are also defined as well as the internal loads such as the lighting power density and schedule of the running hours for that particular building typology.

4.1 Characteristics of the Base Building Model

The basic properties and constants of the model are shown in Table 1.

Description	Inputs
Building dimensions	12 m deep x 60 m long x 3.2 m high
Orientation	Longitudinal axis of building on North-South axis (East and West facing)
Building typology	Office usage with occupied hours between 08:00 and 17:00
North (or South) façade	No windows
East & West façade	Strip windows of 1.65 m long x 58 m high with glazing visual light transmittance of 0.50
Glazing ratio	R_{gf} of 0.27
Shading angle	45°
Lighting power density	12 W/m^2
Illuminance target	500 lux on an analysis grid of 1 m x 1 m offset at 720 mm high from the floor level and 500 mm deep from the exterior walls

Table 1: Characteristics of the base building model.

4.2 Simulation Iteration 1: Cape Town – Vertical Louvres

The first iteration of the base model includes the use of vertical louvres of 400 mm deep with 400 mm spacing on the windows with the building located in Cape Town.

4.3 Simulation Iteration 2: Cape Town – Horizontal Louvres

The louvres on the first iteration are then exchanged for horizontal louvres of 400 mm wide with 400 mm spacing and analysed again in Cape Town.

4.4 Test for solar mediation – annual cooling and heating energy consumption

The Ecotect model is exported to Energy Plus in order to analyse the net thermal load of the building with respect to its internal heat loads, external solar loads and climatic data for that location and resulting cooling and heating energy requirements.

4.5 Analysis of daylight availability

An analysis grid is established in Ecotect and then exported for both options to the Radiance/DaySim daylight calculation engines using the climatic solar information for the building location. The results are then, subsequently, evaluated using in-house Lightview software, developed in-house for the analysis of the DaySIM results to provide the lighting energy consumption, daylight autonomy and useful daylight index during the occupied hours of the day for that specific building typology.

The graphs indicate an abundance of daylight availability for both options with slighting deeper penetration of light when horizontal louvers are used.

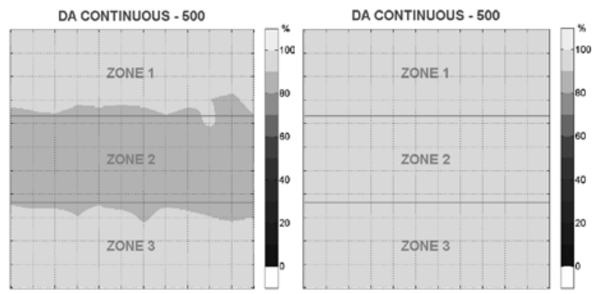

Fig 4: Daylight autonomy for vertical (left) and horizontal (right) in Cape Town

4.6 Comparison of the lighting energy consumption

The Lightview software provides an indication of the lighting energy consumption as the next performance indicator based on the assumed light power density and the schedule of the running hours and operating strategy of the light fittings within the modelled space.

As expected from the daylight autonomy results, there is no difference between the lighting energy consumption between the building with vertical and horizontal louvres, as seen in the figure below which shows dimmed fittings against non-dimmed fittings for both options.

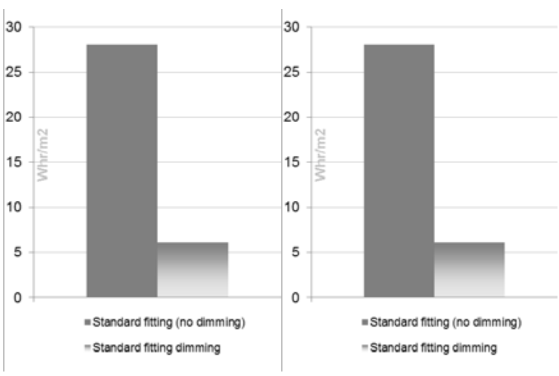

Fig 5: Comparison of the lighting energy consumption in Cape Town (vertical louvres –left and horizontal louvres – right)

However the lighting analysis assumes that blinds are always up. The following analysis was performed to understand the impact of glare and the likelihood that the occupants would lower blinds.

4.7 Availability of External Views - Analysis of diffuse glare

The following graphs show the results of the diffuse glare analysis. There is a slight improvement when changing from vertical devices to horizontal. According to this there is no more probability that occupants will draw blinds with horizontal shading than with vertical shading. There would therefore be no more impact on lighting energy consumption due to blinds being down, or reduction in duration of availability of external views on the basis of this analysis.

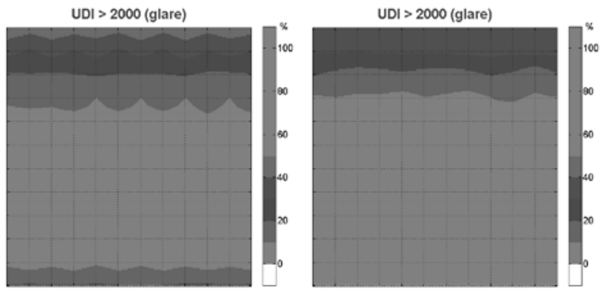

Fig 6: useful daylight index above 2000 lux for vertical (left) and horizontal louvres (right) in Cape Town

4.8 Availability of External Views Analysis of Direct Glare

From the Ecotect model, the percentage of the time throughout the year where direct sunlight penetrates into the space is analysed on an internal grid to obtain the frequency of time when glare due to direct sunlight is induced for both shading variances.

From the results indicated in the figures below, there is a significant improvement in having horizontal shading devices with regards to direct glare control. Occupants will be able to raise their blinds sooner and more often on the East Facade and drop them later and less often on the West Facade, increasing the duration of availability of external views and natural light.

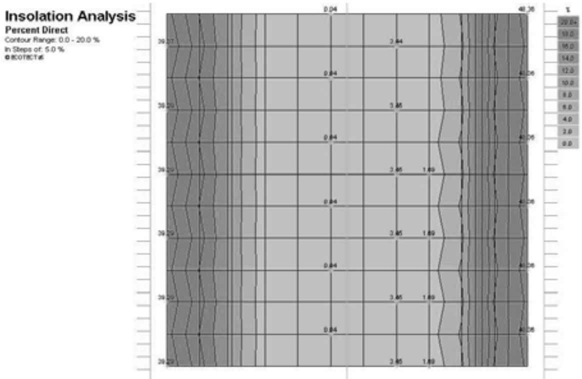

Fig 7: Percentage of direct sunlight on analysis grid for vertical louvres

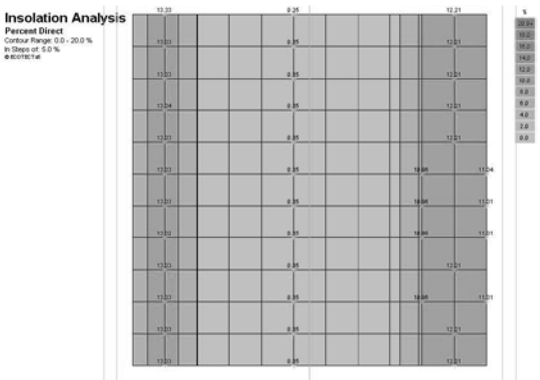

Fig 8: Percentage of direct sunlight on analysis grid for horizontal louvres

These results, thus, show that external views will be much more available when using horizontal louvres rather than vertical louvres in Cape Town throughout the year from the fact that the occupants will be less likely to pull their blinds down due to glare from direct sunlight.

5. Additional variables to be considered in further analysis

This paper has proposed a simplistic building for comparison. The extent of shading required can vary according to a number of variables including the nature of the occupation of the building, the specific climate at that latitude, the glazing ratio driven potentially by views or by cost, shading variations responding to aesthetic requirements, reflection of nearby water bodies or other buildings, and/or more subtle shading angles.

6. Conclusions

It would appear that the original hypothesis that vertical shading on an east or west facade is actually valid for a higher northern latitude could be wrong, however this would need to be confirmed via a similar process of analysis to determine the full impact. However this paper is focused on establishing this for a lower southern hemisphere latitude.

The cliché that is being disproved considers that vertical shading is more appropriate for an east and west facade compared to horizontal shading. As indicated in these results, the performance is quite similar when looking at some of the individual indicators like lighting energy consumption and daylight autonomy. However there is a clear higher performance in direct glare control for horizontal shading providing greater duration of external views and natural light availability due to blinds not being drawing.

As stated in the introduction, the intention is not to replace this cliché with another and so this paper does not propose that only horizontal shading be used on the east and west facades, but should be strongly considered. In addition, other shading strategies should be evaluated and determined to be appropriate or not. The designers might choose to add evaluation criteria that could be specific to their particular building context which could include for example cost, or availability of specific views.

7. Acknowledgments

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8. References

Reinhart C. F., Mardaljevic J. and Rogers, Z. 2006. Dynamic Daylight Performance Metrics for Sustainable Building Design. Leukos, 3(1), 7-31