A design strategy for daylight control for the project “Vertical City” in Rotterdam

Summary

The present thesis was carried out as part of the on-going research in the architectural office “Broekbakema” regarding the project “Vertical City,” Rotterdam. The focus on light performances was a key issue in the design of the building, seen that the main volume will occupy a depth of 22 m. At the same time, all the interior spaces occupy the interior of the volume, at the “core” as it is referred to by the architects of the building.

This was the main challenge of the design in terms of daylight, and the main parameter that determined the daylight strategy and the tests which were done during this thesis. The main problem that we had to solve, was to reverse the unfavorable situation of the partially daylit building volume and to validate a system that could provide the building with adequate levels of daylight during the year. At the same time, the possibility of glare problems had to be specified, so that comfort could be assured for the occupants of the rooms.

Due to the enormous volume of the building, we had to work on a modular unit (13x13x22m), that is a repetitive typical space, so that the simulations could be carried out without the demand of extreme computing power.

Research question: How can we achieve maximum use of daylight in a typical unit of the building?

Methodology

The daylight design proposal followed a number of consequent steps: analysis of the current design strategy; analysis of the problem and research; formulation of a design strategy and validation of a system that can ensure adequate daylight and glare control.

In order to achieve the latter, a number of systems had to be applied: a gap was opened at the overhang, reflectors were tested and validated and glare-control solutions had to be specified.

In order to validate the daylight design solution, a number of tests were performed:

1. Tests on the primary geometry, including an insight in the optimal number and position of floors inside the unit.
2. Complementary tests on the geometry, including the finalized sizing of the architectural elements (slabs, walls etc) and tests on possible solutions for its improvement.
3. Tests on sun-control systems. These tests evaluate the luminance values that the systems result in.
4. Tests on shading systems, including the calculation of the optimal cross-section of a modular unit (13x13x22m), that is a repetitive typical space, so that the simulations could be carried out without the demand of extreme computing power.

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Results

- The overall geometry of the unit (length to height ratio) is the most important factor that determines the amount of light that reaches the interior. For a 5m overhang the illuminance drops by 4,5% along the first 2m, whereas this drop decreases to 4,16% for the next 4,5m and to 0,49 for the next 5,5m. The percentages change for the different positions of the sun and for different lengths of the overhang or positions of the floors. Steeper drops in illuminance should be expected for a clear sky during the summer, and for floors with a lower ceiling.

- The maximum number of floors that we can have inside the unit, is 2 and they should not be evenly distributed along the height of the volume. On the contrary, it is optimal that the ceiling height decreases as we move from the top to the lower floors (floor=1 to 3.3m, floor=2 to 7.00m).

- A gap in the overhang can improve the levels of incident light in the interior of the volume, yet the improvement is considerable for a clear sky. The results we obtain for an overcast sky are less encouraging. In any case, the gap should have a width of at least 2.5m, seen that the final thickness of the slab will be 1.5m.

- The results on the gap proved that zone 2 is still underlit for the summer period during an overcast or clear sky, and for the winter period during an overcast sky. For this reason, further devices had to be researched, so that light could be reflected/reflected deeper into the volume.

The results on the light shelves can be summarized in the following:

- An effective cross section for the system of reflectors could use the "REFLEX" cross-section as designed by prof. Köster.
- The most effective combination of reflectors occurs when they assume radial dimension= 1.25m.
- Two reflectors at position 1 and two reflectors at position 2 with rotation angles= 11° and 17° respectively, in combination with a highly reflective ceiling inside the room (reflectance=90%) provided optimal results. The material that was used for the calculations was polished steel.

Once the system of shelves is validated, we reflect on the levels of light that the final solution could provide for the unit.

The results on reflectors proved the following:

- The resulting levels of light are adequate for zone 1 throughout the year.
- The levels of light are not adequate for the end of zone 2 during an overcast sky. Yet zone 2 in total can be adequately lit throughout the year during a clear sky.
- Zone 2 can be underlit during a winter overcast sky, seen that the reflectors have a smaller effect when the perform with diffuse light.
- Glare occurs during the evening hours, especially in winter period. The occupants of zone 1 may also experience glare during a summer, clear sky.

Due to the above results a number of tests were performed for the specification of the characteristics of shading systems. The results on shading are the following:

- Shading is necessary for a zone=90%, for the western sun.
- The use of a translucent shader is more optimal than the use of an opaque shader.
- The system should preferably be linear.
- The distribution of lines in a translucent shader does not significantly affect the results.

Name: Marina Stavrakantonaki
Student number: 4118057
Track: Building Technology
Subtrack: Façade Design

First mentor: Tillmann Klein, Faculty of Architecture, Building Technology
Second mentor: Michela Turrin, Faculty of Architecture, Building Technology
Third mentor: Truus Hordijk, Faculty of Architecture, Building Technology