Evaluation on the Daylighting performance of 'generative façade components' In the digital simulation

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Abstract
The aim of this study is to find out a role of the computer simulation on sustainable design projects and development of façade elements with results of daylighting simulation and energy performance. 3D components of façade modeling get to realized in Rhino 3d with some help of Paracloud encoding. With simulation program of Ecotect and eQuest, thus, the result will show influencing factors of each generative components on the radiation & dayligthing factors. And not only that, the result will move to further arguments which is how many factors are related in design of generative skin and which factors should be mainly considered in development façade elements of a sustainable building.

Keywords: performative envelope, generative component, daylighting analysis, digital energy simulation

Introduction

Recently, the better to get realized a sustainable design in architecture, the more collaborations with variety of parts are required. Environmental architecture needs some kind of mechanism about down to earth building elements that allow it to become sustainable.

Correspondingly, there is a trend to contrive integrated process at the early stage of design in architecture. One of this kind of architect's effort seems to appear as a development of the performative building envelopes which is something to do with strong interests among some architects about an innovative building façade. It gives rise to make a building dress up with digitally designed facade which each composing elements are designed through so called 'algorithmic' digital design processes. However, there is need to examine how well these façade design functions environmentally in real and further, to investigate the energy saving effect itself. Thus, digital simulation plays a significant role on this stage of design. In this study, it is the main stream to prove relationship between results of simulation, in particular, solar radiation and daylight analysis, and develop performative components on facade.

Objectives

As a way of examination environmental efficiency of component design, The Main idea is the reification of relationship among three counter parts - daylight efficiency, solar radiation energy performance.

Method

In order to proceed a quantitative comparison of the environmental performance, it selects a real, but simulated in this paper, target building - As shown in both Fig.1 and Fig.2, the head office of SAMSUNG electronics corp. in Seoul. Presuming that it would be renovated recently, the analysis is conducted within ranges of digital manipulation, focusing on alternating of façade of typical floor. And the several simulation tool are suggested - ParClould Modeler and Rhino as generative component design and solar analysis, DOE-2 for energy simulation, ECOTECT of solar and daylight calculation tool.

A three step process is followed for using both ECOTECT and eQuest. First, baseline set up. a digital modeling of the target building is made in ECOTECT (Fig. 3, Fig. 4), which is set up with a 'baseline design' to follow the criteria of ASHRAE 90.1-2007 Appendix G.
It is followed by solar analysis in ECOTECT in the limits of fundamental design factors shown in architectural drawing (Fig.5) with present climate condition. The offset distance of an analytical plane (analysis grid in Ecotect) set to 1.5m above the finish level of typical floor.(see Fig.7) In analytical plane, the void and core parts are excluded. External glasses consists of all low-E double glazing of which are SG 28%, Conductivity 1.65 (Table 2)
Secondly, proposed design analysis. Two different types of façade components are suggested. Each application is ordered as proposed design1 and 2.(Fig. 10 and Fig. 15) The proposed design 1 consists of one components –CASE 1.(Table 4). Proposed design 2 is made up with three different kinds of elements – No.5 to 7 in CASE2. A significant difference between 1 and 2 is the weaving method of façade. Proposed design 1 refer to uniform repetition of one

component. However, It is combination that three elements are applied to proposed design 2. It means, with both ParaCloud Modeler 1.0.4 and Rhinoceros, that intensity of solar radiation on the façade analyzed and it made combination of each elements optimized by its result(Fig 14). For example, in the point of high solar intensity on the façade, components with smaller size fenestration are applied.

All properties of proposed design, including overall size of façade, are the same with the baseline design shown in Table 2 to 3, Except one thing – fenestration and its ratio.

Third phase is the analysis of energy consumption. Considering estimation that daylight control affects directly on the energy consumption of artificial lighting, Annual Energy use on the whole building was checked on each case –baseline, proposed 1 and 2 by using DOE-2. Boundary conditions are illustrated through Table 5 through 8.

Results and Discussion

The 'effective' glazing portion of the façade of the target building is 67.7% (*glass mullion should be considered horizontal/vertical louver). Table 1 shows the interesting result. As though Proposed design 1 has similar fenestration ratio with baseline, its illumination on the floor is multiplied from 325.97 to 596.57 (83% increment). And in the case of proposed design2, the fenestration ratio is decreased by about half. However, the result of daylight level shows just 3% decrement. Solar radiation on the floor ,measured during a year, shows slight difference but a bit. It reaches at a point at least over 80% of the maximum daylight autonomy value within the scene.

Table 1 Final Result of Analysis

		Illumination lx	Insolation $kWh/m^2 \cdot yr$	Fenestraion %	Electricity consumption
Baseline design		325.97	82.13	67.7	20,260MWh
Proposed design	case1	596.57	83.19	61.3	21,660MWh
	case2	577.36	79.53	34.4	19,432MWh

More focusing on the energy comsumption, though the variation of fenestration, insolation and energy consumptions are relatively stable without fluctuation. Through Fig. 19 to 21,The green and yellow area corresponds to the 'daylight area' whereas purple indicates a shortage of daylight. Leading much daylight on the floor not necessarily refers to excessive consumption of energy. Proposed case 1 and case2, though difference of fenestration, their energy consumption are relatively constant.

Conclusions

In brief, This simple set of models show uniformly distributed fenestration bring about daylight efficiency with little regard to any increment of energy consumption - the efficient inflow daylight with little increment of insolation. Moreover, better performative result of optimized arrangement is caused by both elimination of unnecessary numbers of glazing and more glazing on the south elevation.

References

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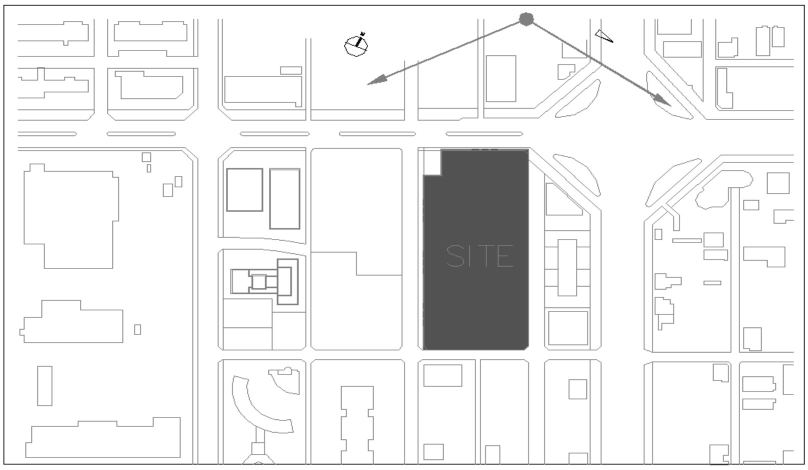
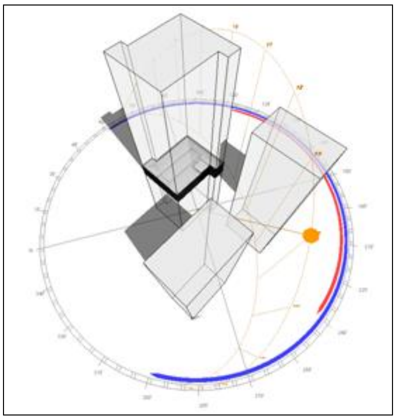


Fig. 1 (left) Target building : the headquarter of SAMSUNG.
Fig. 2 (right) The site plan of the building



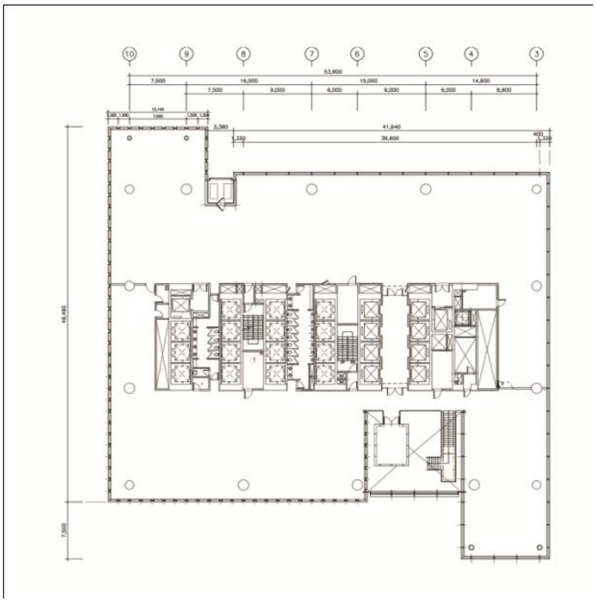


Fig. 3 (above left) Shadow map of target building and Typical floor (marked in red color)
Fig. 4 (above right) Orientation and Daily Sun-path of the building
Fig. 5 (below) Typical floor plan (17F)

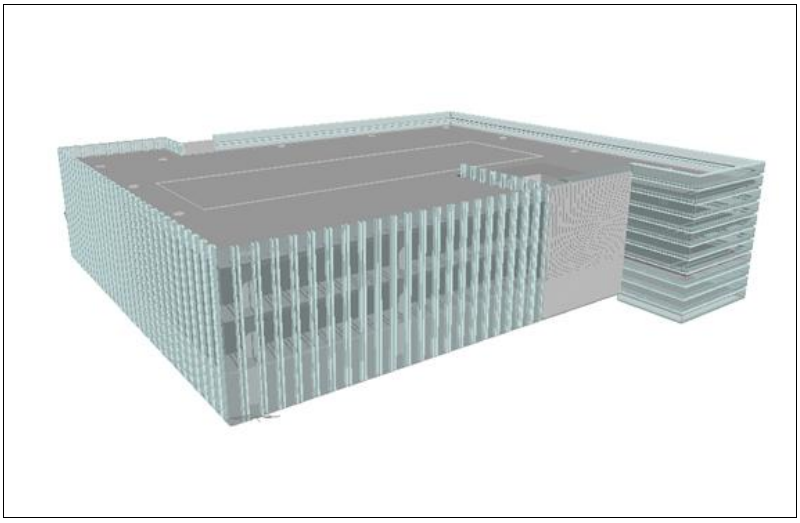


Fig. 6 Digital Baseline modeling of typical floor(16F~18F) in ECOTECT

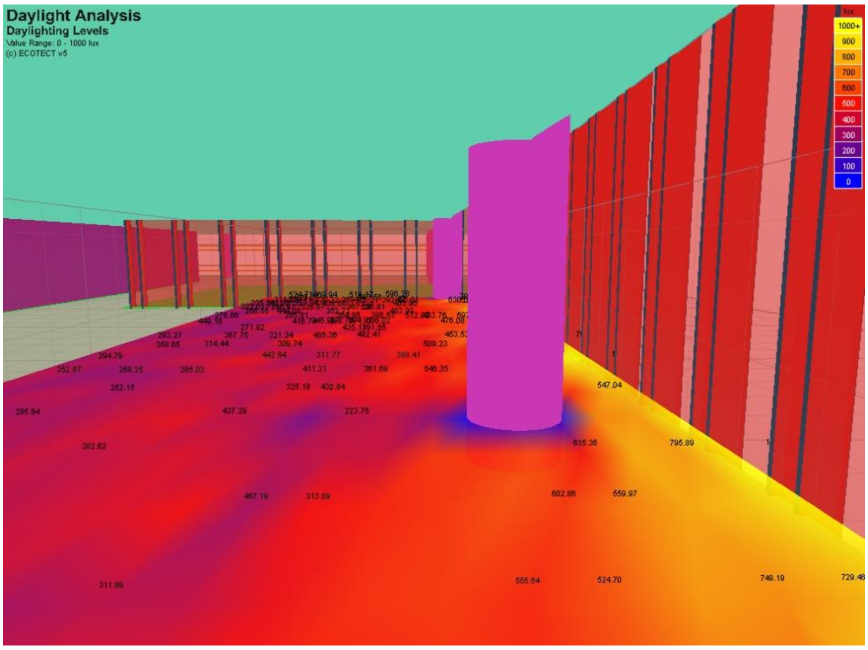


Fig.7 3D Interior view of Illumination levels in baseline modeling

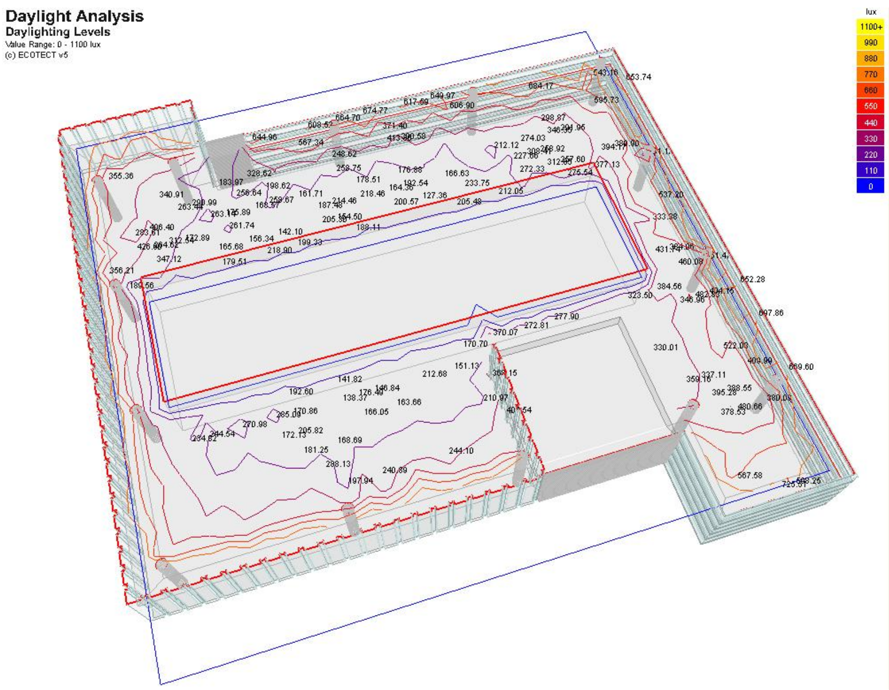


Fig.8 Illumination levels in baseline modeling (average 325.97 lx)

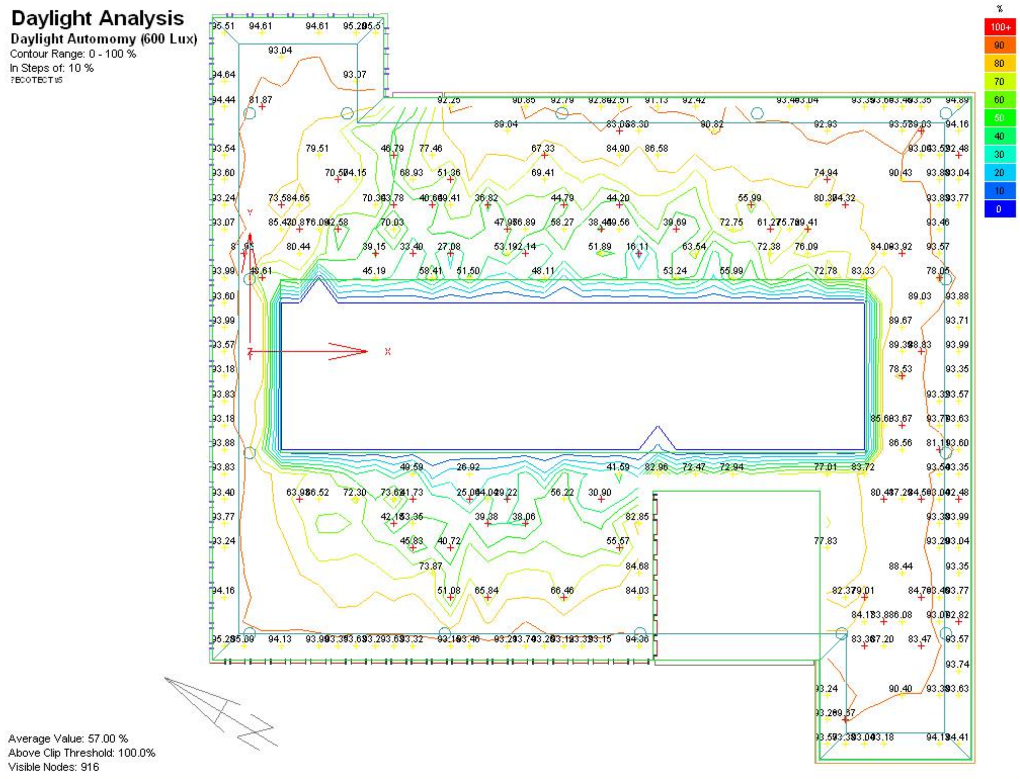


Fig. 9 Daylight Autonomy above 600lx in baseline modeling (average 57%)

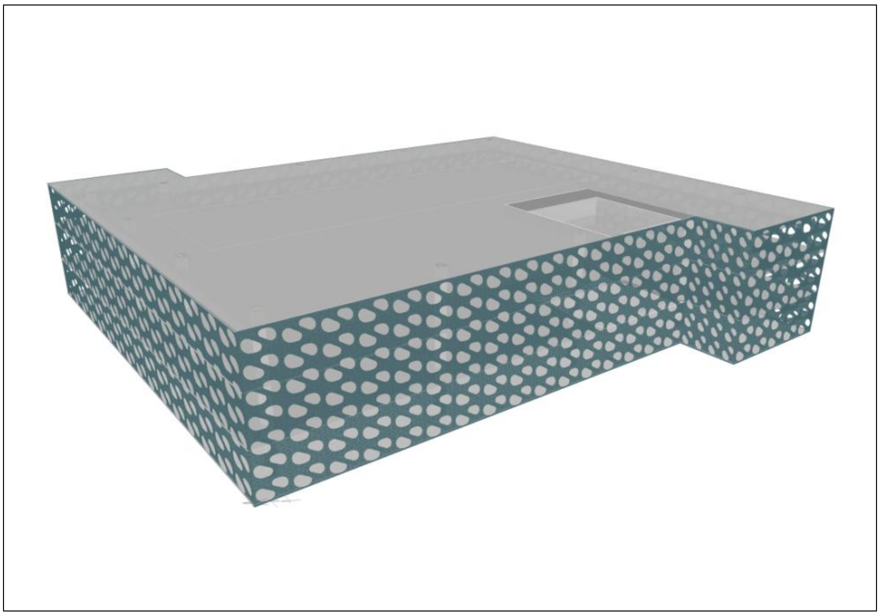


Fig.10 Proposed façade design - alternative 1

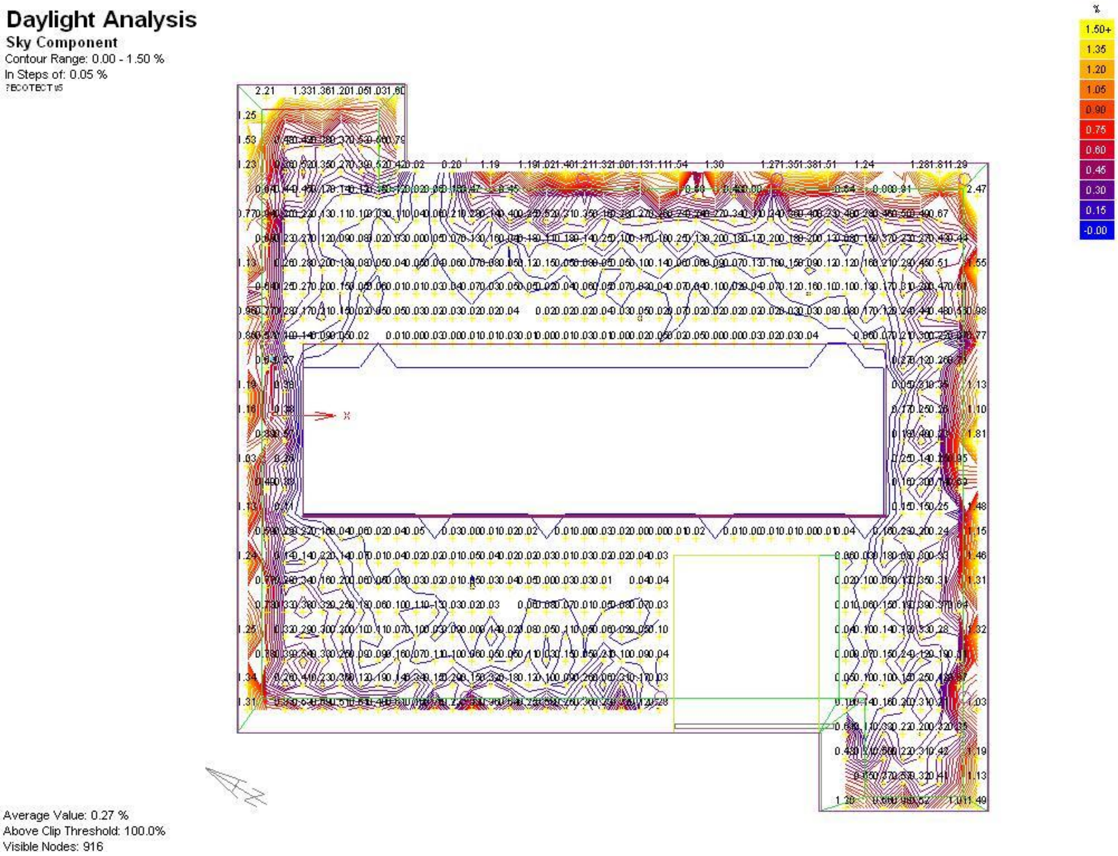


Fig.11 Sky component distribution in Proposed façade design 1(average 0.27%)

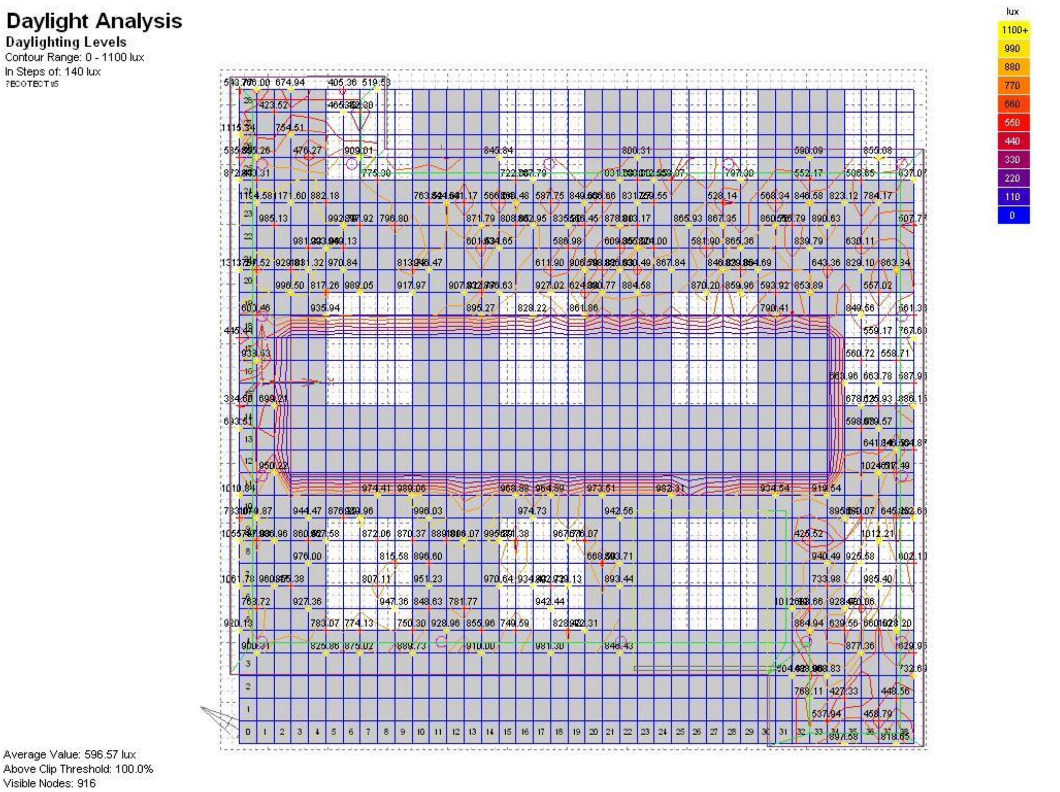


Fig.12 Illumination level in Proposed façade design 1 (average 596.57lx)

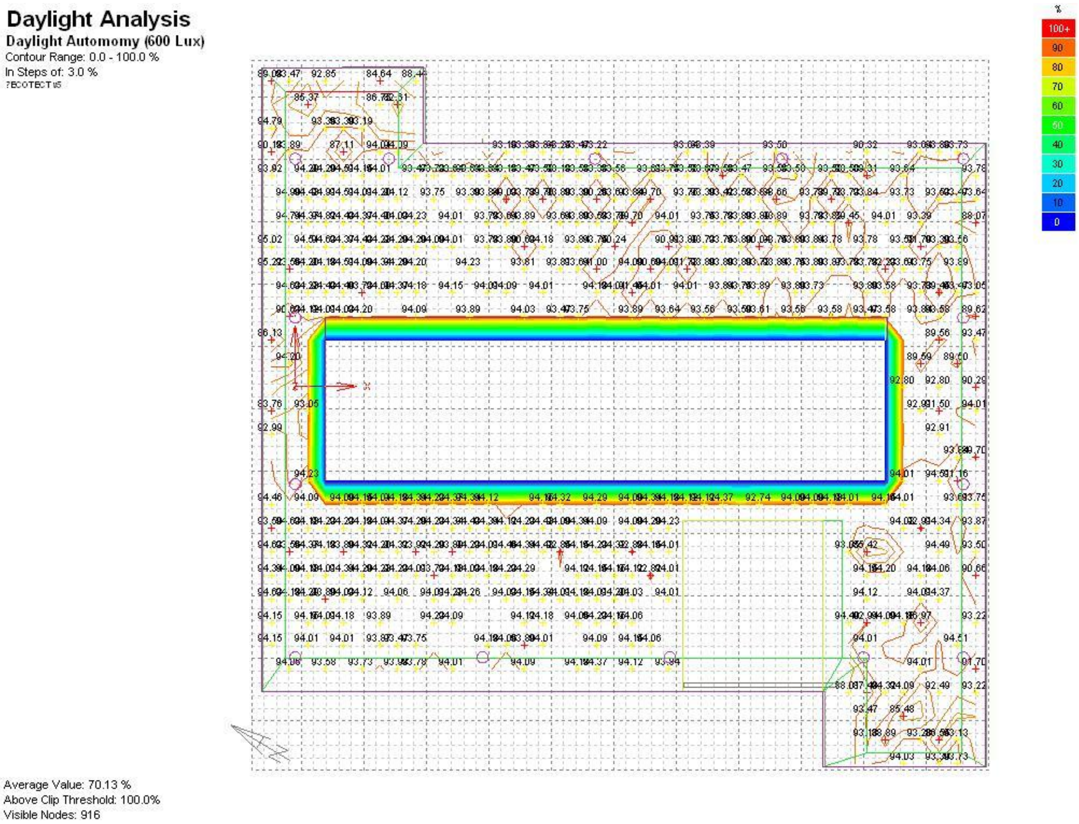


Fig.13 Daylight Autonomy above 600lx in Proposed façade design 1(average 70.13%)

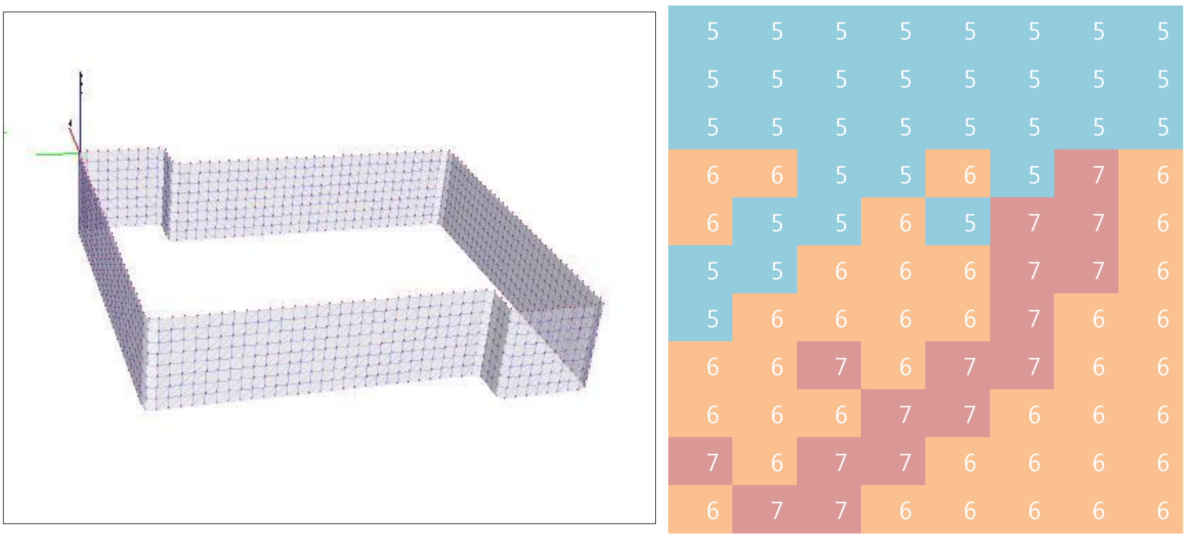


Fig.14 Solar optimization process of proposed design2 in ParaCloud Modeler

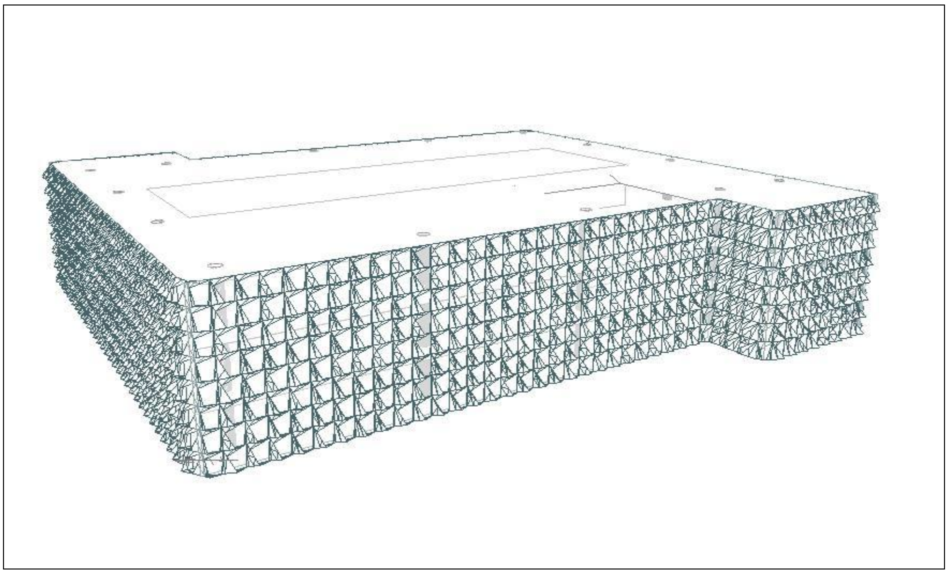


Fig.15　Proposed façade design - alternative 2

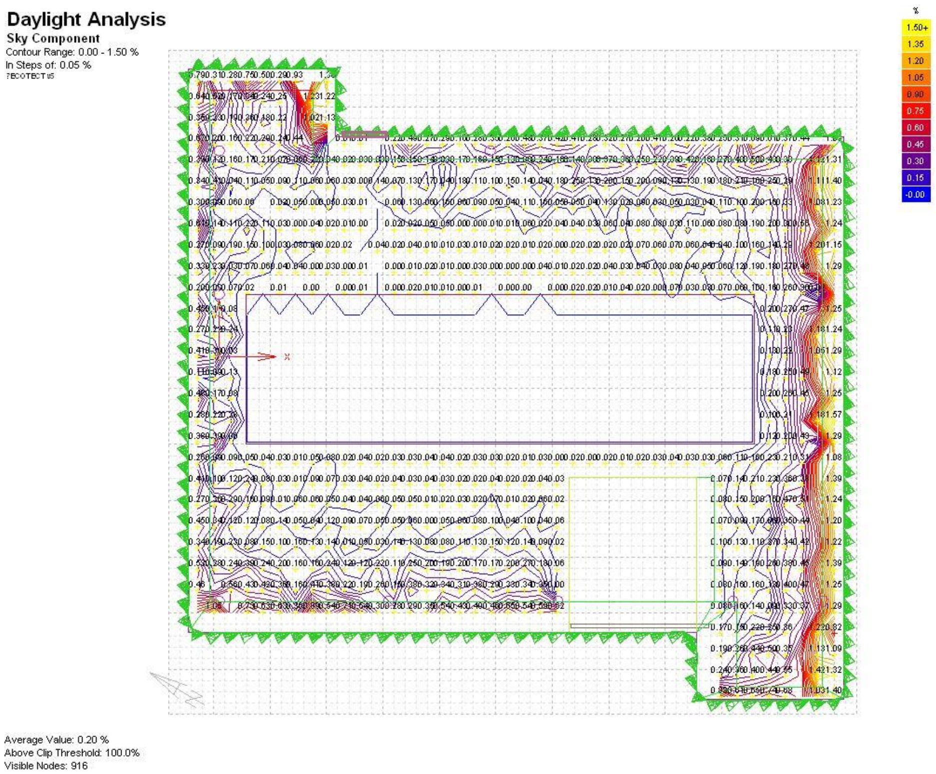


Fig.16　Sky component distribution　in Proposed façade design 2(average 0.2%)

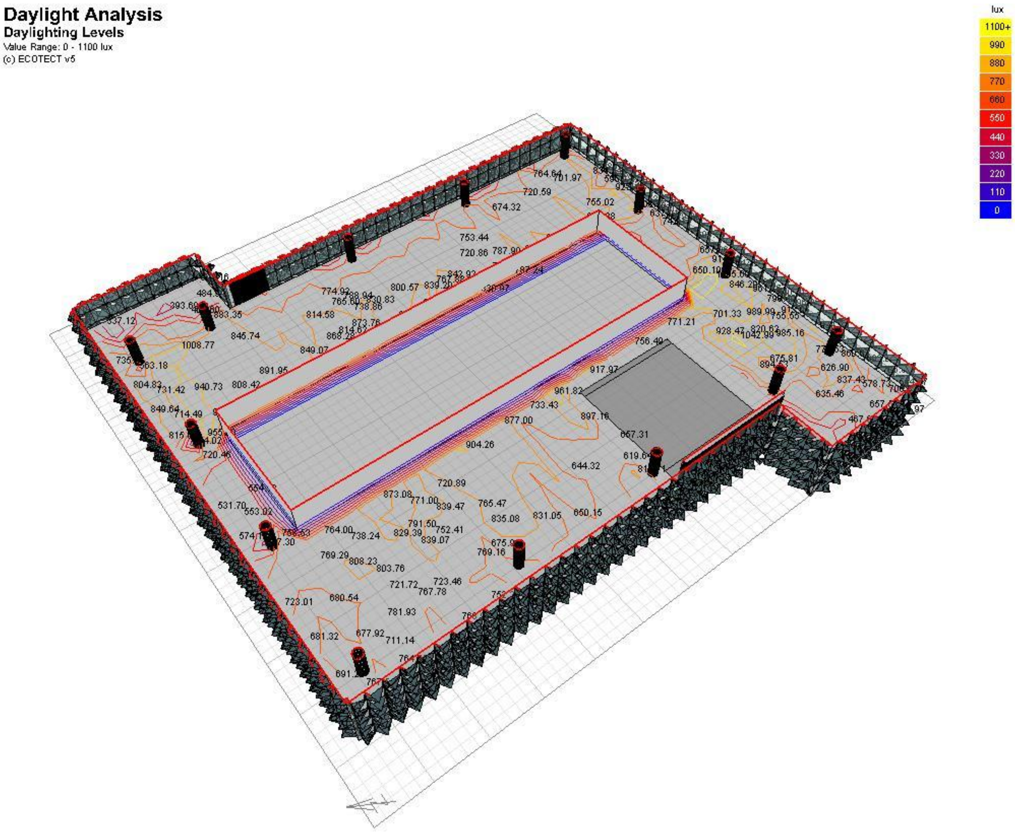


Fig.17 Illumination levels in Proposed façade design 2 (average 325.97 lx)

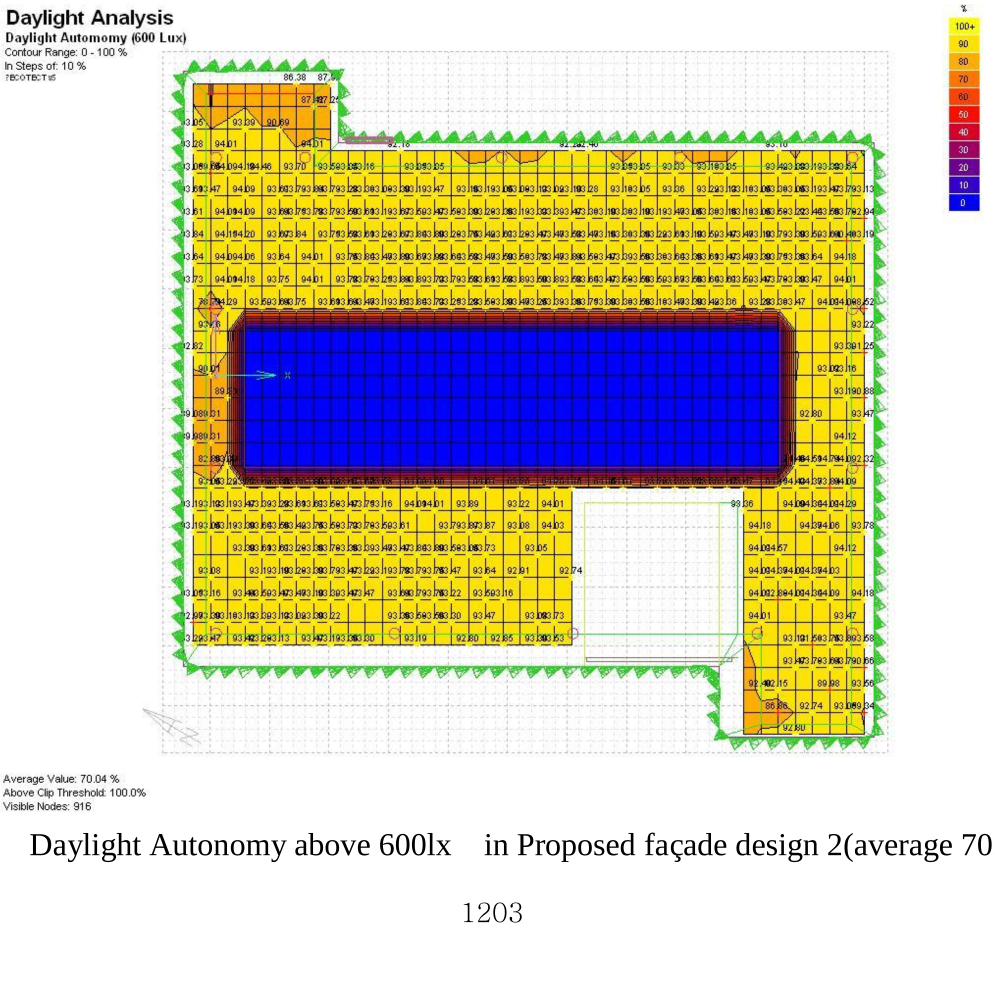


Fig.18 Daylight Autonomy above 600lx in Proposed façade design 2(average 70.04%)

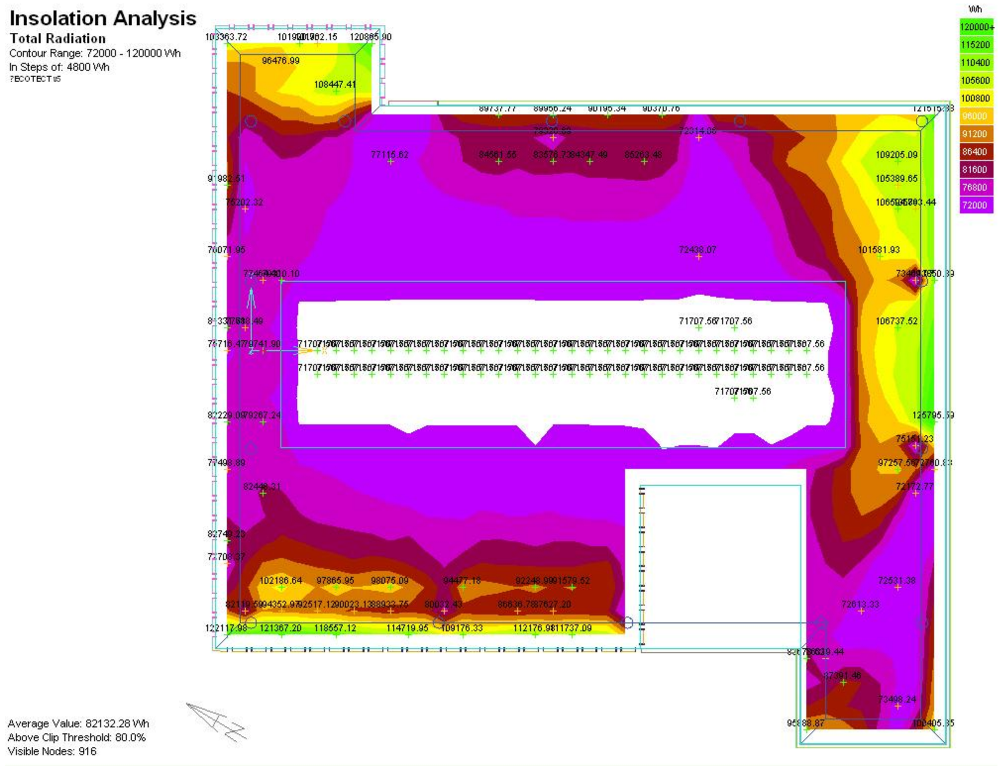


Fig.19 Insolation distribution in baseline design (average 82.13 kWh/m^2·yr)

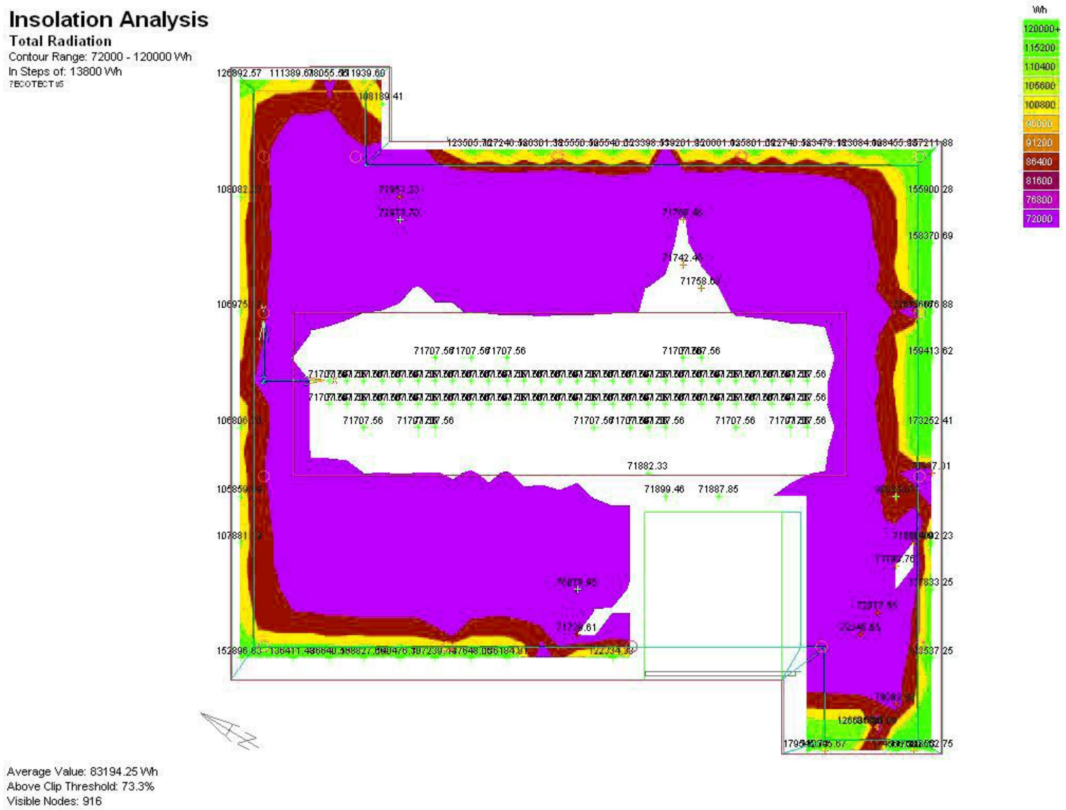


Fig.20 Insolation distribution in Proposed design 1 (average 83.19 kWh/m^2·yr)

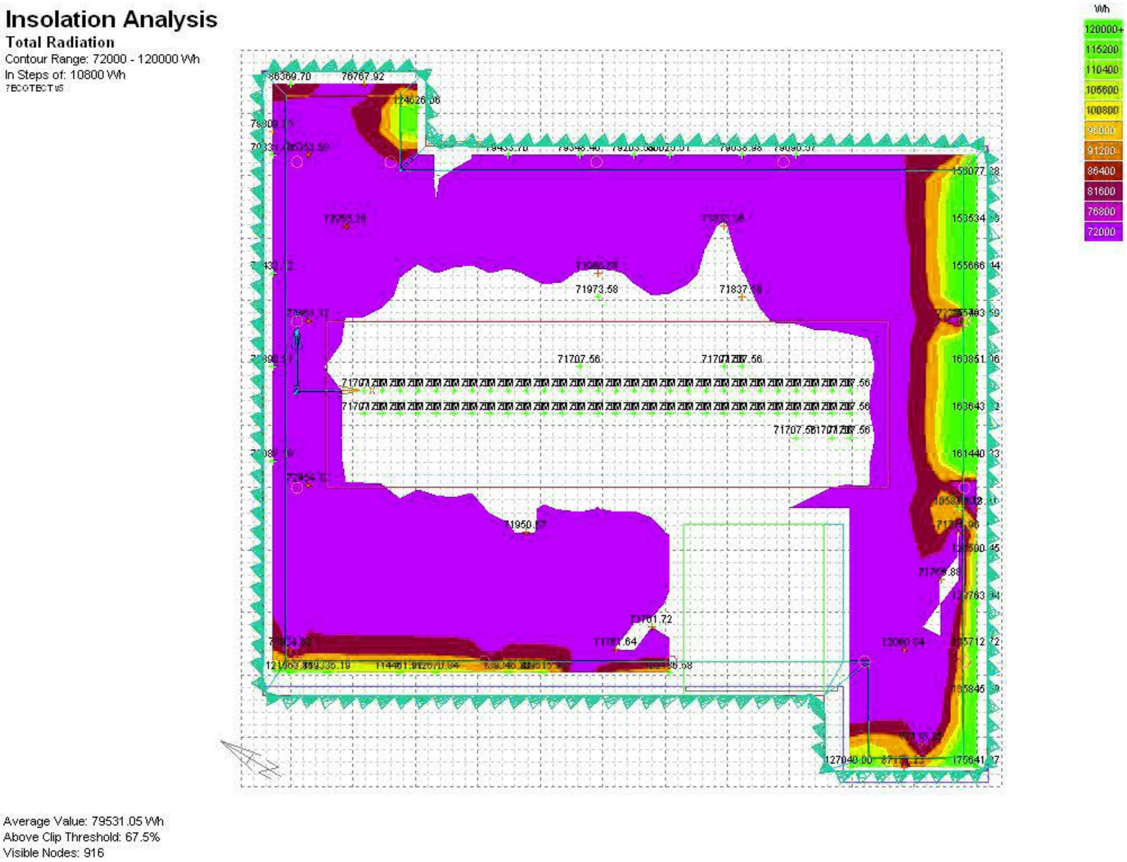


Fig.21 Insolation distribution in Proposed design 2 (average 79.53 $kWh/m^2 \cdot yr$)

Table 2 CurtainWall detail Input data

VRE1 – 46 (Reflective Double glazing, low solar gain low-E)

U-value	1.65 W/m^2 K (0.29 Btu/ft^2h ℉)
SHGC	28% (= SC 0.32 X 0.87)
Visible Transmittance	43%
Refractive Index of Glass	1.9

Table 3 Premium Reflective Films Input data

No.	Visual Ray		SC	Solar Heat Cut off	Ultra Violet Cut off
	Reflectance	Transmittance			
RS-440	42%	36%	0.38	66%	99%
SRS-220	**55%**	**15%**	**0.25**	**78%**	**99%**
SRS-220-EXSR	63%	15%	0.22	81%	99%

Table 4 Information of component cases and elements

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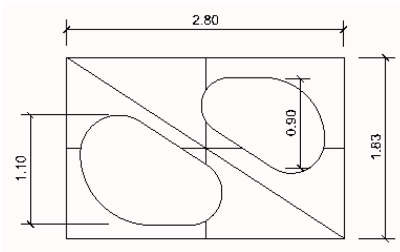
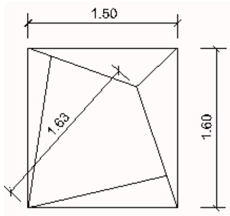
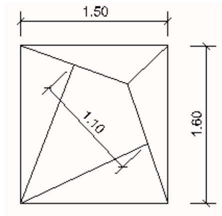
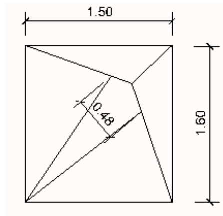
<tr><td colspan="2" rowspan="2"></td><td>No.5</td><td>No.6</td><td>No.7</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Horizontal Projection Area</td><td>5.12 m^2</td><td colspan="3">2.40 m^2</td></tr>
<tr><td colspan="4">Fenestration ratio (%)</td></tr>
<tr><td>61.3</td><td>56.6</td><td>37.5</td><td>16.0</td></tr>
<tr><td>Material</td><td>Aluminum Panel THK 12</td><td>Aluminum Panel THK 12</td><td>Aluminum Panel THK 12</td><td>Aluminum Panel THK 12</td></tr>
<tr><td>Glazing</td><td colspan="4">Window properties are the same with baseline design.</td></tr>
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Table 5 Portion of each space program on typical floor and CFM

Area Type	**Percent**	**Max occup.**	**CFM. /per**
Office	51.0 %	150	20
Stroage	2.0%	22.5	20
Corridor	11.4%	150	7.5
Meeting room	1.0%	450	22.5
Mech. / Elec. Room	21.8%	450	67.5
Copy room	1.0%	187.5	93.75
Restroom	4.5%	52.5	55.0
Lobby	7.3%	150	15

Table 6 Operation Schedule

DAY1 (Typical)	Weekday	8 – 6h (90%)
DAY2	Weekend(Saturday)	9 – 14 h (30%)
DAY3	Holiday	Off

Table 7 Boundary condition of HVAC

Cooling Source	**Heating Source**
-**Steam turbine Centrifugal Chiller** w/CHW loop. (Individual Chiller pump) COP: 6.0	- **Smoke Fire-tube packaged Boiler** (forced draft) w/ HW loop - **Steam boiler** (forced) - Effi. : 88% / 90%
Single Zone AHU / Ducted VAV sys. (Variable Speed fan)	Fuel : Natl gas
CHW loop Head: 899 ft / ΔT : 14℉	

Table 8 Setpoints of Heating and Cooling source

Thermostat Setpoints	*Occupied*	*Unoccupied*
Cooling Setpoints ℉	80.6	86.6
Heating Setpoints ℉	66.2	60.2
Design Temperatures	Indoor	Supply
Cooling Design Temp ℉	78.8	58.8
Heating Design Temp ℉	68.0	88.0