PERFORMANCE-BASED DESIGN FOR ACTIVE LEARNING SPACE AND CO-RESEARCH LAB: ROOFTOP EXTENSION IN AN ARCHITECTURE SCHOOL

SANTIRAK PRASERTSUKE and PATANA RATTANANAVATHONG

Thammasat Design School, Thammasat University, Pathumthani, Thailand

This research presents the architectural research-design process of learning spaces that utilized performance-based design techniques. It is the exploration of creating new learning and research environments on the rooftop of the Faculty of Architecture and Planning building. It consists of a co-research lab for faculty members, active-learning classrooms, and semi-outdoor community spaces. To achieve the design goals, the research process consists of surveys of functional requirements from the users, student participation in a design competition, building's structure inspection, development of performance-based architectural design, and construction document preparation. The whole building energy and computational fluid dynamics (CFD) simulations were used to simulate microclimate maps and conditions that used to informed design-decision making. The final design proposes a new architectural expression in contrast to the monotony of horizontal elements of the existing building. A sustainable design approach as a response to the tropical climate of Thailand, as the human comfort, is generally achieved through HVAC system. The south-facing facade is equipped with vertical sunshades, some are automatically adjustable to optimize the daylight efficiency, corresponding to the daily sun’s movement. The solar panels are installed on the roofs to supply electricity and to reduce carbon emissions. Due to the site’s very strict regulatory issues and budget, the steel structural system and dry-wall construction are selected to reduce additional dead-loaded weight and limited construction time.

Keywords: Architectural design, Building simulation, Design process, Design solution.

1 INTRODUCTION

New recent educational philosophy shows that 21st century educational system demands the new skills such as process-oriented teamwork, flexibility, problem solving and skills in digital technologies (Noss 2012). The learning environments for schools and higher education institutions, including universities, need to reflect this change by becoming flexible at different scales, inspiring to those learning, supportive of effective teaching and learning, and involving of the users and wider community (Heppel et al. 2004). A university thus is no longer thought of as a passive space for teaching and learning, but as an association of individuals brought together for the common purpose of creating and disseminating knowledge as a community of learners. With the advent of knowledge economy, new digital technologies and flexible academic programs, universities need to prepare flexible spaces for active student-centered learning, often featuring natural elements in the environment (Potworowski 2015).
This project is the exploration of creating new learning and research spaces on the rooftop of the six-story building of the Faculty of Architecture and Planning, Thammasat University. The new extension contains co-research labs for faculty members, active-learning classrooms, and semi-outdoor community spaces for students, covering the total area of 1,400 sq.m. The design concept consists of: expressing new architectural language in contrast to the monotony of horizontal element of the building; creating active student-centered spaces to serve different learning and creative activities; concerning for sustainability and responding to the tropical climate of Thailand; and using adaptable and re-useable structures and materials for the future changes.

To achieve the design goals, this research-design process consists of as follows:

(i) Online-surveys of new functional requirements and building problems from the faculty members, administrative staffs, and undergraduate and graduate students.

(ii) Student participation in a design competition, held by the faculty in order to obtain new ideas.

(iii) Building’s structure inspection by a team of specialized engineering consultant.

(iv) Development of performance-based architectural design by using computer software to simulate microclimate maps and conditions to solve local climate problems.


Co-research lab, multi-purpose and meeting rooms on the south side of the building are the areas focused for daylighting simulation because Thailand has a hot-humid climate and located in the northern-hemisphere, south-side of the building is the most effective area to reduce the solar heat gain. The simulation was done parametrically to find the most optimal solution in Rhino and Grasshopper. Ladybug and Honeybee (Roudsari 2013) was used to connect the building model with Radiance (Reinhart 2001), a validated daylight simulation tool. Annual daylight simulation was performed with the Spatial Daylight Autonomy (sDA) as an evaluation criterion. The sDA, in this research, indicates the percentage within the analyzed space that has the illuminance between 500 lux to 2,000 lux, annually. Although some green building standard such as LEED use the sDA at 300 lux with no high-ended threshold, Thailand’s building regulation suggest that the space for working should has a minimum illuminance at 500 lux and more daylight for hot-humid climate area leads to more solar heat gain hence, 2,000 lux as the high-ended threshold was used.

Vertical shading is the based case for the simulation. Although horizontal shading generally performs better on the south facing façade, due to the narrowed view angle and to break the similarity from the existing façade on lower floors as shown in Figure 4, the vertical shading was chosen design option. The parameters for the shading were rotate angles for 180 degrees at the step of 10 degree, which makes the total of 18 possible iterations for each shading. There are 160 shadings hence, the total of possible combinations, 18160, is too large for the current computational power to brute force through all the combinations hence, the Genetic Algorithm (GA) optimization technique from Grasshopper was used.

The computational fluid dynamic (CFD) was performed to ensure that the corridors are ventilated. OpenFOAM version 7 was used to perform the simulation (Jasak 2009). Wind directions are east, south, west and south-west with the velocities of 0.55 m/s, 0.9 m/s, 0.62 m/s and 0.72 m/s, respectively. The measurement was done 1.5 meter above the ground.
2 DESIGN SOLUTION

The design of this new extension, therefore, is aimed to reflect this change of education by creating a new learning community on the unused rooftop space. To avoid structural problems, the spatial arrangement of the new spaces conforms to the building’s existing reinforced-concrete structure as much as possible (Figure 1). The old roofs used to protect rain and some unused building equipment are removed. To express the research-design teaching approach, the co-research labs with a shared area, a multi-purpose room and two meeting rooms are located to the south - the main building’s façade, and three active-learning classrooms, the north, overlooking a university’s soccer field. Restricted by the limited space on the south side of the building, the classrooms have to be placed on the north side, which left co-research lab to be placed on the south, regardless of how it is arguably more suitable to be on the north side since it has more potential to utilize more diffused daylight. All rooms are clustered around the existing central curved roof and connected by three natural ventilated corridors: green, learning, and design and innovation corridors, providing different semi-outdoor activity spaces lit with natural light (Figure 2).

Figure 1. This image shows the new rooftop spaces and the steel structure and dry-wall system.


The design of active-learning classrooms promotes learning as an activity, providing movable furniture and flexible spaces equipped with three large projection screens and movable digital
boards on three walls. It supports both formally lecture-based teaching and group work and discussion. The learning corridor before the classrooms offers expanded working space lined with a long bench and movable tables. The random pattern of the walls and floor of classrooms volume is generated from a scientific concept of cellular automata\(^1\) articulating digital and creative elements to the environment (Figure 3).

![Figure 3. An example of furniture layout to support group work (left), the view of learning corridor (right).](image)

Due to the site’s relatively strict regulatory issues, the steel structural system and dry-wall construction are selected to reduce additional dead-loaded weight and limited construction time. Exterior wall material is painted fiber cement boards with thermal and sound insulation. To prevent direct sunlight yet allow outside views for the co-research labs, the southward oriented glazing is installed with a series of vertical sunshades made of white aluminum sheets (Figure 4). Each louver is rotated in various angles according to the daily sun’s movement. Only the sunshades of the multi-purpose room are automatically adjustable with a solar tracking sensor.

![Figure 4. South elevation with vertical sunshades (left), north elevation showing random pattern of walls (right).](image)

3 ENERGY EFFICIENCY AND VENTILATION

Human comfort is generally achieved through HVAC system – all rooms are air-conditioned and automatically real-time controlled by smart sensors. Over room entrances are equipped with air curtains to isolate the interior and exterior air environment and also to function as a barrier against air pollution PM 2.5. To reduce heat gain, most glazing is low-e glass, and roof material

---

\(^1\) Cellular Automata is a model of a system of cells that evolve over time according to a set of specific rules. It represents a complex system behind nature, living organisms, social behaviors, geography, etc.
is metal sheet with a single layer of 2-inch-thick PU thermal insulation. All three main corridors are natural ventilated with translucent louver walls for rain protection on east, west and south. To supply electricity for this new extension and to reduce carbon emission, solar panels are installed on the south-facing roofs.

The results from the CFD simulation shows that the corridors can be naturally ventilated all the time, except the south corridor that is blocked from south wind for around 4 months, from February to May. The potential wind speed in the corridor is around 0.5 m/s or 1.8 km/h. According to the Beaufort wind force scale (Water 2005), the speed is classed as light air, which does not cause discomfort to the users. However, the windspeed is relatively low which may need mechanical fans to be installed.

4 DAYLIGHTING

The results from the daylight simulations shows that the vertical shadings only rotated toward east direction with the rotation angle between 0 to 30 degree. This behavior is expected since rotating toward west direction would result in too much daylight and rotating more toward east direction would result in not enough daylight. The pattern of the shading angle is random as the optimization method was genetic algorithm. The design team utilizes this finding to design a façade with a wave pattern with the rotation between 0 to 30 degree toward east direction.

The simulation of the final design shows 30% improve in daylighting performance compared to the base case where there is no shading. From the base case, Figure 5 shows that the area close to the window receive too much daylight, whereas the far end of the room receives a good amount of daylight. The proposed design shifts the area with high sDA to center of the room and reduce excessive daylight.

Figure 5. sDA of the base case (top), sDA of the proposed design (bottom).
5 CONCLUSION AND RECOMMENDATION

This research demonstrates an architectural research-design process of the rooftop extension project for the architectural school in Thailand by applying the active learning education paradigm into the extension of an existing building coupling with building performance-based design. The design solution presented in section 2 illustrates the results of the design-decision making when encounter the challenges of making an extension from the existing building such as, the existing structure and material, construction and climate. The proposed design is not driven exclusively by the performance from the simulation, however, the design is also driven by the performance from functional and structural aspects.

Existing building has arguably the most impact on the proposed design solution. The existing building was not designed with the preparation of the rooftop extension. Building structure and space were limited which restrict how the room could be placed and divided. This notion leads to a contradiction of how functions are placed. Especially, the co-research lab at the south side of the building, even though the space is arguably more suitable to be placed on the north side of the building which has lower solar heat gain, while the co-research lab can benefit from larger windows. However, the space on the south side is limited which is not enough for the classrooms, resulting in the classrooms have to be placed on the north side and co-research lab on the south side. This zoning led to the carefully design south side façade vertical shading. The shading was thoroughly investigated on how to maximize the view angle from the inside and minimize the solar heat gain that would cause discomfort and higher energy consumption.

Daylight simulation was done in order to utilize the optimal natural daylight in co-research lab and multi-purpose rooms. Although the rooms need natural daylight, south façade receives solar heat gain most of the time. Vertical shading was the design choice as an architectural expression. The initial investigation of possible rotation angles for each shading was done parametrically and optimized with the genetic algorithm. The range of 0 to 30 degrees rotation toward east direction was the outcome which designer developed into a wave-like pattern for the façade.

The rooftop extension in this research is now at the stage of preparing for construction. Post occupancy evaluation should be carried out when the new extension is operated for the researchers to monitor and compared the actual results from the design intents.

References


