A PROPOSAL OF ROW- HOUSE COURTYARD AREA FOR ENSURING NATURAL LIGHTING EFFECTS

ĐỀ XUẤT DIỆN TÍCH SÂN TRONG CHO NHÀ LIÊN KẾ NHẰM ĐẢM BẢO CÁC YÊU CẦU VỀ CHIẾU SÁNG TỰ NHIÊN

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Abstract - Natural lighting with courtyard's solutions for row-house has become one of the passive design principles which brings efficiencies of saving energy, improving the lighting conditions for indoor environment, contributing to increase aestheticism and use space diversity. However, the current design for courtyard is also much qualitative, the designer does not have a scientific basis to propose reasonable solutions with the aim of satisfying lighting requirements as well as natural use area. The study was carried out according to a 04 step process including: researching overview; selecting case studies; simulating natural light, and evaluating and suggesting. The findings aim to propose a logical area for courtyard in order to meet the requirements of natural lighting for row-houses.

Key words - Row-house; Natural lighting; Courtyard; Illuminance; Ecotect.

Tóm tắt - Chiếu sáng tự nhiên bằng giải pháp sân trong cho nhà liên kế đã trở thành một trong những giải pháp thiết kế thụ động mang lại nhiều hiệu quả nhất về tiết kiệm năng lượng, cải thiện điều kiện chiếu sáng, góp phần làm tăng tính thẩm mỹ và đa dạng các không gian sử dụng. Tuy nhiên, việc thiết kế sân trong hiện nay còn mang nhiều định tính, người thiết kế chưa có những cơ sở khoa học để đề xuất giải pháp sân trong hợp lý về diện tích vừa thỏa mãn các yêu cầu chiếu sáng tự nhiên cũng như diện tích sử dụng. Nghiên cứu được thực hiện theo quy trình gồm 04 bước bao gồm: nghiên cứu tổng quan; lựa chọn trường hợp nghiên cứu; mô phỏng ánh sáng tự nhiên, đánh giá và đề xuất giải pháp. Kết quả nghiên cứu hướng đến việc đề xuất một diện tích hợp lý cho sân trong nhằm đáp ứng các yêu cầu về chiếu sáng tự nhiên cho nhà liên kế.

Từ khóa - Nhà liên kế; Chiếu sáng tự nhiên; Sân trong; Độ rọi; Ecotect.

1. Rationale

A row-house is a category of housing which has recently become common and popular in Vietnamese urban areas. Its attraction is not only shown in the figures of 75% of all housing categories [1], but also demonstrated by the growing number of scientific studies and design solutions relating to this category. They are all aimed to answer the questions of what the most reasonable and effective design solutions are for row-houses.

In particular, there are currently more concerns for the issue of sustainable architecture, energy saving and design solutions which make use of natural elements (passive design) and bring comfort. This also solves a critical problem of natural lighting that row-houses are facing.

The courtyard, an experience lesson which was inherited from the forms of traditional row-houses, has been modified and applied effectively to the row-house space currently. In addition to improving the quality of natural light, the courtyard also creates aesthetic effect and usage of space diversity.

In fact, the courtyard design still has many problems, including conflicts between the benefits of natural light and efficiency in using land area. The Vietnam Standard 29:1991 TCXDVN suggested that the minimum land area of the courtyard in row-houses is 6m² [2].

However, it is necessary to calculate to check this data in order to find a reasonable area for a courtyard which meets the requirements of natural light, area and usage. This will be the main issue that we aim at studying and focusing on finding solutions.

2. Research Overview

2.1. Definition of Row-Houses

2.1.1. Development History of Row-Houses

According to the standard TCXDVN 353-2005, "a row-house is a private housing type, including apartments built adjacent to each other, with multiple floors. Row-houses are built close together in adjacent plots which have the width being many times smaller than the depth (length). These row-houses use the same system of common infrastructure of urban areas" [2] (see Image 1).

Figure 1. *Courtyard and solutions for a courtyard*

Based on the characteristics of construction site, utility, or surface, a row-house is also known by different names such as: *town-house* (according to the location in the metropolitan area); *tube-house* (according to surface shape); or *shop-house* (according to combination of business elements).

2.1.2. Characteristics of Row-Houses

One characteristic of row-houses is that the length is 3 to 4 times greater than the width, and the common area of a row-house is usually 5 x 20m or 4 x 18m. Each row-house is adjacent to other houses on two sides. Therefore, row-houses are often limited with the outside environment. This is the biggest drawback of row-houses, because the space inside the home might lack natural light and it might be difficult to organize ventilation solutions.

Normally, when the land area is limited, increasing the number of floors is an effective solution to enlarging the space for usage. A row-house has common floors: from 2 to 4 floors. The number and characteristics of the floors depend on the demand, investment ability of homeowners as well as regulations on urban planning.

Developmental courses from traditional to modern row-houses have had various diversities in architectural styles, and architectural trends and tastes of their owners also changed from time to time,

Because of the advantages of privacy, independence for every household, easily earned income, suitable scale of investment possibilities, ease of construction, repair and conversion of the ownership, the row-house has become the most common housing category in current Vietnamese urban areas.

2.2. Natural Lighting

2.2.1. Characteristics of Natural Lighting in Building:

The benefits of natural lighting are not only shown in the role of creating space's aesthetic value, comfortable living environment, but also contributing to saving energy and operating costs of the building. A research by Zain-Ahmed and colleagues pointed out that artificial lighting accounts for 25 - 40% of consumption energy for a building, while using simple natural lighting solutions, we will save as much as 10% consumption energy [3].

The characterics of natural lighting in building are determined by the value of *Daylight Factor (DF)*, which is defined as *illuminance due to daylight at a point on the indoors working plane (Ei) to simultaneous outdoor illuminance on a horizontal plane from an unobstructed hemisphere of overcast sky (Eo)* expressed as a percentage value (see Formula 1) [4]:

$$DF = (EI / EO) \text{ X } 100\% \quad (1)$$

In particular, the value of internal light level Ei is measured in the point considered on the horizontal plane at an altitude of 0.8m above the floor (also known as conventional working surface) [5] (see Figure 2).

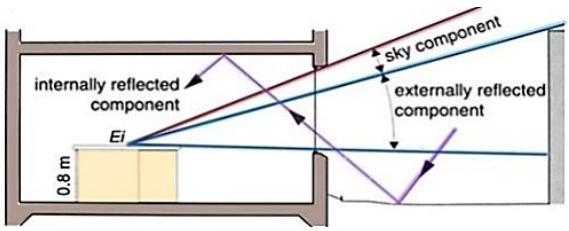

Figure 2. *Characteristics of natural lighting in a building [6]*

The value of natural light illuminance Ei is summarized from 3 components SC, ERC, IRC and is calculated as formula 2 [6]:

$$EI = SC + ERC + IRC \quad (2)$$

Therein:

- SC (*sky component*) – Direct light from a patch of sky visible at the point considered.
- ERC (*externally reflected component*) – Light reflected from an exterior surface and then reaching the point considered.
- IRC (*internally reflected component*) – Light entering through the window but reaching the point only after reflection from an internal surface.

2.2.2. Requirements of Natural Lighting for Housing rooms:

Natural lighting for building is divided into three categories: side-lighting; roof-lighting; and mix lighting. For row-houses, the solution of roof-lighting and side-lighting is often used. In particular, the roof lighting through courtyard brings the most effectiveness.

In order to have a basis for the natural lighting design in buildings, the standard TCXDVN 29:1991 proposed regulations on *Daylight Factor* (DF) which apply to functions of the housing space (see Table 1) [5]:

Types of room	The plane's regulations to the ratio DF – the height from the floor (m)	**The ratio of natural light illuminance – DF (%)**		
		Roof-lighting and mix lighting	Side-lighting	Notes
Bedroom	horizontal – 0.8	2	0.5	
Kitchen	horizontal – 0.8	2	0.5	
Restroom	horizontal – 0.8	2	0.5	

Table 1. *Standards of daylight factor to functional rooms in the house [5].*

2.3. Solutions of Courtyard Design for Row-Houses

2.3.1. Definition of a courtyard:

A courtyard is located within the boundaries of a row-house and connected to the roof [7] (see Image 1). The solution is applied to architectural traditional row-houses in Vietnam with major effects as follows:

- Helping natural lighting for functional rooms in the middle, where we cannot get natural light from the front and the back side.

- Creating natural ventilation by ventilating through temperature differences. This contributes to reducing the temperature, humidity, air flow, to improving thermal comfort and environment for users.

- Creating aesthetic value to interior design and bringing nature closer to people.

2.3.2. Solutions of the Courtyard Design in a Row-House

In reality, solutions of the courtyard design are diverse in location, shape, size, decoration, wall – roof form,... Selecting solutions should be depended on the basis of the plot shape, scale, investment funds, courtyard function, homeowner's tastes and architect's design intention.

On the basis of integrating into real design solution, it is necessary to classify design solutions of courtyard into characteristics of location, performance, roof form.

a. Location: Depending the location of the courtyard in the plane, there are 7 cases, including (see Figure 3):

- (a1): horizontal, between the stairs and the bedroom.
- (a2): vertical, after the stair break
- (a3): along the stair steps and corridors.
- (a4): horizontal, between functional rooms.
- (a5): along the room, bordering on the stair break.

• (a6): the courtyard in the split-level house.

• (a7): in the corner of the house.

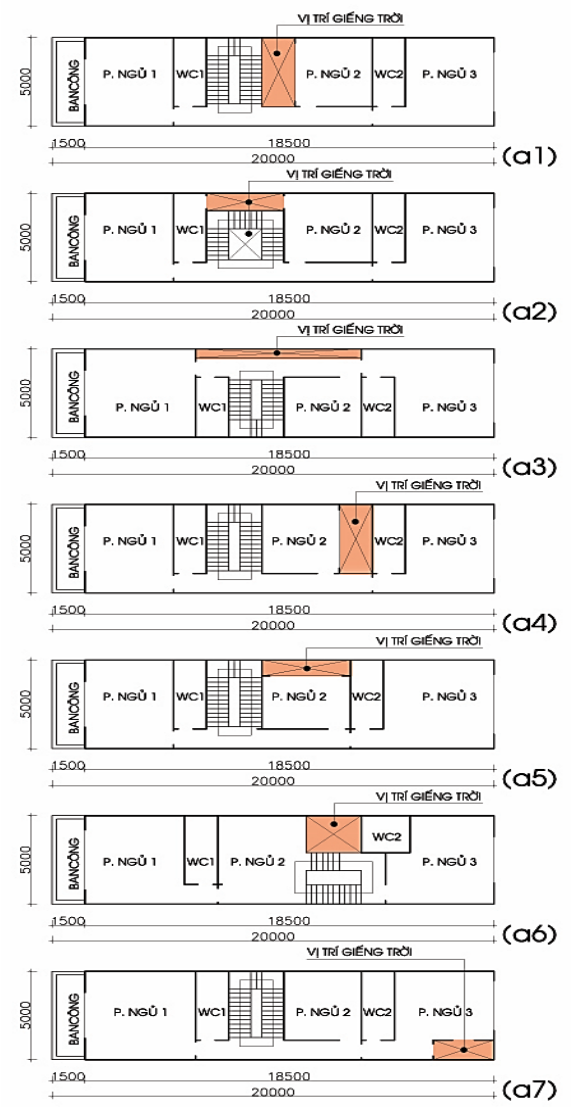

Figure 3. *Solutions of location of row-house's courtyard*

b. Function:

A courtyard generally functions as: gardening (trees, water), making miniatures (dry garden, ornament).

The solution is commonly used:

- Reinforced concrete is 100mm thick, translucent brick (200 x 200mm). This type usually has a courtyard for ventilation.

- Each reinforced concrete 100 x 200mm is spaced 300mm apart, there is a Fibocarbon roof to get light in the top (with steel frame). The roof is opened and closed by electric motor or by hand.

- Steel mesh (Steel box 30 x 30mm is spaced 150mm spacing apart, there is a Fibocarbon roof to get light in the top (with steel frame). This solution also uses opening and closing system of electric motor or hand.

3. Research Methodology

3.1. Sampling Study

3.1.1. Selecting Type of a Row-House

After analysing the most common characteristics, the study selected a row-house 5 x 20m, which is located towards the South and has 3 floors in Danang city. The location of selected courtyard is similar to the case a4 (horizontal, between functional departments). In particular, the study selected the bedroom 2 in the 2nd floor as a survey sample of natural lighting calculation (see Image 3).

3.1.2. Identifying the Research Hypothesis

- The selected bedroom window has the height o f2.4m and the width of 3.0m, 0.9m away from the floor. The window is made from aluminum and glass (5mm thick).

- Considering the case that there is a rectangular in the courtyard (the common form and most reasonable). The cover of the courtyard is made of reinforced concrete 100 x 200mm far from 300mm, there is a Fibocarbon roof above for getting light and covering from the rain.

- A row-house is made from common structural frame and reinforced concrete. The wall is 200mm thick, built of brick and finished with white paint.

- The plane to study natural lighting is taken at 0.8 m height compared to floor 2.

- The timing of the survey is at 09 a.m on the 22th of June. This weather data is taken from the climate of Danang City.

3.1.3. Values That Needs Identification.

With the assumptions stated in Section 3.1.2, the study aims at identifying the values measured at the room surveyed including:

- Natural light illumination (Ei), measured in units of lux and takes the average value for the whole room.

- Coefficient of daylight factor (DF), measured by percentage % and takes the average value for the whole room.

- Surveying illumination at a fixed position on a plane surveyed.

These values are checked along with 10 cases, the courtyard width changes from 300 - 3000mm, and the length of 3900mm is unchanged.

3.2. Selecting Research Tool

3.2.1. Tools of Lighting Simulation in Building

Today, the science of building performance simulation has started a new era in architectural design, construction and the environment. Some common tools to calculate, simulate natural lighting including: Ecotect, Radiance, Daysim,… Ecotect software with some advantages such as simple interface, visual, easy to use and common in the modern design.

3.2.2. Ecotect Analysis 2011 Software

Designed and powered by the famous software vendor Autodesk through trial or copyrighted version, Ecotect Analysis 2011 is a tool to calculate typical performance simulation with many analysis applications: shade, solar energy diagrams, solution of lighting cover, thermal comfort, natural and artificial light, sound,...

The process of calculation in Ecotect is conducted through 03 main stages, including: *building model; setting calculated data, and outputting analysis results.* In order to have results with high precision, it requires users to install the complete information and establish building data which are similar to the reality.

Some studies show limitations of Ecotect, for example error when this software is compared with others, there is a calculation or limitations in the construction of curve models,... However, these limitations are not significant, and may be acceptable. Ecotect has become more popular and highly appreciated.

3.3. Establishing Steps to Install Calculation

3.3.1. Setting Calculation Model:

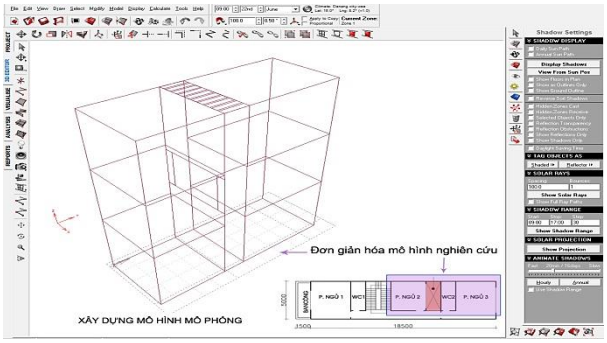

Figure 4. *Modelling the case of the size of the courtyard 3.9m x 1.5m*

On the basis of the architectural features of the case study (a4), the calculation model is built according to simple criteria by focusing on the main parts related to the contents which needs calculating (see Image 4). Setting calculation model can be performed directly in Ecotect through using modeling tools. Or you can import files from the graphics software 3D such as Sketchup, 3Ds-max,...

3.3.2. Setting Calculation Data

From the research hypothesis, the weather data of Danang is set by the weather file DanangMeteonorm.wea [8]. It provides complete information about Danang climate which is the basis data for temperature, wind direction, rainfall analysis tool...

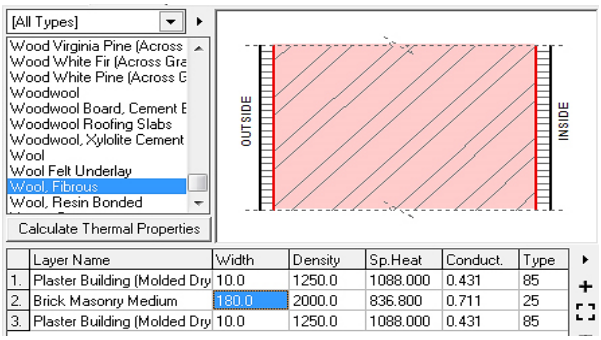

Figure 5. *Installing the material parameters for 200mm wall*

The research sets parameters of wall materials, windows, floors, ceilings, roofs... which are correlative with real characteristics. Figure 5 presents a example of installing the material parameters for 200mm wall, built of brick and finished with the white paint.

In addition, the study also established outdoor illumination value due to an unobstructed hemisphere of overcast sky (Eo) 14000lux – this value is automatically calculated by the software, according to the weather data at the time surveyed being 9 am on the 22th of June. The value Eo is used to convert the value Ei into DF or vice versa with the application of the formula (1).

4. Findings and Discussions

4.1. Simulation Results of Each Case

The calculation simulation is performed for 10 cases, basing on the changes of the courtyard from 1.17m² to 11.7m². In particular, the value of the length remains with 3.9m, the width is changed with the amplitude from 0 to 3.0m. Calculation results are summarized in details in Table 2:

Case	Courtyard size (length x width) (m)	Courtyard area (m²)	Average natural light illuminace (lux)	Average daylight factor (%)
1	0	0	0	0
2	3.9 x 0.3	1.17	5.46	0.04
3	3.9 x 0.6	2.34	19.72	0.14
4	3.9 x 0.9	3.51	41.78	0.3
5	3.9 x 1.2	4.68	67.41	0.48
6	3.9 x 1.5	5.85	96.07	0.69
7	3.9 x 1.8	7.02	126.91	0.91
8	3.9 x 2.1	8.19	163.77	1.17
9	3.9 x 2.4	9.36	197.41	1.41
10	3.9 x 2.7	10.53	234.91	1.68
11	3.9 x 3.0	11.7	271.2	1.94

Table 2. *Summary of simulation results for case study*

It can be seen from the Image 6 that the value of natural lighting illumination (Ei) is higher when the width of the courtyard is being increased.

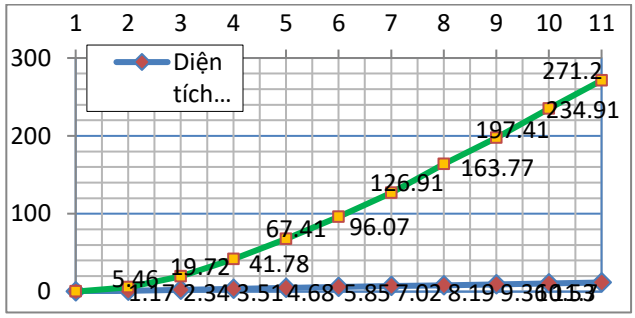

Figure 6. *Diagram of average natural lighting illumination of calculated cases*

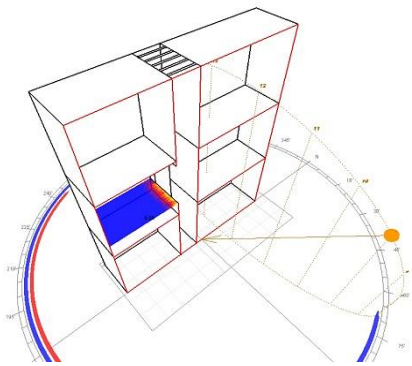

Image 7. *Natural lighting illuminace for calculation model (case 3.9m x 1.5m)*

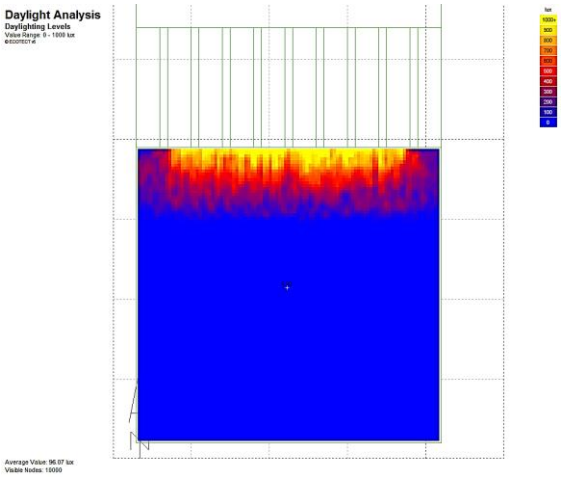

Figure 8. *Distributing light area in the plane surveyed (case 3.9m x 1.5m)*

Figure 7 & 8 introduces an example of calculation simulation results for the case 6 with the courtyard area 5.85 m² (3.9mx 1.5m). The simulation result for the value of average natural lighting illuminace in the whole room is 96.7 lux. The diagram shows the concentration of high illuminance values in the area near the window and diminishing inward illuminace value.

4.2. Assessment of Simulation Results

The simulation results reflect the relationships between the courtyard area and the quality of indoor natural lighting. Figure 9 shows the change in lighting scope on the plane for 10 different simulation cases:

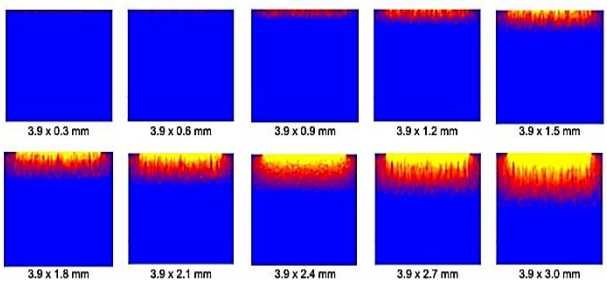

Image 9. *Comparison of the brightness distribution of 10 cases*

4.3. Suggestions of the reasonable area for a courtyard

Caculation results of daylight factor (DF) for 10 calculation cases is presented in the chart below. The increase of the value DF is proportional to the increase of the courtyard's area.

Basing on the standard TCXDVN 29:1991, the daylight factor (DF) for the indoor room gets 0.5% [5]. By the deduction principle from the chart below, the researchers proposed the minimum area for a courtyard: 4.8m² (see Figure 10). This value which is equivalent to natural lighting illuminance (Ei), is 70lux.

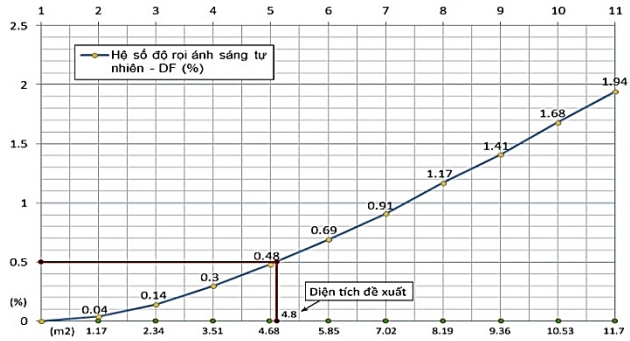

Figure 10. *Suggesting reasonable area for the courtyard's row-house*

Compared with the provision of the standard of courtyard's minimum area in row-house 6m² [2], the courtyard's area which the researchers proposes is 1.2m², smaller than this provision. Therefore, this will take advantage of the land for the other space, and still ensure to meet requirements of natural lighting inside the building.

5. Conclusions and Suggestions

Through this study, the role of the courtyard to natural lighting is clarified. The research has presented that the courtyard is one of the most efficient solutions for row-houses.

The research has also introduced an important methodology in the use of building performance simulation tools for the application of building design processes. With these advantages, Ecotect promises to be a useful tool for designers in the development of sustainable solutions.

Last but not least, the research has proposed the reasonable area for a courtyard: 4.8m². As a result, this indicates conflicts between natural lighting and land usage. The designer will have an important reference source in designing row-houses at the present time.

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