Influence of Open Wall Type of Corridor on Indoor Lighting - Unilateral Corridor University Classroom in Central Taiwan

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Abstract. The study explores the impact of classroom corridors and the design of the wall on indoor lighting performance. First, the field survey method was used to investigate classrooms with unilateral corridor design in eight universities in Taichung. The researchers compared parameters such as wall window type, aperture ratio, glass material, corridor width, etc., and measured corridor and indoor illumination to calculate the illuminance and uniformity. The factors that influence the indoor light efficiency of the aisle and the wall are analyzed, and four representative classroom space samples analyzed. The field survey obtained the following results: 1) The wall opening type is fully open, and the transparent glass material has a better light-emitting rate; 2) The wall surface is the upper opening, and the transparent glass material has a better uniformity. 3) The indoor lighting efficiency is better when the aperture ratio is significant; the dimming rate decreased when the corridor width increased.

1. Introduction

1.1. Climate natural lighting and energy saving
Building energy consumption is essential for energy management and conservation. Taiwan located in a subtropical environment, and daylight applications and energy conservation contribute to the goal of sustainable development. Establishing a healthy and comfortable teaching space is also the goal of Taiwan's "Permanent Campus Promotion Program [1]." In the past decades, the world's energy consumption and associated CO\textsubscript{2} emissions increased rapidly due to the increases in population and the comfort demands of people [2]. Residential and non-residential types of buildings and four types of energy consumption were analyzed. Domestic lighting in the UK consumed 19\% of carbon emissions [3].

Natural lighting saves 25\% of the building's energy consumption. Building's window shall put in glazing on daylighting. It allows the penetration of natural light into buildings and fulfills the providing of natural lighting [4]. Sunshades may have different effects, including controlling direct sunlight inside, controlling light, and natural ventilation [5]. The light transmittance was calculated by the equation: Light transmittance (\%). The mono-layer sunshade net in which light transmittance was 65.6 [6]. Corridor floor slabs are equivalent to continuous horizontal sunshades, which have an impact on indoor natural lighting.

The classrooms with unilateral corridor design reviewed around Central Taiwan University. The opening corridor will improve ventilation efficiency, which is higher than that of the unilateral opening corridor. The length of the inside corridors should be long enough [7][8]. The authors
explored the influence of the window opening type, aperture ratio, glass material, and corridor width. According to the factors affecting the light efficiency, the luminescence rate and the uniformity analyzed, and the indoor space size and the window type measured for the several wall design approaches.

1.2. Lighting environment

The lighting environment can prevent fatigue and improve learning motivation. Intensive light sources produce an uncomfortable glare. Natural lighting design does not significantly increase the cost of building construction [9]. The indoor lighting factors are: construction state, window opening/shading, and light source usage. Glass material, wall material, roof material, glass curtain material require within reasonable cost range. Minimizing the envelopes’ construction cost, which satisfies green building regulations are essential [10].

The basic definitions of lighting are:

1. Luminosity (I): The intensity of light emitted by a light source in a particular direction is called light intensity. The luminous flux received by the unit area under illumination.
2. Brightness: The luminous intensity emitted or reflected in a specific direction per unit area of the object.
3. Reflectance (ρ): The degree of reflection of an object on luminous flux.
4. Luminescence rate (DF): The rate indicates by the percentage of the outdoor sky illuminance of the room. The more significant the DF value, the higher the lighting efficiency.
5. Uniformity (Au): The ratio of the minimum to the highest illuminance at the working area. An Au value close to 1 indicates a very uniform illumination.

2. Research methods

The researchers utilized the field survey method to investigate the "unilateral corridor classrooms" of selected universities. The illuminance and uniformity calculated by measuring the illuminance equidistantly. Researchers sorted out the factors affecting the light efficiency of the wall through survey data (Figure 1), which divided into four representative classroom spaces (window type and lighting efficiency). According to the results, representative spatial samples and screening factors are evaluated the lighting efficiency.

The contents of the field investigation include a survey of the current situation of the window opening, parameters of the corridor, and the lighting measurement of classroom corridors.

![Figure 1. Field survey and investigation](image-url)
Investigate universities located in the Taichung area (Taiwan), which have similar latitudes. Researchers explored the window type, aperture ratio, glass material, corridor width, etc. The representative universities of the lighting performance survey include Donghai, NCHU, Fengjia, Providence, Chaoyang, Asia, Hongkong, and Hsiuping university. According to the definition of the previous study (Ander et al., 1995), we use portable illuminance to measure. The assessment conditions are limited to the diffuse light environment of the cloudy sky. The measured aspects of near dusk hours are one meter outside the corridor handrail, handrails, and inside of the corridor wall (Figure 2). The height of the measuring point based on the height of the user's table (75 cm), and the measuring points per meter are four. After that, a total of 8 measuring points recorded. The survey tools are as follows (Table 1) (Figure 3).

![Figure 2. Diagram of indoor measuring points](image)

| Table 1. Illumination survey tools |
|-----------------------------------|
| Pen | notebook | camera | ruler | portable illuminometer |
| ![Pen](image) | ![notebook](image) | ![camera](image) | ![ruler](image) | ![portable illuminometer](image) |

3. Survey results and analysis
Researchers investigated the window types form selected universities. The Record data consisted of the number of classrooms in the unilateral corridor.

3.1. Data collection
The data of window sill height, window size, opening position, aperture ratio, glass material, corridor width, etc. (Table 2).

The primary opening type is the upper opening/clear glass material, and the ladder (step-wise) classroom is made up of the upper-middle (MU) opening/clear glass material (Figure 4). The distribution of classroom orientation highlighted by the north (N) and south (S), the major lecture halls are mostly facing the southeast (SE) (Figure 5).
Table 2. Window type table

| School building          | Floor | room | Stepwise | Sill height | Window height | Open % Glass | Location | corridor width |
|-------------------------|-------|------|----------|-------------|---------------|--------------|----------|----------------|
| Manage-M                | 1,2   | 23   | 3        | 0           | 295           | 71.46% C     | open     | 220            |
| Humanities              | 1     | 4    | 0        | 0           | 275           | 63.53% C     | open     | 230            |
| Manage-N                | 1,2   | 3    | 0        | 75          | 220           | 75.00% C     | MU       | 220            |
| Design Art              | 1,2   | 22   | 0        | 90          | 185           | 53.70% C     | MU       | 230            |
| Law school              | B1,1,2| 3    | 0        | 90          | 185           | 53.70% C     | MU       | 230            |
| Agricultural            | 1,2   | 17   | 0        | 90          | 185           | 53.70% C     | MU.      | 230            |
| Social Sci.             | 1,2,3 | 8,4  | 90       | 170         | 53.33% C      | MU.        | 250      |                |
| Art college             | 1     | 8    | 0        | 100         | 200           | 58.67% C     | MU.      | 320            |
| Humanities              | 2,3   | 9    | 0        | 100         | 210           | 40.00% C     | MU.      | 460            |
| Teaching                | 1-5,10| 53   | 0        | 120         | 150           | 24.87% C     | MU.      | 340            |
| Social                  | 1,2,3 | 23   | 0        | 210         | 80            | 9.10% C      | U        | 305            |
| Architecture            | 3     | 1    | 0        | 180         | 120           | 35.66% C     | U        | 180            |
| Science                 | 3,4   | 4    | 0        | 220         | 80            | 26.67% C     | U        | 300            |
| Engineering             | 3,4   | 6    | 0        | 220         | 90            | 26.71% C     | U        | 305            |
| Siyuan                  | 1,3,4 | 6    | 0        | 80          | 220           | 46.25% C     | U        | 340            |
| Bo-Yi                   | 1-4   | 11   | 0        | 85          | 225           | 41.73% C     | M. U.    | 190            |
| Ren-Yilou               | 3,4,5 | 24   | 0        | 115         | 200           | 29.41% C     | M. U.    | 330            |
| Jing'an                 | 1,2   | 4    | 0        | 210         | 110           | 34.38% C     | U        | 245            |
| Teaching                | 2-8   | 33   | 1        | 210         | 120           | 27.68% C     | U        | 270            |
| Management              | 1-4   | 24   | 0        | 210         | 100           | 21.00% C     | U        | 395            |
| Humanities              | 1-5   | 19   | 0        | 165         | 100           | 15.18% C     | U        | 240            |
| Information             | 1,3-5 | 16   | 0        | 240         | 50            | 11.46% C     | U        | 310            |
| Health M                | 2     | 3    | 0        | 240         | 50            | 11.46% C     | U        | 310            |
| Teaching                | 3-5   | 3    | 0        | 100         | 200           | 56.20% CF    | MU.      | 345            |
| D Food Tech             | 5     | 4    | 0        | 140         | 140           | 34.62% C     | MU.      | 230            |
| B Teaching              | 3     | 2    | 0        | 160         | 65            | 32.96% C     | U        | 245            |
| Shuyi                   | 1-5   | 33   | 0        | 220         | 80            | 24.66% C     | U        | 280            |
| Derlin                  | 1-5   | 25   | 0        | 220         | 80            | 24.66% C     | U        | 280            |
| Open Clear glass        |       |      |          |             |               |              |          |                |
| MU-C                    |       |      |          |             |               |              |          | 154            |
| MU-CF                   |       |      |          |             |               |              |          | 11             |
| U                       |       |      |          |             |               |              |          | 199            |
| Rooms                   |       |      |          |             |               |              |          | 391            |

Middle and upper (MU), Upper (U); Clear glass (C), Frosted glass (F)
Figure 3. Four spatial samples, where: 1: Fully open/clear glass material, 2: Middle upper opening/clear glass material, 3: Middle upper opening/clear+fog glass, 4: Upper opening/clear glass material.

Figure 4. Window type distribution (a) normal (b) step-wise room
The aspect ratio showed a bimodal fraction, the maximum value was an aperture ratio of 75%, the minimum aperture ratio was 9.1%, and the average rate was 37.78%. The min opening ratio was 21.44%, followed by a max opening ratio of 53.33 (Table 3). The width of the corridor, the maximum value is 460cm, and the minimum amount is 180cm, the average amount of the corridor width is 272.14cm (Table 4).

| 5%~15% | 15%~25% | 25%~35% | 35%~45% | 45%~55% | 55%~65% | 65%~75% |
|--------|--------|--------|--------|--------|--------|--------|
| B2: 9.1% | B1: 24.9% | C2.3: 26.7% | A9: 40% | A4.5.6.7:53.7% | A2: 63.5% | A1: 71.5% |
| F2: 3:11.5% | E2: 21% | D3: 29.4% | C1: 35.7% | D1: 46.3% | A8: 58.7% | A3: 75% |
| F1: 15.2% | D4: 34.4% | D2: 41.7% | G1: 56.2% |
| H1.2: 24.7% | E1: 27.7% |
| G2: 34.6% |
| G3: 33% |

Table 3. Window openance statistics

Tunghai (A), NCHU (B), Fengjia (C), Province (D), Chaoyang (E), Asia University (F), Hongkuang (G), Shiuping (H)

The window type survey concluded four categories of items. Two samples taken for investigation of the current situation employing a picture, reproduction, and layout mapping. The data recorded from a portable illuminometer were analyzed using the SPSS statistic package.

### 3.2. Lighting performance measurement

The window type survey concluded four categories of items. Two samples taken for investigation of the current situation employing a picture, reproduction, and layout mapping. The data recorded from a portable illuminometer were analyzed using the SPSS statistic package.
Figure 6. Field survey space sample (A1), Management Building (M)

The Code is A1 (Figure 6): location: 1F, 2F, orientation: North, Northeast, East, Southwest, Northwest. The window height is 295cm with opening ratio: 71.46%, and the fully open window utilized clear glass. The corridor width is 220cm. Figure 7 shows Code: A2 located at 1F, which acquired a Northeast, Southwest orientation. The window height is 275cm, with an opening ratio of 63.53%. Window type is fully open-clear glass.

Figure 7. Field survey space sample in Humanities and Technology building (A2)

The study selected the full-open-clear glass material, taking the humanities and technology (A2) and management building (A1) as an example. The fully open-clear glass material shows the DF is worthy of a gentle downhill slope. The design has a relatively low DF value and a better uniformity (Figure 8.
(a)). The uniformity calculation of A2 is: \(49.44 \div 299.2 = 0.165\), and that of the A1 is: \(28.76 \div 65.63 = 0.438\) (Figure 8(b)).

![Graph](image)

(a)

![Graph](image)

(b)

**Figure 8.** Analysis of lighting efficiency of A1 and A2 with fully open-clear glass (a) Intensity of light, (b) Luminescence rate.

4. Conclusions and recommendations

This study explores the impact of classroom corridors and wall design in indoor natural lighting. Investigate the classrooms of the unilateral halls of the eight universities, and record the window type, aperture ratio, and material of the corridor wall. The corridor and indoor illumination were measured, and the efficiency and uniformity calculated. After the analyzed four representative classroom space, the following results were obtained.

1. The wall opening type is fully open, and the transparent glass material has a better dimming rate; The wall surface is the upper opening, and the explicit glass material has better uniformity.
2. The higher the aperture ratio, the better the indoor lighting efficiency, and the better the brightness and uniformity;
(3) The corridor width increases, the luminosity is reduced, but the uniformity is within the average range. The wall is open at the top, and the transparent glass material has excellent uniformity, especially for those with fully-open and clear glass.

Sunshine helps with vision and mood. With the surrounding objects, you can use the sun in the appropriate position at the time of design to save energy.

5. References

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