

## **KALEIDOSCOPE: PRODUCTION ROOM OF GARMENT FACTORY DESIGN IN SURABAYA CITY, INDONESIA**

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## ABSTRACT

Monotonous work in the garment industry may cause high levels of stress and reduced productivity caused by the boredom of work. Therefore, the production rooms of garment factories design is required to reduce the boredom of workers, especially in Surabaya, Indonesia. Through biophilic design approach, the boredom can be reduced by bringing emotional bond between the workers and nature inside the building. Kaleidoscope concept is used to explore the production room design to bring the natural color that changes over time to reduce the monotony without disturbing the workers' concentration. Direct analogy design method is chosen to find the solution of design problems by using the working principle and characteristics of the kaleidoscope. The design exploration results production room with diffraction grating skylights cantilever with different lengths on each side of the building that produce a spectrum of colors which changes with the angle of incidence of sunlight at certain times.

**Keywords:** *boredom, sunlight, skylight, spectrum*

### 1. INTRODUCTION

Labor-intensive industry is a sector with an important role on the economic development in Indonesia. To develop labor-intensive industries in Indonesia, such as garment industry, it is needed to remind the comfort of workers in the working environment to improve the quality and quantity of product produced. However, the influence of the pressure, demands of production, and the type of monotonous work in the garment industry may cause negative psychological impact which is the boredom of work. These problems can lead to high levels of stress and decreased worker productivity so as to reduce workers well-being. In order to overcome the problem of boredom on the garment industry work environment which is caused by the uncomfortable work environment and repetitive or monotonous work routine, it is necessary to design the production room of garment factory that can reduce the boredom of workers, especially in the city of Surabaya, Indonesia. Through biophilic design approach, the problem of boredom can be reduced by bringing the emotional bond between the workers and the nature inside the building.

Biophilic design is an attempt to translate the understanding of human attraction to the natural systems and processes into the the built environment (Kellert, Heerwagen, and Mador, 2008). Biophilic design approach focus more on the psychological effects of nature on human well-being, especially about how the environment can reduce stress and provide restoration effects in humans (Hidalgo, 2014). As described by Stephen R. Kellert, Judith Heerwagen, and Martin Mador (2008) that the design of the building and landscaping that accommodate the positive experience of nature can results health benefits for the physical, emotional, spiritual, and intellectual health. There are several major elements in the biophilic design that can bring the people back on their natural environment in the built environment that is natural form and shape; natural daylight; natural ventilation; natural color changing pattern; natural sounds; as well as the incorporation of species of plants and animals in and around the building (Benyus, 2008).

Kaleidoscope concept was appointed to explore the formation of the production room to bring the natural color changing pattern as a biophilic design element that changes over time to counter the monotony without reducing the concentration of workers. Kaleidoscope is an optical instrument that can produce a wide variety of beautiful patterns and colorful by utilizing the properties of light. Kaleidoscope also means a pattern or scene change (Brewster, 1858). Kaleidoscope can be a source of ideas for generating design work environment that can increase the confidence of workers to minimize the negative impact psychologically to rebuild a positive relationship between man and nature in the built environment. The concept of the kaleidoscope in this design can adapt the working principle and characteristic of kaleidoscope to generate the building design with a natural color pattern changes over time. The natural color changes may occur as a result of reflection and refraction of sunlight that experiencing angle change of incidence.

The design method chosen in this scheme is a direct analogy method in which the completion of design problems solved by the working principle and characteristics of the kaleidoscope. Characteristics and working principle of the kaleidoscope used as a source of analogies to realize compositions form that can accommodate the natural pattern of color that changes passively in buildings in certain areas to produce a dynamic work environment and is able to provide an intense relationship between workers with nature. The form of the buildings are arranged so that the spectrum of colors that emerge from the diffraction of sunlight focusing only on areas which not disturbing the concentration of workers while performing their duties.

## **2. THEORITICAL REVIEW**

### **2.1 The Boredom of Work**

As discribed by Leksono (2014), the boredom of work is one of the psychological problems that often occur in industrial workers. Boredom occurs because workers are required to do monotonous repetitive work and face activities that tend not attractive. But boredom can also be caused by things once considered exciting but became boring later . One of the factors that can lead to boredom work at the factory according to Hurrell, et al. 1988 (in Leksono, 2014) is an intrinsic factor in the work, including the demands of the task, the social relations between individuals in the working group, as well as environmental conditions which may affect workers' physical and psychological conditions that can generate stress.

### **2.2 Biophilic Design**

Biophilic design is an attempt to translate the understanding of human attachment with the natural systems and processes into the design of the built environment (Kellert, Heerwagen, and Mador, 2008). This theory discusses the need to maintain, enhance, and restore the attraction and positive feelings toward a particular habitat, activities and objects in their natural surroundings into the artificial environment (Dubos, 1980). There are several major elements in the biophilic design to bring the people back on their natural environments in the built environment that is formed from the natural; exposure to natural daylight; natural ventilation; natural color changing pattern; natural

sounds; as well as the incorporation of species of plants and animals in and around the building (Benyus, 2008).

Natural color changing pattern is one of biophilic design element in the form of environmental features that relatively easy to recognize in the built environment. Humans tend to be attracted by the colors of the flowers are bright, rainbow, sun setting beautiful, sparkling water, blue skies, and other colorful natural features (Kellert, Heerwagen, and Mador, 2008). Therefore, natural color changing pattern become the main focus in the biophilic design exploration applied in this production room design.

### **2.3 Color**

Consideration of the composition of the selection color in the room factory production also needed to improve the psychological health of the workers. Following the election on the color composition in the production room in the building industry (Mahnke, 1996):

- For jobs that require precision and high accuracy requires colors that improve concentration and tranquility. Strong colors will distract workers.
- For jobs that have procedures that are repetitive or monotonous but it does not require too much concentration, required colors against monotony by giving some colors that cheer on the environment.

The type of work at the garment factory production room is repetitive and monotonous, but it also requires concentration . Therefore, the color is applied to the design of the production room is dominated by the light colors that improve concentration and tranquility with cheerful colors on a certain area to fight the monotony.

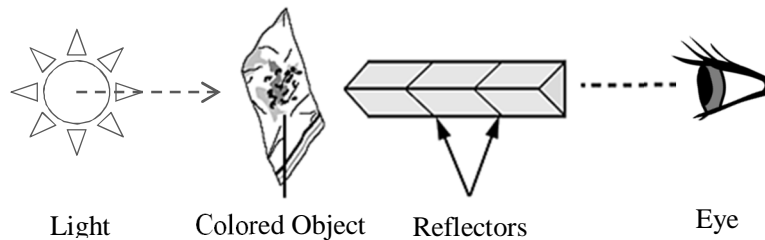
### **2.4 Natural Light**

Light is one form of energy emitted by objects or light sources in the form of electromagnetic waves. Visible light is a light that can be perceived by the eye. Natural light is the light that comes from the sun. Sunlight belong to the type of polychromatic beam composed of seven color components, namely red, orange, yellow, green, blue, indigo, and violet. Refraction on two clear areas with a surface that forms a certain angle (prism) will break down the sunlight into some colors. This can occur because each color in sunlight has a different velocity so as to have a different angle of refraction. The nature of the natural light can be harnessed to create changes in the pattern of natural color by using a refractory material that can break the sunlight into a spectrum.

### **2.5 Kaleidoscope**

Kaleidoscope as a main concept define as beautiful pattern or view that changes as a result of repeated reflections from the colored object. Kaleidoscope is an optical instrument made of several mirrors arranged in a certain angle so as to produce a light reflection with beautiful colors (Brewster, 1858). There are various types and sizes of kaleidoscope which produces a different pattern, but basically all use the same basic physical principle by manipulating light and reflection. Here are some of the main parts of a kaleidoscope (Figure 1):

- Light
- Reflector
- Colored Object



**Figure 1.** Main Components of Kaleidoscope

Kaleidoscope generate color patterns with specific characteristics, are changeable, colorful, and had a corner/a certain slope. The changing pattern of colors on a kaleidoscope can be generated in several ways, such as changing the position of colored objects or changing the composition of the reflectors that are used. In practice, the pattern changes of kaleidoscope can be applied to building components that can produce patterns which can be changed to avoid boredom in the production room.

### 3. DESIGN METHOD

Direct analogy design method is used to apply the working principle of the kaleidoscope on the design. Design exploration process is done by analyzing the incident angles of sunlight that is done by using SketchUp software to gain formations that meet the criteria and design concepts that have been determined. The schematic design of production room is presented as the result of the design exploration.

### 4. ANALYSIS, RESULT, AND DISCUSSION

The objective of this design is to create a garment factory production room to alleviate the boredom of work in industrial work environment by presenting the attractions of the natural environment into the building using biophilic design theory approach. Therefore, in exploring production room design that refers to the design concept, an assessment of the kaleidoscope working principle is done for the analogy. The goal of the analogy of the working principle is to find the strategy to accomodate changing pallete of natural color in the room without infering workers on the job.

By analogy made by the working principle of a kaleidoscope, changing patterns of natural color in a room can be created in two ways, namely changes in the position of colored objects or change the composition of the reflectors which are used. In practice, changes in the position of colored objects can produce passive changes of the color pattern, while the color pattern changes

caused by changes in the composition of the reflectors require human intervention or an active changes. Therefore, through biophilic design approach with the analogy, the exploration of this room design using passive changing palette of color concept can be applied by utilizing the nature of sunlight that can be diffracted. Diffracted sunlight will produce color spectrum that can be analogized is as colored objects of kaleidoscope that can change position according to the incident angle of sunlight at certain hours. Since Indonesia is a tropical country that is on the equator, the sun's position changes toward the equator in certain months are also considered to produce changes in the pattern of natural colors more varied.



**Figure 2.** Satellite Photograph of Location

Source: [www.google.co.id/maps](http://www.google.co.id/maps)

The design is located in the city of Surabaya, Indonesia at  $7^{\circ}12'$  South Latitude up to  $112^{\circ}39'$  East Longitude. Sun movement analysis is done at extreme points of sun toward the equator, namely on March 21<sup>th</sup>, June 21<sup>th</sup>, September 23<sup>th</sup> and December 23<sup>th</sup> using SketchUp software to find the slope angle of incidence of sunlight on the building/room. The times selected are at 08.00 GMT +7 when the work starts, 12:00 GMT + 7 until 13:00 GMT + 7 at the break hours, and 16:00 GMT +7 at the end of working hours. The results of analysis of Sketchup software is illustrated on the diagram (Figure 3).

The analysis was made assuming a rectangular production room with a ratio of height:length:width = 3:5:3 with the longest sides are on the north and south sides. The red line indicates the incident angle of the sunlight at the times specified. Direction of the incidents of the sunlight are focused on the area above the orange line, that is only visible when the workers are resting or not doing his job.

To create the attractive natural colors from the sunlight, diffractive grating material is used to diffract the sunlight into a spectrum of colors. The blue line on the diagram shows the diffractions of the sunlight assuming the angle of light that diffracted is at  $15^{\circ}$  from incident angles. The diffracted lights would be manipulated to be applied to the design concept (Figure 4).

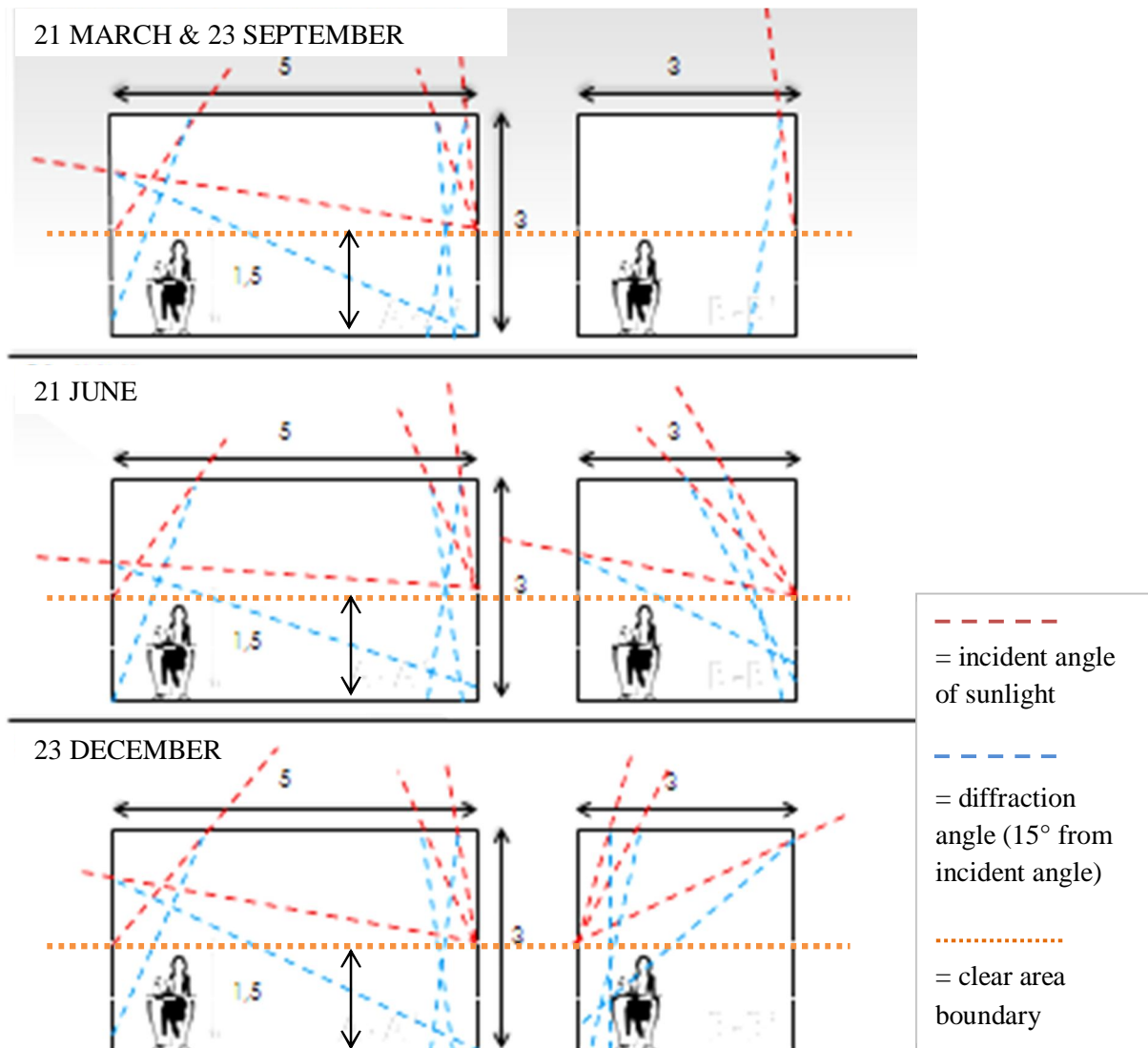
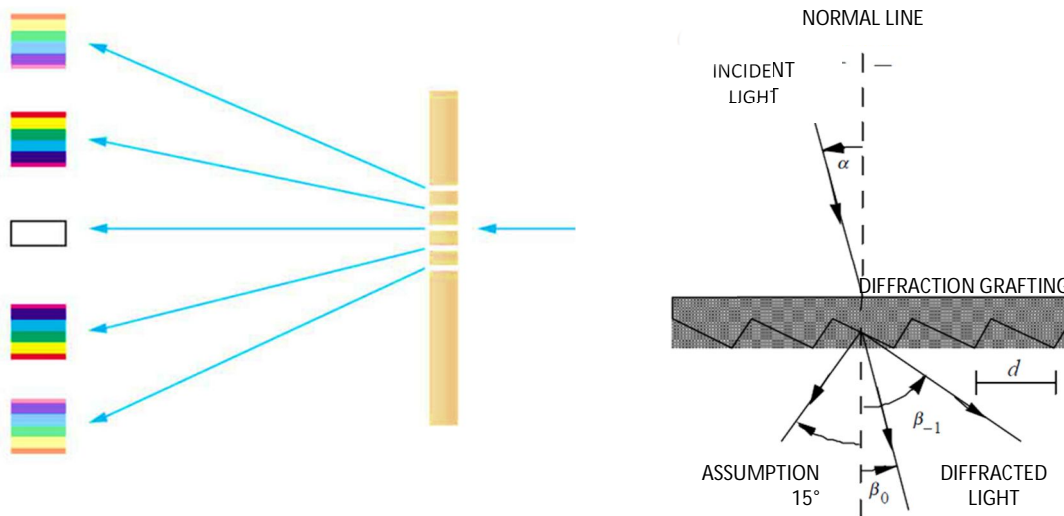


Figure 3. Diagram of Sun Analysis Results



**Figure 4.** Diffraction of Light with Diffraction Grating

Based on the diagram at Figure 3, it can be found that the diffracted sunlight that radiated is on the area below the orange line which is the area visible by the workers while doing their job. The existence of those attractive colors on the working time can disrupt the concentration of the workers. Therefore, in response to the results of the sun analysis, the skew is applied to the wall so that diffracted sunlight will not exceed the area below the orange line (See Figure 5). The skew of the walls resulting skylight cantilevers with a certain length on each side of the room, as follows:

- The length of skylight on the west side of the room:  $\pm 1,6$  m
- The length of skylight on the east side of the room: 0,3 m – 1,1 m
- The length of skylight on the south side of the room:  $\pm 1,4$  m
- The length of skylight on the north side of the room: 0,6 m - 2,2 m

On the west side of the building, the dominant solar light has a slope that produces openings with the same width, which is 1.6 meters at points of extreme sun. Therefore, to produce any change in the pattern of colored light created by the sun, the opening is designed with a width of 0 to 1.6 meters on the west side of the building (see Figure 6).



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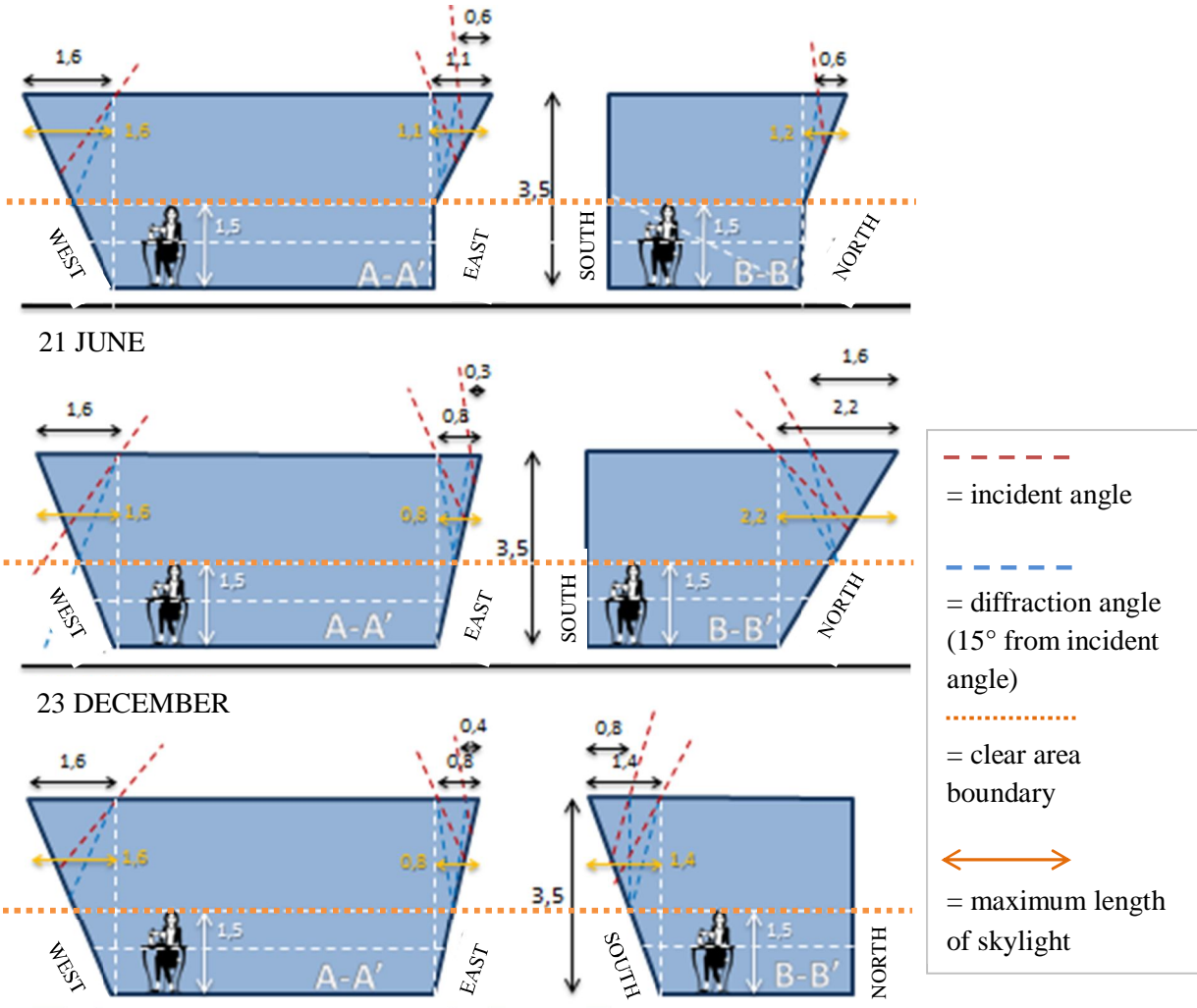


Figure 5. Skew of the Walls Responding the Incident Angles of Sunlight.

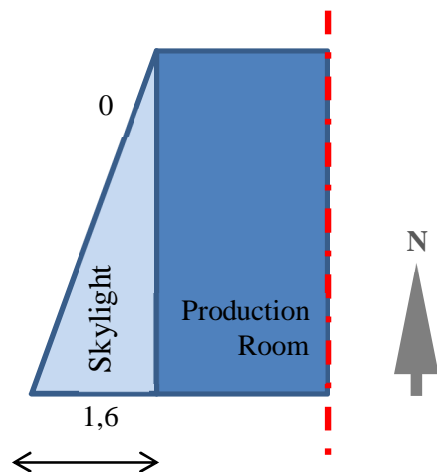
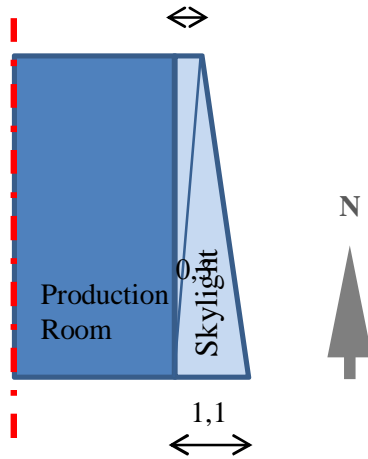
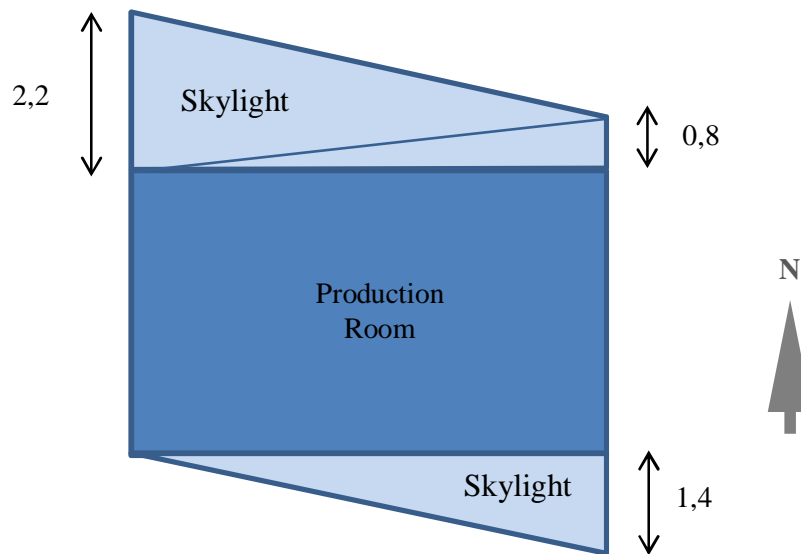


Figure 6. West Side of Production Room Skylight Layout

On the east side of the building, there are differences in effective skew of the building envelope at the selected times, which on March 21<sup>th</sup> and September 23<sup>th</sup> the sun is leaning on the north side (on the building), so that to avoid the light on the field of work, the wall is skewed considering the view of workers which is about 1.5 meters with a length of openings of about 0.3 to 1.1 meters (See Figure 7). On the south side of the building, the sunlight is not much on the buildings so that the openings produced has a different length at around 0 to 1.4 meters. On the north side, the opening is generated on the lengths of about 0.8 to 2.2 meters (See Figure 9).



**Figure 7.** East Side of Production Room Skylight Layout

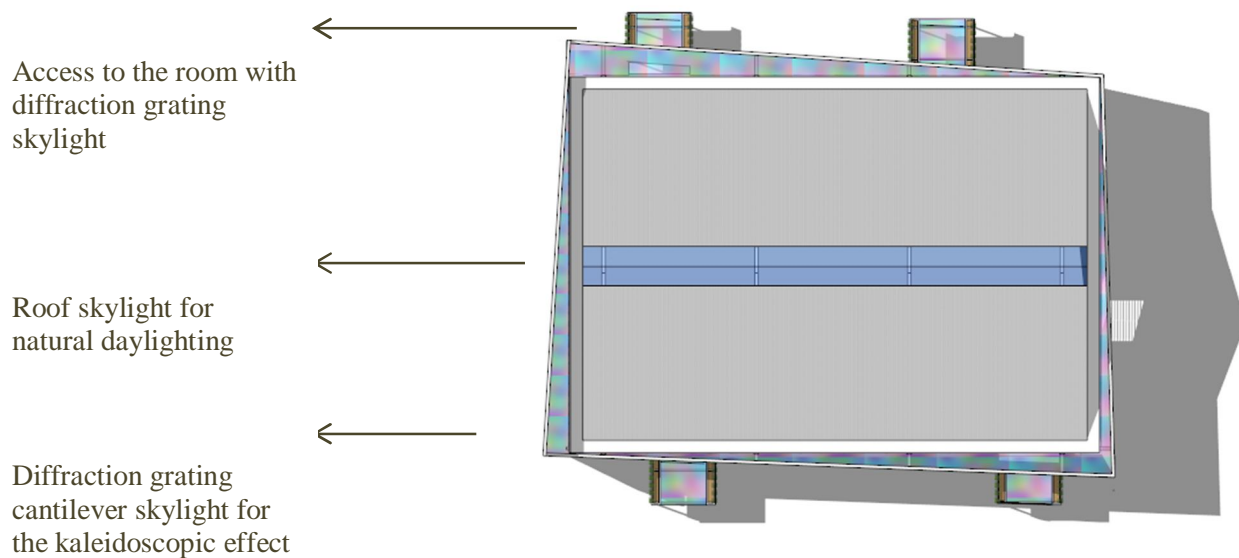


**Figure 8.** North and South Side of Production Room Skylight Layout

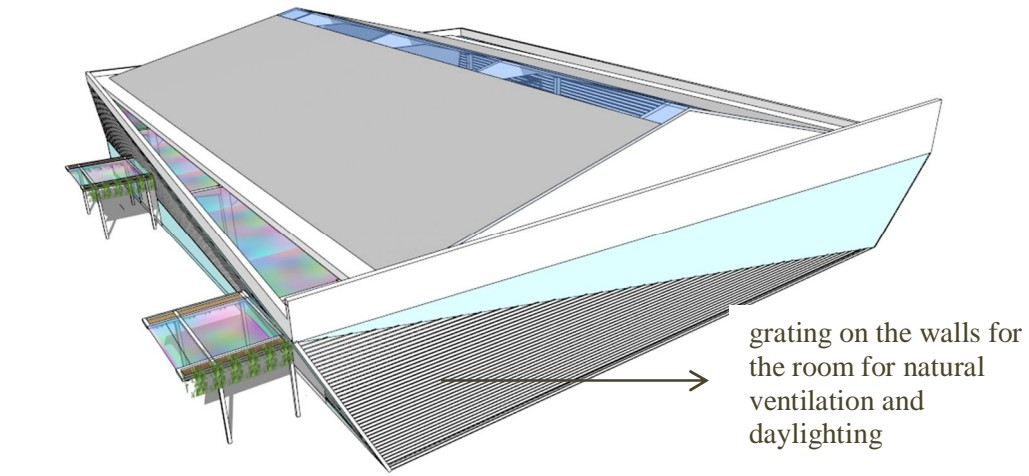
The resulting shape of the production room is designed by considering biophilic design elements which is inspired by nature. In this case, the inspiration of nature came from the

movement of the sun to the Earth that are changing at certain times. The shape applied to the production room that are widely used by production workers daily to reduce the monotony of the work environment (Figure 9 & 10).

Consideration of natural colors spectrum position in certain areas is based on a literature review about the color in the work environment industry by Mahnke (1996) in where work procedures that are repetitive or monotonous but does not require too much concentration, it is necessary to apply colors against monotony by giving some colors that cheer on the environment. And for jobs requiring precision and a high degree of accuracy requires colors that improve concentration and calmness. In this case, the production room of the garment factory has both these properties which are monotonous work and requires precision. Therefore, the selection of the color composition is determined by providing attractive color as relieving boredom in areas beyond the reach of workers' eyes when carrying out work to maintain the concentration of workers.

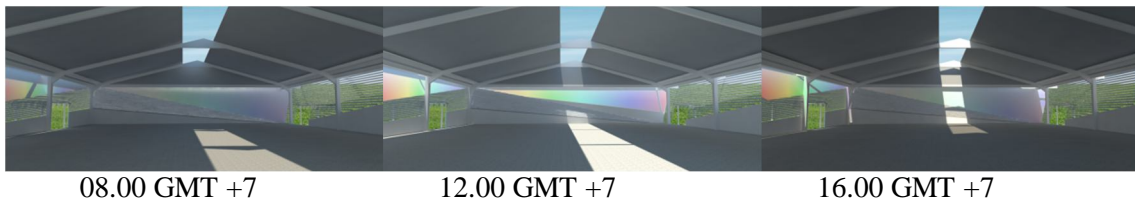


**Figure 9.** Production Room Schematic Design (Upper View)

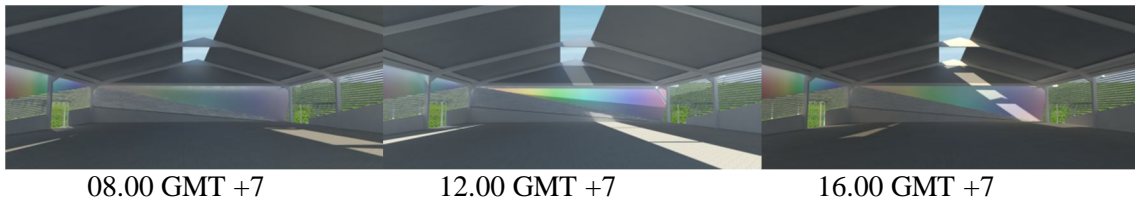


**Figure 10.** Production Room Schematic Design (Bird Eye View)

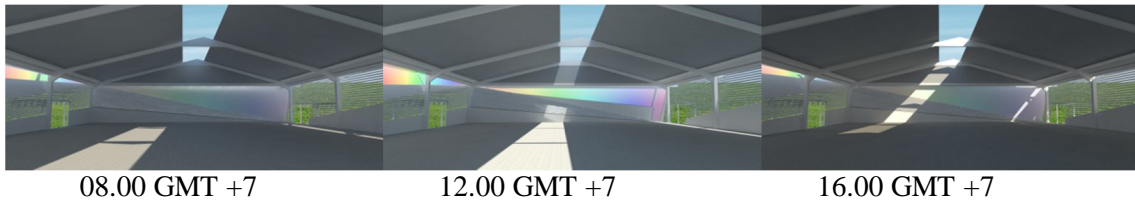
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**Figure 11.** Simulation of Color Changing Inside the Production Room (Using SketchUp Vray Software)

## **5. CONCLUSION**

Biophilic design is chosen as an approach to overcome the problem of boredom in industrial work environments that occurred due to the monotonous and repetitive work, and activities that are not attractive. The boredom of work in industrial work environment can be reduced by creating a built environment that accomodates human attachments with their natural environment. Therefore, the design of the garment factory production room is trying to find the ways to bring the attachment into the building.

The concept of kaleidoscope can accomodate the attachments by implementing passively changing pattern of natural colors of biophilic design element in the production room. Considering the type of work in the garment factory production room, kaleidoscope concept can be applied to the formation of a more dynamic mass. In addition, the concept of the kaleidoscope also show something new to bring the building envelope design of production room that can provide positive psychological effects for the workers.

## **6. ACKNOWLEDGEMENTS**

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