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THE INTEGRATION MOVEABLE KINETIC ROOF TO SUN ORIENTATION ON VELODROME BUILDING

Wan Mahdzir Yason (a), Azhar Ghazali (a)*, Hazril Sherney Basher (a),
Mohd. Hafizal Mohd. Isa (a)
*Corresponding author

(a) School of Housing, Building & Planning, Universiti Sains Malaysia, 11800, Penang, Malaysia,
wanmahdzir@gmail.com, azhar.ghazali@usm.my*, hazril@usm.my, hafizal@usm.my

Abstract

Daylight performance in a velodrome cycling track arena is essential to create splendid scenery for the athlete to perform during the event held. Therefore, a moveable kinetic roof according to the sunlight path on top of the building is important to implement. A specific requirement for cycling track is to avoid any shadow from the cyclist to steer clear any incident from happening during the game begins. The new technology of kinetic roof that integrate creativity with the sun movement would help to control the amount of sunlight that will enter the indoor area. The integration of kinetic roof to be placed at the top of the sports indoor arena would help to reduce the electricity consumption for that building as it integrates to control the amount of light to pass through into the private area. This study is divided into two parts; the analysis on the preference of local velodrome in Malaysia, which is in Nilai, Negeri Sembilan and 3D model daylight analysis using VELUX. Based on the analysis, the implementation of the kinetic roof in velodrome design in Malaysia will be able to let the required amount of daylight appear for the internal area. While passive skylight that integrated at the current velodrome was not capable of controlling the daylight and it is dependable on the weather condition.

Keywords: Daylight, velodrome design, kinetic roof.

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1. Introduction

There are many typologies to represent sports building in architectural. Most of the sports buildings need to fulfil the requirement for each sport. A velodrome is one of the sports building typologies in the architectural understanding of building types. It functioned to be a building that operates to assign a space for the cyclist to have an event generally. The cycling track is designated to be steep into a certain angle on two straights, and it bends to create a loop design integration (Flowers, 2011). In having a good experience in the internal environment of the velodrome, the intention of designing a building is adapting the natural daylight into the internal arena. By the requirement needed of Union Cycliste Internationale (UCI), the indoor environment must have enough light to let the cyclist can see the track during the event (Parrish, 2003). The best lighting environment will create an excellent feeling to the cyclist as the performer in the track and crowd to watch the games. The experience for them to watch the games with good visualization will be affecting their behaviour (Navvab, 1999). According to the guideline, the facilities of the building need to ensure that the building provided an excellent, bright environment. It's depending on using natural light or by artificial lighting (Caddy, Fitton, Symons, Purnell, & Gordon, 2017). The goal is to get the best amount of illuminance to be in the track for the cycling. The illuminance needs much as it can to avoid any shadow placed on the track during the event (Llewellyn, 2011).

In Malaysia, the first indoor velodrome has been constructed by the past few years, and it already has begun with the implementation of natural energy such as daylight. Malaysia National Velodrome is the first to become an indoor cycling track arena that was constructed in 2017. However, this is the first attempt to create an indoor cycling track arena, and it does not have any better example to be revised as the previous velodrome in Malaysia were designated as opened stadium arena. In a tropical climate in Malaysia, the best solution is to tackle the natural day lighting to enter the internal environment (Nabil & Mardeljevic, 2005). In way to have better daylight integration with the building, it is good to improvise an engineered structure of kinetic roof on top of the building. The dynamic roof will take the useful amount of light to be into the interior arena of the velodrome.

2. Problem Statement

According to the guideline, the facilities of the building need to ensure that the building provided an excellent, bright environment. It's depending on using natural light or by artificial lighting (Harries, Brunelli, & Rizos, 2013). The goal is to get the best amount of illuminance to be in the track for the cycling. The illuminance needs much as it can to avoid any shadow placed on the track during the event. It is because they want to avoid distraction from the cyclist (Pan, Sun, Turrin, Louter, & Sariyildiz, 2018). The amount of lux was determined to be enough for any emergency, safety, operations, and security situation. From these implications, the performance of those spaces can be utilized by user wisely and improving the quality of production (Bryans & Jump, 2001).

Thinking to make the new integration of natural light into the indoor velodrome is to think the critical element of the shape of velodrome's geometry that has the vast roof that required covering the O-shape cycling track (Brown & Cresciani, 2017). It needs to offer a much opportunity to allow daylight into such a vast deep space. The criteria have yet to be clear that it is going to implement daylight into

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that environment. Instead of targeting to achieve 2000 lux to cater for the international event that was going to be held inside the building, an environmental target for a minimum is 300 lux which looks like 90% of the additional artificial lighting (Navvab, 1999).

Architectural element evolves through times along with the technologies that were created from time to time (Linn, 2014). The current technology is adapting the kinetic element into one of the architectural elements on the building. The kinetic architecture was designated to be dynamic, adaptable and capable to be installed into the building structure (Barozzi, Lienhard, Zanelli, & Monticelli, 2016). It is one of the technologies that integrate with the motion with the built environment along with the aesthetical value, design and performance of the building (Ramzy & Fayed, 2011). Although the aesthetic value of virtual motion may always be a source of inspiration, its physical implementation in buildings and structures may challenge the very nature of what architecture is (El Razaz, 2010)

Application of kinetic architecture on the building can improve the quality of the building performance also to human comfort (Pesenti, Masera, Fiorito, & Sauchelli, 2015). The technology was created to be a strong transformative and mechanized structure that aims to target what the human needs into the building function by integrating with outside environments. The intention is to solve the problem on how to control the amount of light that passes into the internal environment of the velodrome track arena with the help of technology of kinetic roof that places on top of the building.

3. Research Questions

In order to understand the integration of moveable kinetic roof on velodrome design in Malaysia have a positive effect on daylight requirement for indoor cycling sport, two research questions have been developed:

- What is the current situation of daylight performance of Velodrome in Malaysia?
- How can a moveable kinetic roof system improve the daylight performance in Velodrome in Malaysia?

4. Purpose of the Study

In order to investigate the implementation of moveable kinetic roof system on velodrome design in Malaysia, some physical characteristic needs to be taken seriously to make sure that the idea can be implemented in Malaysian climatic condition. Therefore, the aim of the research is:

- To study the daylight performance of current velodrome design in Malaysia
- To understand the performance of moveable kinetic roof that was installed at the top of the building of velodrome to control the amount of light that passes through inside the building environment.

5. Research Methods

This research encompasses two methodologies which are case study of National Velodrome Malaysia to evaluate and understand the current situation of daylight in velodrome design in Malaysia and

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analysis using VELUX software to analyse the integration of moveable kinetic roof for velodrome design to achieve the required illuminance for cycling sport.

5.1. Case Study: National Velodrome Malaysia

National Velodrome Malaysia in Nilai, Negeri Sembilan is an excellent example of velodrome building in Malaysia. Located at 2°50'34"N and 101°47'11"E is the latest velodrome in Malaysia used as the main venue for cycling track event during ASEAN games and it can accommodate 2000 crowds per event. The construction of the roof component on top of the building is made of long-span steel trusses while it covered with aluminum panels decking. Some of the facades were allowing the daylight to pass through into the interior arena according to the design layout that been created from the architects. Figure 1 shows the existing roof design and diagram for National Malaysia Velodrome that integrated with translucent roof as skylight.

Figure 01. Images and diagram of existing roof design for National Velodrome Malaysia

Based on the diagram, a measurement of the illuminance level was taken on December 13, 2018, at 2.00 PM, and Lux reading taken when lighting in off light mode, semi lighting, and fully lighting. Identifying the current illuminance that been implemented in the first indoor velodrome in Malaysia is to understand whether is the design that been used is practically suitable to having the illuminance amount of light in that indoor environment.

The illuminance level (lux) was taken using a lux meter based on the measurement point shown in Figure 2. The reading was calculated three times, according to the lighting situation inside that arena as

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shown in Table 1. Most of the light inside the velodrome arena was installed with the fluorescent LED that hanging on top of the cycling track.

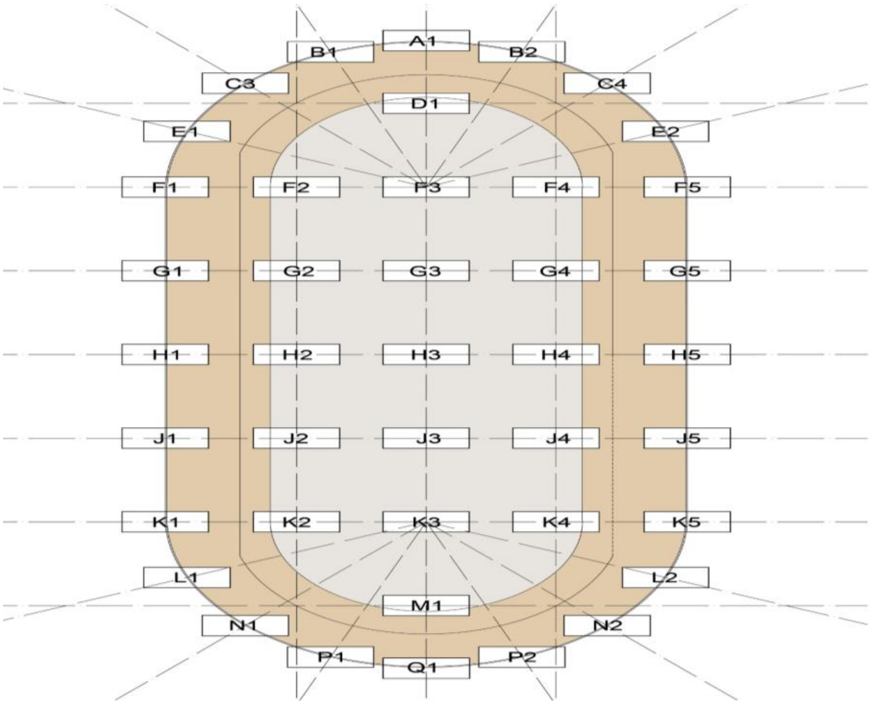

Figure 02. Images of Lux meter tools (left) and grid measurement point represent of daylight reading (right)

Table 01. Lighting Scenery Inside the Velodrome

Scenario	Definition
Off light (fully daylight)	The lighting system is fully turned off from the electric current. This is when they didn't use the internal arena of the velodrome. During this scene, the entire arena was fully occupied by the natural daylight from outside the building that passes through the roof.
Semi-lighting	Semi-opened lighting system where there was 50% of LED light is turned on and it almost covered all the area of the arena. This mode is used when the velodrome arena is used by the athlete during the training session. Usually, a semi-lighting mode is used all day.
Full lighting	Most bright scenery during the event held at the velodrome. This is when all the lighting system is turned on by the LED that were hung on top of the timber track. The lighting is fully covered its bright by following the specification rules stated by the UCI.

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5.2. Simulation: VELUX

The intention to do a virtual analysis by using the VELUX Daylight Visualizer software is to identify how much the best result if the velodrome has installed a kinetic roof that can rotate it panel by following the sun path on top of it. VELUX Daylight Visualizer is a tool for daylighting design and analysis. This software is able to predict and document daylight levels and appearance of a space prior to realization of the building design. Velux Daylight Visualizer can predict accurately daylight levels and appearance of a space lightened with natural light, prior to realization of the building design (Labayrade, Jensen, & Jensen, 2009).

The model was created from SketchUp will be integrated with VELUX software were tested in many ways as the analysis need to identify the reading result of each rotation that has been moved by the kinetic panels. The angle is rotated manually using the computer as following the specific edge according to a particular time during the daytime. In this analysis, there is 2 test model as shown in Figure 3 and Figure 4.

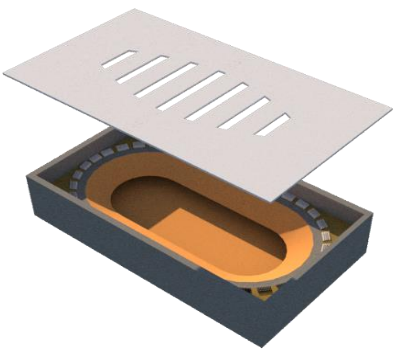

Figure 03. Re-model of National Velodrome Malaysia with existing roof design.

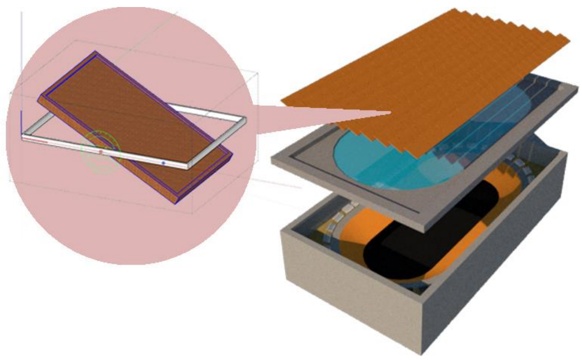

Figure 04. Re-model of National Velodrome Malaysia with the placement of moveable kinetic roof.

As the time taken has been identified into a particular time, the software rendered the visualized image of the interior arena of the velodrome. Those visualize images were set up into seven times in daily schedules (Table 2). It started in the early morning and ended in the late evening. Due to the local daylight hour is 12 hours, it will be divided evenly and precisely the perfect angle of 180 degrees. All the time taken will be rendered and produced a daylight factor, luminance and illuminance images. The reading takes the amount of the lux that diffuse into the internal area also changes for every month taken. It is because of the session through all the years changes and creates a different amount of light to the nature surrounding. It has been stated in a study before where in Malaysia, the climate changes due to the sun path moved slight a bit from it coordinate. This create a monsoon season to the tropical climate country (Zain-Ahmed, Sopian, Abidin, & Othman, 2002).

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Table 02. Rotation angle and time taken for VELUX analysis

Angle Rotation	Time	Lux Range Analysed
22.5°	0815 – as the morning sunlight is passing into the surface	750
45°	0930 – the mid reading of the morning sunlight	800
62.5°	1045 – a final morning sunlight before it reaches the mid-day sunlight	850
90°	1200 – mid-day / afternoon sunlight	1200
112.5°	1445 - after mid-day sunlight passing afternoon reading	860
135°	1630 – the mid reading at the evening daylight	800
157.5°	1715 – the final reading at the evening before the sun is set to dawn	720

6. Findings

6.1. Daylight measurement of National Velodrome Malaysia.

All the reading taken is according to the lighting scenery inside the velodrome arena. Each scenery was giving a different result to the lux meter. From the observation, each scenery works with natural daylight that pass through the roof by then the electrical lighting system work as an additional lighting support into that arena as it required a bright view as much as they can. After adding all the information of those three-lighting mode is reading into the grid. The reading was graded according to the lowest to the highest point with a colour gradient. (Figure 5). Meanwhile Table 3 summarized the findings for each scenario.

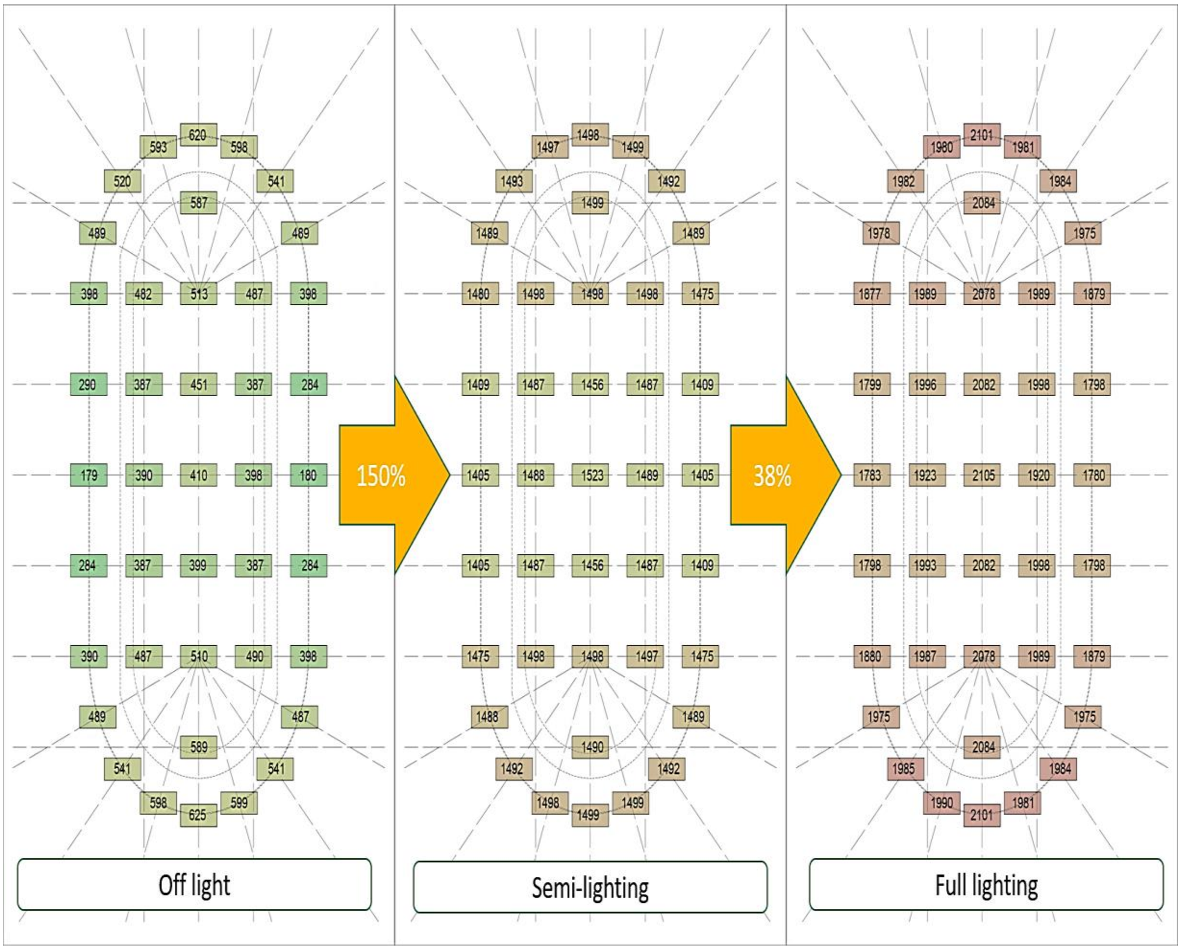

Figure 05. The images of mapping graph of daylight factor showing the increasing brightness implemented

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Table 03. Summary of finding for lighting scenario for National Velodrome Malaysia

Scenario	Findings
Off light (fully daylight)	▪ The whole arena was insufficient lighting that diffuse from outside through the translucent roof panel at the top of the cycling track. ▪ The translucent roof designated horizontally, and it is about 20% covered all roof area. ▪ The light preference did not apply to the specification needed by the UCI.
Semi-lighting	▪ The total electrical consumption for the building comes from the lighting system that has been installed into the building. ▪ There was 50% of the LED to be switch off as it needs to save some energy from the electrical services. ▪ For training and rehearsal that need to be done inside the velodrome arena. ▪ The amount of light was brighter than natural daylight diffusion effect during all the electrical lighting system is being turned off. ▪ Lighting inside the velodrome increase as the interior environment was added on with the artificial lighting system has been turned on. Half of the electrical lighting system been used to brighten up the timber cycling track. ▪ Minimum amount of light that need for the cyclist to do the training session, but it did not follow the requirement from the international standard of UCI.
Full lighting	▪ The entire timber tracks were lightened up and brighten up. ▪ No shadow should occur on the cycling track. ▪ During cycling event. ▪ Reading show increases in light amount inside the velodrome. The amount is much as it reaches almost more than the specific lighting need for the international standard.

According to the result that has been clarified into the grid map, it shows that the increases of lux unit in every mode environment. The increases start when they switch on the semi-bright mode of the artificial lighting system. The amount of lux arises as it mixed up with the current daylight that diffuse from the translucent area of the roof panels — the amount that was already enough to be used for the cyclist to cycle on the velodrome track. In conclusion, after all the light has been switch on, the most splendid scenery inside velodrome was visualized. All the interior arena was fully brightened with the LED light, including the natural daylight that through the roof.

6.2. Daylight analysis of moveable kinetic roof

After both analyses on these two models of velodrome have been done, the reading of the daylight given by the software will be taken note and analyse. These intentions to differentiate the graph of light transmit into internal area of the velodrome. The reading measures the amount of light transmit into the internal area, while the whole data reading will be place on the graph that represent each month in a year (Figure 6 and 7). Based on the analysis, its shows that the implementations of kinetic roof on National Velodrome Malaysia able to allow more illuminance from daylight compare to existing roof design.

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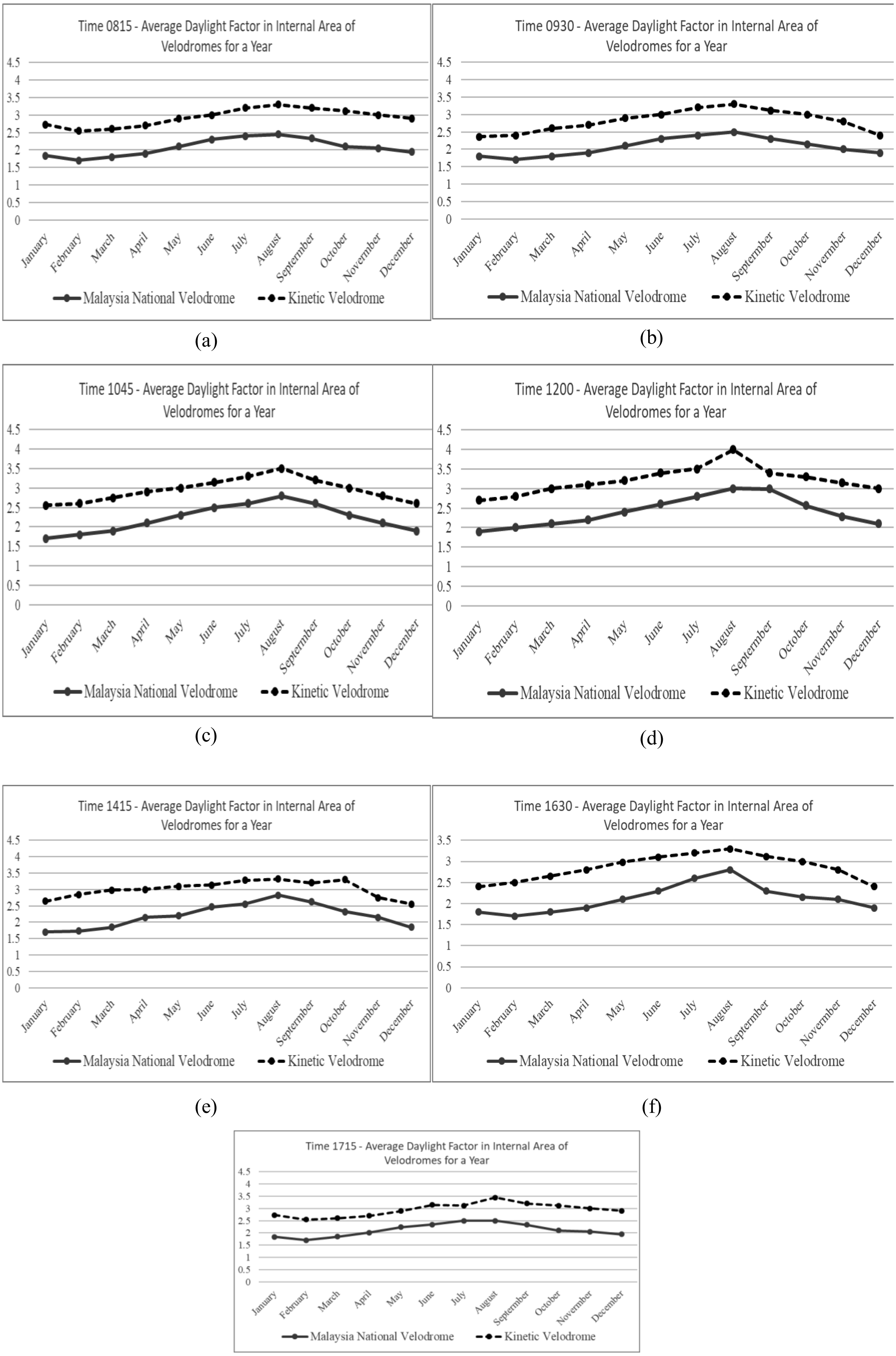

Figure 06. Comparison of average Daylight Factor of different roof design for National Velodrome Malaysia

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7. Conclusion

In conclusion, the implementation creates a new perspective of how the efficient installation of moveable kinetic roof panel to be placed at the top of the building. Based on the differentiation analysis stated that all the reading show that implementation of the moveable kinetic roof was able to bring sufficient light into the private area and able to allow more illuminance from daylight compare to existing roof design. Thus, it will reduce the electricity consumption for artificial lighting during each cycling event. Based on the research that has been made, the result shows that:

- The differentiation between a moveable roof was able to control the amount of daylight to appear inside the indoor area rather than using a passive design. The kinetic façade will capable to control the usage of artificial electrical energy consumption as it controls the amount of light pass into the building. Those panels precisely controlled the amount needed into that area as it was set up to having some certain amount of daylight lux intake. It blocks the direct sunlight to be into the arena while taking the indirect light to be diffused into the area. These show that the implementation was a success to let the required amount to appear inside the internal arena. While the passive skylight that was integrated at the current velodrome was not capable of controlling the daylight and of depending on the sky weathers.
- Integration of moveable kinetic roof panel on top of the building show that it is capable of understanding the amount that needs to be control and light intake. As the mobile system was determined to understand the movement of the sun, the kinetic panel capable of blocking direct sunlight from passing through inside the private area. It allows the indirect sunlight to be bias and diffuse to be taken into the arena. The allowed light that passed into the internal arena was controlled well according to the machine determination. By then, it will capable to have sufficient light according to the requirement needed. As well to save the usage of electrical consumption.

The result that been taken from the software was qualified to be analysed. As a result, it gives excellent result to understand how the integration of light into space through the years can be determined. The differentiation of the two models shows the different reading that determines each of them has different integration to the sunlight. In the end, the result has finalised an informative understanding of proper implementation to have a capable moving roof panel that can control the light pass into an area. Therefore, the future intention to create a sports arena has to consider this implementation as it brings an excellent advantage to implementing a sustainable building in the future..

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