Comparison Of Dynamic Elements On Football Stadium Retractable Roof Case Study: Singapore National Stadium In Singapore, Toyota Stadium In Japan, And Commerzbank Arena In Germany

Nadya Carmelianda, Etty R. Kridarso, Julindiani Iskandar, Sri Novianthi

Abstract: Planning dan designing football stadium with retractable roof aims to accommodate outdoor and indoor activities (multievent arena) such as football matches and music concerts. Dynamic element is applied in one of football stadium part which is the roof, this is chosen as a representation of future dimensions. The football stadium which become the object of this research is Singapore National Stadium in Singapore, Toyota Stadium in Japan, and Commerzbank Arena in Germany. The object of this research has rectractable roof with different forms, structures, and environmental aspects. This research uses qualitative methods by comparing secondary data about the application of dynamic elements which applied to the rectratable roof of each research object that has different kind of weather conditions, function, roof shape, structural design, and types of roof movement, then analyzed based on dynamic element criteria. With this research about the application of dynamic element on football stadium retractable roof, it can be concluded that Singapore National Stadium in Singapore has the most dynamic retractable roof.

Index Terms: comparison, dynamic element, football stadium, retractable roof

1. INTRODUCTION

FOOTBALL is a sport with the most enthusiasts in the world and has been developed into an entertaiment that can be enjoyed by various groups. It affects the planning of today's football stadium, which is the concept of multi-event arena. According to Indonesian Dictionary (KBBI), multi means many; more than one; more than two, while according to Oxford Dictionaries event means an event. It can be concluded that the football stadium with multi-event arena concept is a football stadium that able to accommodate various types of activities. The design of retractable roof on football stadium serves to accommodate a variety of indoor and outdoor activities to the fullest without worrying about weather changes. According to the times, football stadium increasingly applies dynamic element as an embodiment of the future. Football stadium with retractable roof is not a new thing, but the forms that applied are not developing. It is expected that dynamic element can be applied not only in form but also in retractable roof. This is to show that the design of football stadium retractable roof continues to grow compared to before. By analyzing the retractable roof from several football stadium, it could be determine what factors that influence the using of dynamic elements.

Singapore National Stadium, Toyota Stadium, and Commerzbank Arena are some of football stadiums that have implemented retractable roof with a different embodiment. Each football stadium is located in different countries that has different aspects of environment, form, structure, and type of movement of the retractable roof. The results of this study aims to determine which football stadium that has the most dynamic rectratable roof.

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1.1 Definition of Comparison

Comparison based on Indonesian Dictionary (KBBI) is a comparison. According to Winarno in Introduction to Scientific Knowledge book (1986: 84), comparison is a descriptive investigation to find solutions through analysis of causal relationships, which has certain factors that related to the situation or investigated phenomenon and compared the factor with other factors.

1.2 Definition of Dynamic Element

According to Indonesian Dictionary (KBBI), dynamic is a situation that is full of enthusiasm and energy so it moves quickly and easily adapt to circumstances and so on. Oblique and elliptical are dynamic, that by their very nature have an emotive power a thousand times superior to that of perpendiculars and horizontals, and that there can be no dynamically integrative architecture that does not make use of them (Antonia San't Elia, 2009).

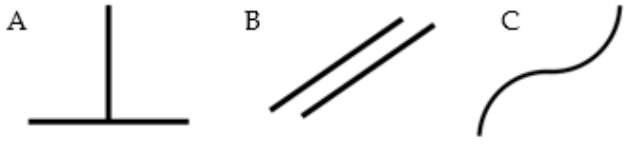

***Fig. 1**. A. Perpendicular line (not dynamic); B. Oblique (dynamic); C. Elliptical (dynamic).*

It can be concluded that the criteria of dynamic form are formed from oblique or elliptical (the bigger the degree of curve, it is more dynamic).

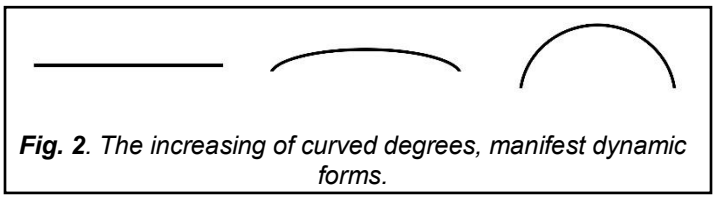

***Fig. 2**. The increasing of curved degrees, manifest dynamic forms.*

1.3 Definition and Types of Football Stadium

Stadium is a building for organizing football, sports activities, athletics, and facilities for the audience. On the scale of cities and regions, stadium is the main sport infrastructures because of its existence which able to be the center of sports activity (Standard Procedure for Stadium Building Engineering Planning, 1991). Based on Standard Procedure for Stadium Building Engineering Planning (1991), football stadium can be classified based on the type of roof:

a) Outdoor Stadium is football stadium without a roof;
b) Enclosed stadium is football stadium whose entire space is closed or inside a building;
c) Moving Stadium is combination of open and closed stadium. Roof of football stadium can arranged to be open and close based on need.

1.4 Definition and Types of Football Stadium Retractable Roof

Retractable roof structures in stadiums and sports halls can be defined as follows: “Retractable roof structures are a type of roof structure, which can be completely or partly moved or folded in a short period of time so that the building can be used with an open or closed roof” (Ishii, K, 2000).
According to Andrej Mahovic (2015), typology of retractable roof can be divided based on:

a) Frequency of opening and closing

The frequency of opening and closing roof is observed based on the weather, the frequency when closes and then opens, the frequency when opens and the closes, and repetition (opening and closing).

b) Structural design

Based on the structure, retractable roof can be divided into three types, which is structures composed of rigid elements, membranes, and combinations of various elements.
Retractable roof structures composed of rigid elements. The entire roof or individual smaller parts of the retractable roof are composed of rigid elements that are moving in various ways, such as the Wembley Football Stadium in London, UK.

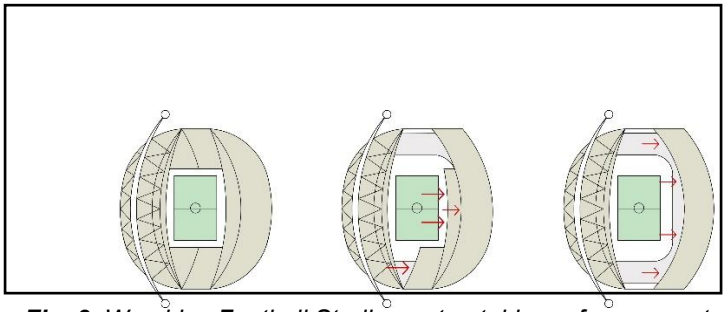

***Fig. 3**. Wembley Football Stadium retractable roof movement.*

Retractable roof structures composed of membranes. The entire roof or individual smaller parts of the retractable roof are membranes that are moving in various ways, for example is Rothenbaum Tennis Stadium in Hambrug, Germany.

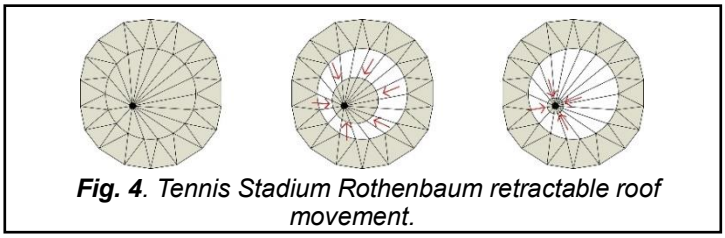

***Fig. 4**. Tennis Stadium Rothenbaum retractable roof movement.*

Retractable roof structures as combination of different structure designs. Entire roof or individual smaller parts of the retractable roof are composed of different elements that are moving in various ways. For example is The Big “O” Olympic Stadium, Montreal, Canada (1976). Structure design of fixed roof is rigid and for the movable roof is using membrane.

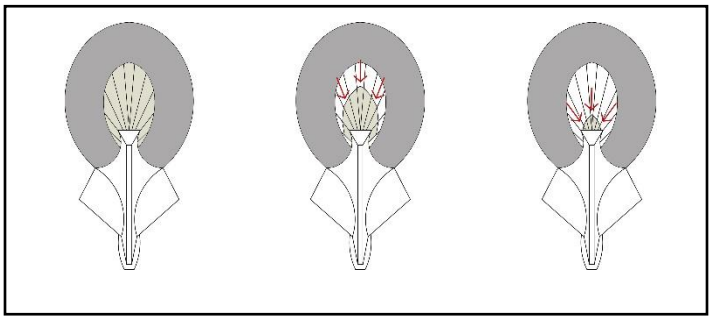

***Fig. 5**. The Big ”O” Olympic Stadium retractable roof movement.*

c) Type of movement

Retractable roof movement systems can be divided into sliding system, lifting system, rotating system, folding system, expandable system, and combination system.

Retractable roof with sliding system is a movement shifts horizontal direction. This movement are applied in Ariake Colosseum Hall in Japan (1987), Amsterdam Arena in Netherlands (1996), and Gerry Weber Tennis Stadium in Germany (1994).

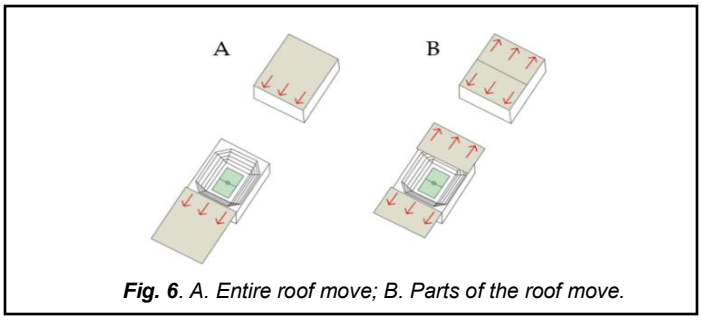

***Fig. 6**. A. Entire roof move; B. Parts of the roof move.*

Retractable roof with lifting system could be lifted and lowered to desired height.

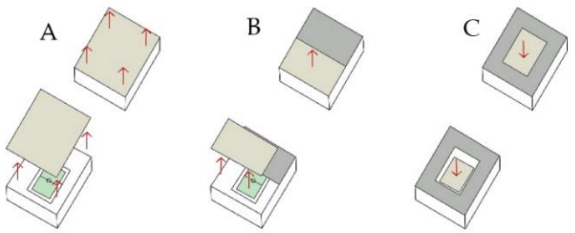

***Fig. 7**. A. Entire roof structure lifting; B. Parts of the roof lifting; C.*

Parts of roof lowering.

Retractable roof with rotating system is a movement that rotated around the axis. This movement is applied in Civic Arena in USA (1961).

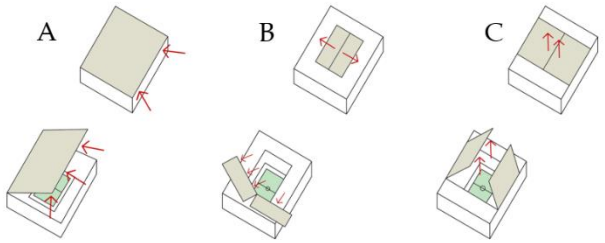

***Fig. 8**. A.Entire roof rotating; B. Parts of the roof rotating around vertical axis; C. Parts of the roof rotating around horizontal axis.*

Retractable roof with folding system enables the elements of roof to be folded. This movement are applied in Toyota Stadium in Japan (2001) and Waldstadion in Germany (1925).

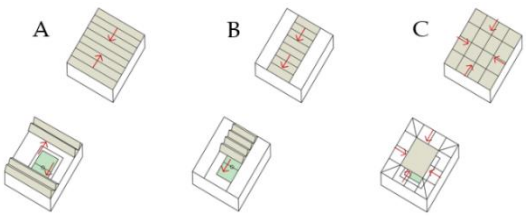

***Fig. 9**. A. Entire roof folding; B. Parts of the roof folding; C. Parts of the roof folding into one spot (centered).*

Retractable roof with expandable system enables the roof to expand and contract. This movement is applied in Iris Dome.

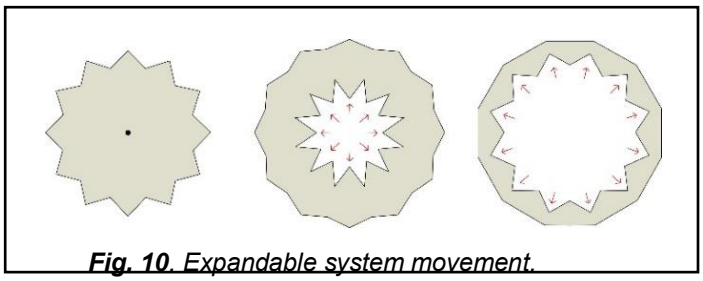

***Fig. 10**. Expandable system movement.*

Retractable roof could used combination of different systems. This movement is applied in Toronto “Skydome” in Canada (1989), its applied combination of sliding and rotating movement.

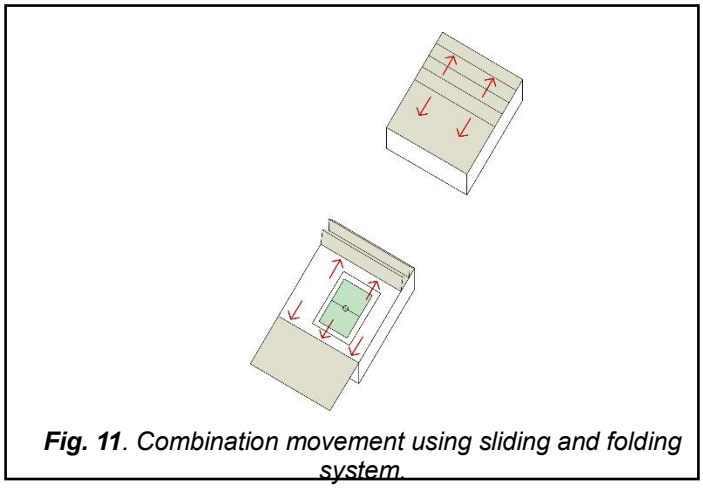

***Fig. 11**. Combination movement using sliding and folding system.*

3 RESEARCH METHODOLOGY

The methodology used in this research is qualitative method. According to Sugiyono (2014:9), qualitative research is a research based on philosophy of postpositivism, it is used to examine the natural conditions of object (opposite to experiment) where the researcher is the instrument key, data collection techniques are carried out in combination, data analysis tend to be inductive or qualitative, and the results emphasizes the meaning rather than generalization. This method used to analyze the dynamic element that are applied to the retractable roof on some football stadium. The method of data collection uses secondary data from literature studies and case studies. Secondary data is obtained through books or ebooks, journals, and websites. Literature studies are carried out by data collection about understanding and criteria of dynamic elements in architectural science and typology of football stadium retractable roof. Case study is by analyzing the application of dynamic elements on the retractable roof of the Singapore National Stadium, Toyota Stadium, and Commerzbank Arena. All of data regarding to retractable roof from each case study will be described in table and analyzed based on the criteria of dynamic elements. The analysis result from each football stadium will be compared and will conclude which football stadium that has the most dynamic retractable roof.

4 RESULTS AND DISCUSSION

The dynamic element on retractable roof case study is analyzed based on several factors, such as the condition of the roof (open or closed), the weather of each country, activities, roof form, roof structural design, and rectractable roof type of movement.

TABLE 1

DYNAMIC ELEMENT ANALYSIS WHEN RETRACTABLE ROOF OPEN

	Singapore National Stadium, Singapore	Toyota Stadium, Japan	Commerzbank Arena, Germany
Weather	Hot and rainy	Hot, rainy, and snow	Hot, rainy, and snow
Activities	Football, athletic, cricket, and concert.	Football, rugby, concert, and industrial events.	Football, concert, and business events.
Roof Form	**Dome** Fixed dome roof is formed from curved lines so that the roof has a **dynamic** shape.  The open roof exterior looks. Source: www.dezeen.com (4th April 2019)  The open roof interior looks. Source: www.dezeen.com (4th April 2019)	**Curve** The fixed curve roof is formed from several curved lines so that the roof has a **dynamic** shape.  The open roof exterior looks. Source: www.visitjapan2019.com (4th April 2019)  The open roof interior looks. Source: www.arcspace.com (4th April 2019)	**Membrane** The flat fixed roof does not apply slashes or curves so that the roof has a **non-dynamic** shape.  The open roof exterior looks. Source: www.pinterest.com (4th April 2019)  The open roof interior looks. Source: www.de.fiylo.com (4th April 2019)

TABLE2

DYNAMIC ELEMENT ANALYSIS WHEN RETRACTABLE ROOF CLOSED

	Space frame dome shaped	Space frame curve shaped	Membrane flat shaped
Structural Design	The space frame structure of moveable roof is dome and it is across the entire roof. This roof has **dynamic** properties.  Source: www.arup.com (4th April 2019)	The curved movable roof using membrane structure and follows the curvature of the fixed roof structure. This roof has **dynamic** properties.  Source: www.stadiumDB.com (4th April 2019)	Flat-shaped movable roof using cable structure and follows the shape of a fixed roof. This roof **does not have dynamic** properties.  Source: www.vision4venue.com (4th April 2019)

Based on the comparison results of retractable roof when the position is open, it is concluded that Singapore National Stadium in Singapore has the most dynamic roof. Singapore National Stadium applies dynamic elements into the form and structural design of fixed roof, although the Toyota Stadium also applies dynamic elements into the form and structure of fixed roof but the degree of curved on Singapore National Stadium fixed roof is bigger.

Based on the comparison results of retractable roof when

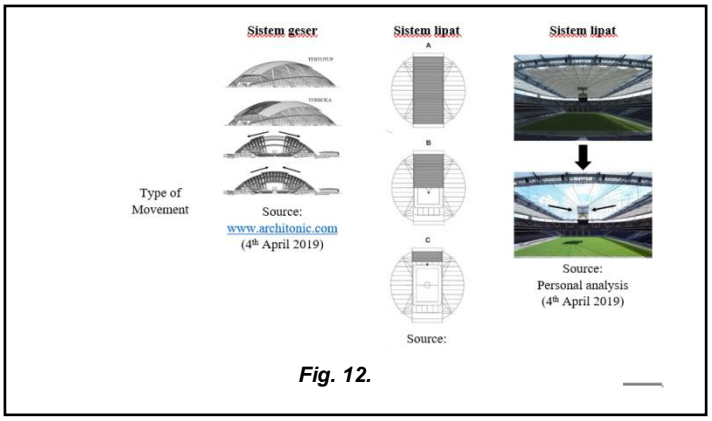

Fig. 12.

the position is closed, Singapore National Stadium roof has the most dynamic moveable roof. The movable roof of Singapore National Stadium has a same form and structural design as the fixed roof, so it has the same curvature with the fixed roof and it is bigger than the degree of the curved of Toyota Stadium fixed roof and moveable roof.

5 CONCLUSIONS

The retractable roof of football stadium can be affected by various factors. Based on the comparison results, weather conditions, activities, the type of retractable roof movement on each case study does not have a big influence on the application of dynamic elements to retractable roof, while form and structural design of retractable roof have a big influence in manifest dynamic elements. Singapore National Stadium in Singapore has the most dynamic retractable roof because of the fixed and moveable roof has the same form which is dome and also the design of space frame structure has the biggest degree of curved compared to Toyota Stadium and Commerzbank Arena. Toyota Stadium has a dynamic retractable roof, but the curvature of the fixed and moveable roof is smaller than Singapore National Stadium, while the Commerzbank Arena only applies dynamic elements in structural design of fixed and moveable roof. So it can be concluded and sorted that the most dynamic retractable roof is Singapore National Stadium in Singapore, followed by Toyota Stadium in Japan and last one is Commerzbank Arena in Germany.

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