DAMAGE TO TEMPORARY CANOPY STRUCTURE BY WIND LOAD

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A report submitted in partial of the requirements
for the award of the degree of
B.ENG (HONS.) CIVIL ENGINEERING

FACULTY OF CIVIL ENGINEERING & EARTH RESOURCES
UNIVERSITI MALAYSIA PAHANG

JULY 2014

ABSTRACT

Numbers of incidents regarding the failure of the temporary structure were widely reported due to the windstorm in Malaysia. The incidents cause injuries and fatalities to people. The canopy structure is one of the temporary structures that widely used in Malaysian surroundings during the small occasion ceremony. Due to the lack of information, mitigation of this kind of hazard is tough to be mitigated. The most important parameter is the potential wind speed that can cause the failure to the canopy. Previous study conducted this structures can be classified as free standing canopy structures. However there are no specific studies conducted for common canopy used in Malaysia. Two common type of canopy structure were identified and analysis due to wind load. Type A is 3m x 3m and Type B is 6m x 6m. The canopy was imposed with two different major direction of wind load. From the result type A canopy will possibility fail at 11 m/s while type B at 13 m/s. Therefore this result information can be use to mitigate the risk of failure on canopy structures due to wind load.

ABSTRAK

Bilangan insiden mengenai kegagalan struktur sementara telah dilaporkan secara meluas disebabkan berpunca dari ribut angin di Malaysia. Kejadian menyebabkan kecederaan dan kematian kepada orang awam. Struktur kanopi adalah salah satu struktur sementara yang digunakan secara meluas dalam persekitaran Malaysia terutamanya dalam majlis-majlis kecil. Disebabkan kekurangan sumber maklumat, mitigasi seperti ini berbahaya dan adalah amat sukar untuk dikawal. Parameter yang paling penting adalah kelajuan angin yang berpotensi untuk menyebabkan kegagalan untuk kanopi. Kajian lepas yang telah dijalankan struktur ini boleh diklasifikasikan sebagai struktur kanopi berdiri bebas. Walau bagaimanapun tidak ada kajian khusus dijalankan untuk kanopi yang biasa digunakan di Malaysia. Dua jenis biasa struktur kanopi telah dikenal pasti dan analisis beban angin di jalankan. Jenis A adalah 3m x 3m dan Jenis B ialah 6m x 6m. Kanopi dikenakan dengan dua arah utama angin yang berbeza. Dari hasil analisis yang dijalankan kanopi A akan berkemungkinan gagal pada 11 m / s manakala jenis B pada 13 m / s. Oleh itu maklumat keputusan analisis ini boleh digunakan untuk mengurangkan risiko kegagalan pada struktur kanopi kerana beban angin.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

The wind behavior was certainly affected by the position and topography of the country on the earth. In designing the temporary structure, the consideration of atmospheric wind plays an important role so it can resist the lateral force exerted on it. Temporary structure comprises a wide range of structure including temporary open canopy. Full scale surveys about the uses of this open temporary canopy in Malaysia have been made and it is shown that this non-engineered structure was widely used in this country for any event or used for specific purposed. But sometimes, the uses of this temporary canopy structure were limited by the wind factor especially during rain and thunderstorm

Malaysia was positioned near the equator. The wind behavior was fully dominated by two monsoon season and inter-monsoon thunderstorm. Awareness among Malaysian about the wind hazard due to monsoon thunderstorm still lacking although it just a localized phenomena. This monsoon situation produce strong and gusty surface wind distribution on wind flow that exerted on the temporary open canopy. Basically, thunderstorm occur in Malaysia were in small scale or specifically in micro scale, (Yusof , 2005) and it takes short duration within 15 to 30 minutes. This strong and gusty wind distribution may cause an overturning pressure to the temporary open canopy structure and hence will cause uplift to the canopy and become hazardous to the people surrounding.

Due to high risk of strong wind distribution exerted on the open temporary canopy, a precaution step of calculation to determine the allowable speed limit or velocity of wind distribution must be carried out at different location with different type of terrain. Therefore, with this result obtain from modeling conducted during this research, it will give a safety guideline to the canopy user and hence reduce the potential failure of the canopy cause by wind load.

1.1 PROBLEM S STATEMENT

The uses of temporary structure especially for open canopy structure were widely used in Malaysia. Failure regarding this non-engineered structured reported widely in our country since past 5 years. The mechanism that contributed to this failure was cumulative overturning moment and sliding force due to uneven strong wind distribution exerted on the canopy structure during the thunderstorm or mostly can be seen during monsoon season. Even the open canopy structure is anchored at one point to resist racking or sliding, but it will experience the lateral force from the wind and hence cause the canopy to rotate or overturn.

1.2 OBJECTIVES

I. To analyze the wind speed distribution that exerted on temporary canopy structure that cause overturning and sliding.

II. To identify the maximum wind speed that can resists by open temporary canopy structure from experience failure.

1.3 SCOPE OF STUDY

The study was conducted based on the wind speed distribution on the canopy structure. Various selected wind speed data were collected to carry out the simulation on the several type of parameter of open canopy structure. The simulation was running based on wind pressure distribution. The parameter of the canopy were measured based on the size and weight of the canopy. In this study, two type of canopy were used with dimension of 3 x 3 m and 6 x 6 m. With the present of this data, the simulation can be carried out using the structural software SAP2000. Reaction at the joint of the canopy can be determined from this simulation and the manual calculation to determine the overturning moment and sliding force can be obtained, hence safety guideline can be purposed in order to reduce the failure of open canopy in the future.

1.4 SIGNIFICANT OF STUDY

This study will give more understanding about the analysis of wind speed distribution to temporary open canopy structure that have related with cumulative overturning moment and sliding force exerted on temporary open canopy structure. When open canopy structures are placed in open space, the wind loads are imposed on the surface of roof canopy structure and the important parameter in designing the temporary open canopy structure was about their stability against cumulative overturning moment and sliding force must be taken into account. From this case of study, proper guidance or knowledge regarding wind load can be provided to user so that the number of failure can be minimized.

CHAPTER 2

LITERATURE REVIEW

2.0 WIND DISASTER

The destroyed of the permanent structure or temporary structure caused by the wind action were commonly occurred in many designs since the atmospheric wind play an important role in designing the structure. In designing the open structure that exposed to this atmospheric wind pressure, most of the engineer used their knowledge based on the code of practice that relate to the wind which gives the aerodynamics shape of the structure that allow the movement of air around the structure.

The safety parameters of the structure to resists all of the critical wind load are very important in order to avoid failure to the structure. An example of wind tunnel experiment were sometimes carry out to determine the limit value of wind load exerted on the structure to know the exact value of wind load parameter to prevent the failure. It became one of the important requirements for the most of the engineer nowadays who are attached to any project regarding the designation of the building structure to follow the wind design code which are the initial step to estimate the wind design load. Most of the wind code follow by the most engineer were different based on their topography. It can be simplified explained by the wind code used by the engineer in designing the building for different country. Obviously every country gives a different parameter value of wind load due to its different topography or surface roughness of the earth. This kind of situation makes sense about the different used of wind code for each country. Simple example can be seen clearly for the wind code used in Malaysia, which is Malaysian Standard on Code of Practice On Wind Loading For Building Structure (MS 1553:2002) were different from the British Standard-Loading for Building : Code of Practice for Wind Load (BS 6399-2:1997). Specific input of wind loading with the using of specific wind code are required to make sure the initial design will give the accurate result during the design submission process then.

According to T.A. Majid et al. (2010) in their Malaysia Country Report states that the occurrence of the wind hazard regarding the failure of the structure of the buildings was due to the windstorm. The design of the buildings at early stage plays a major role in the contribution of the failure occurred caused by the lack consideration of the wind loading exerted on the structure whether it was a high-raised or low-raised building. The occurrence of the thunderstorm event occurred in Malaysia country was just not only focused on the failure of the permanent structure, but most of the temporary structure such as open canopy was also reported widely. In conclusion, most of the failure occurs regarding the failure of the structure due to wind loading was caused by the less consideration of the wind loading at early of design stage (Majid et.al , 2010).

2.1 WIND UPLIFT

The definition of the wind uplift can be well defined as the upward force exerted on structure as the result of the movement of wind around the structure. The wind uplift action plays a major role that must have to consider since the most of the failure on the structure were caused by the excess of this wind uplift action. Wind uplift usually occurred at a roof part of the structure and this situation make one of the important interest to consider for every manufacturer roof product to design properly in term of life safety that compatible with the wind uplift condition. The structure is said to be in the wind uplift condition when it is experience a higher pressure of the wind below the roof rather than the top of it. Usually the wind uplift pressure plays it roles on the side of the building structure and results the movement of the air to move upward since the blowing of air hit accurately to the structure of the building. It can be occurred in many unexpected ways since this wind uplift situation were involve the major pressure from the wind and most of the time the increasing of pressure inside the building could be the larger possibility contribution of the lifting of the roof and the decreasing the pressure above the roof may be the one of the contribution since it exceed the limit of the designation system of the wind resistance.

Wind force was the larger contribution factor of the roof failure and it's frequently occurred to metal roof with a low-sloped roof assembly even to new structurally design roof. (Baskaran et.al, 2012). Apparently, to determine the parameter of the wind force, the experiments using the wind tunnel are commonly used on various type of the structure. Models of the structure are put in the wind tunnel and the specific wind specific are set until the model are experience the failure due to wind loading from the wind blow. For the specific purposed, all the factor that relate to the roof condition must be consider in order to determine the cause of the wind uplift occurrence phenomena on roof part. The mechanism of the 'suction' forces are commonly inter-relate with the uplift force since the increasing of pressure inside the building through the opening part of the structure is something that must take into account.

2.2 TEMPORARY STRUCTURE

Temporary structure is one of the most popular equipment that commonly used by people all over the world. This temporary structure could be a temporary open canopy structure, temporary grandstand, concert or maybe a theatrical stage and many others. But the limitation using this type of equipment always became a problem when it comes to the engineering value specifically when it regarding the wind loading exerted on it. There was no specific wind code that complies with all this kind of temporary structure since they were follows roughly the code that being used for the permanent building for the wind loading. These situations contribute difficulties to manufacturer to estimate the accurate level of wind loading of the temporary structure that can withstand from the failure to occur. From the point of view engineer, the structures have ability to resist the hurricane wind loading and used for a short period, it classified as temporary structure. (William, B.G et.al , 2009).

The uses of temporary structure are widely used in many fields just not only focusing on specific purposed but it can be one of the equipment that can satisfy the entire multipurpose task. The definition of temporary structure can be defined widely in all aspects based on their uses. It is a certainty for the temporary structure to use in a short period rather than in a long time and most of the temporary structure use the same mechanism that is they are relocated and dismantled. Because of their wellness in their capabilities in relocated and dismantled, they are preferable in choices between the permanents structure since they does not need any foundation and all the part of the temporary structure were quickly available to be made. The designation of the temporary structure by the engineer must satisfy the definition of the wind load although it is just used for a day or two. The process of the design of the canopy must fulfill the requirement of safety and they just not only govern about the safety they also must consider the benefit that they will get about the price.

The perspective uses of temporary structure was just not focusing on the point of view of engineer, but it also involve with the local authority or more specifically to local Planning Department who are in charge with the progress of design of the building. The existence of the non-permanent structure will not require planning permission as long as the existence of the structure wills not more than 28 days. The monitoring procedure about the safety of the temporary structure must be frequently check in order to make sure the people surrounding are safe and the safety precaution can be taken during or before the failure occur. The temporary structure is more preferable than permanent structure because of their cost of the maintenances since the material used were cheaper than the permanents structure.

2.3 OVERTURNING MECHANISM

Most of the structures in the world were experience a wind load since they were clearly exposed to the blow of air surrounding. This kind of situation gives a lateral force from the wind that must be considered early in their design. We have seen many event of failure regarding the temporary structure for example in Temerloh, Pahang on 12 August 2010 that involve the temporary canopy structure at night market. For the construction of any permanents building, the design of the building by the structural engineer must required something that very effective that can resist lateral force from the wind. An accurate calculation for the design of wind or seismic force was needed and it was very important. So, the engineer must be creative in the early designation part so that the lateral force can be resists effectively in accurate expected area of the temporary structure.

In the Journal of Architectural Engineering, Wind Loads for Temporary Structures: Making the Case for Industry wide Standard by Bryan, D.W, et.al stated that the visualization of the lateral force specifically in term of wind or seismic force were clearly can be seen when it exerted on the diaphragm of the structure. When the lateral force exerted on the body of the structure, it produce the shear from the sheathing then it will obviously transfer from the top to the bottom of their own wall which is the wall were anchored permanently to resists the impact of the wind force or more specifically the lateral force of wind. This lateral force of the wind involve the mechanism of compression and tension force since the structure experience the press down and lift up during this situation. The design of the temporary structure member plays one important role in the early design since every member has their own function or capabilities to withstand the compression occur caused by the overturning and the natural mother earth gravity force. Based on the International Building Code (IBC), section 2305.37, to prevent the structure from experiencing the uplift force due to the overturning mechanism, the dead load of the structure was not enough to stand alone resisting the overturning, the anchoring device was one of the most preferable alternative to prevent this problem. The anchoring device was clearly acting as an important medium that maintain the continuous transfer of the load to the foundation.

The proper fundamental knowledge in designing a good resisting temporary structure was required in order to avoid any unintentionally errors that can spoil the perfection of the design. Most of the failure in temporary structure was caused by the miscalculation of the overturning and resisting moment due to inaccurate moment arm. Most of the member frame of the temporary structure acts as the medium for the moment to resists and estimates the actual perimeter of overturning forces as it can be seen clearly it uses were very important in term of lengthened arm moment dimension. Measurement of the resisting moment arm in order to get accurate perimeter of tension and compression force are required since the measurement should be started from the center to center of both compression and tension force. The perimeter value of the arm were varying depend on the temporary structure type. This entire factor plays the major factor in the consideration of proper design and construction which can lead to the larger contribution of structural damage or even worse impact to the community.(Structure Magazine, November 2009).

2.4 INTERGRATED SOLUTION FOR STRUCTURAL ANALYSIS & DESIGN (SAP2000 SOFTWARE)

The SAP2000 software is the most common famous software that usually used among the engineer to carry out any simulation regarding the structural behavior of the building. The introduction of SAP2000 software over 30 years ago gives a fully pleasure for those who are really needed to carry out the analysis on the structure since it's method for analysis were very sophisticated and follow the traditional method which comprises latest analysis and design tools which fulfill many construction or the design process of any facilities.

The analysis method of the SAP2000 software was fully based on the 3D modeling object which the model generate through the environment graphical modeling. But the SAP2000 software was just not only focusing on the 3D modeling but it is also compatible with the 2D system model analysis. It was also gives high preferable choices between the designs and it cannot be argued since it was one of the most powerful design and analysis tools admitted by the most engineers since this software have been used before. In other words, SAP2000 turn out most of other software developer to challenge their capability to improve their product which can gives a higher beneficial advantage to their user. One of the important aspects that the developer of the SAP2000 take into their account were they take the initiative for their user of this tools that allow them to produce any model without any destruction long learning to produce the model. So they can generate or build the model rapidly without taking any longer time. It can be say that, the SAP2000 software were ready to generate any model even the complex model since the developers have prepared many example of the model and the user just only can used or modified or even generate their model by their own. The generation of the model also just not limit in term of the structural aspects but it were also have been prepared with others code of design such the wind or seismic loading with various type of the structural design following the compatible mood of the design.

Analytical technique that provided in this software tools allow them to understand more specifically the used of this software since its manual or guidance were step-by-step system. They were many analysis method provided in this SAP2000 tools for the uses of the engineer such as deformation analysis, buckling analysis, and many others which gives a full privileges for the software user to carry out the analysis in anytime without the limitation. With the present of this useful software tools, the estimation of failure to structure regarding to any behavior or properties can be early detected so that there will no problem arise during the construction phase.

In other words, SAP2000 was one of the most powerful software solution tools for the design and analysis of the structure since it gives more option about the design and analysis from a simple structure design analysis to more complex dynamic analysis and it can be said that it was a user friendly solution tools for the design and analysis software. Advanced analytical techniques allow for step-by-step large deformation analysis, Eigen and Ritz analyses based on stiffness of nonlinear cases, catenary cable analysis, material nonlinear analysis with fiber hinges, multi-layered nonlinear shell element, buckling analysis, progressive collapse analysis, energy methods for drift control, velocity-dependent dampers, base isolators, support plasticity and nonlinear segmental construction analysis. Nonlinear analyses can be static and/or time history, with options for FNA nonlinear time history dynamic analysis and direct integration.

From its 3D object based graphical modeling environment to the wide variety of analysis and design options completely integrated across one powerful user interface, SAP2000 has proven to be the most integrated, productive and practical general purpose structural program on the market today. This intuitive interface allows you to create structural models rapidly and intuitively without long learning curve delays. Now you can harness the power of SAP2000 for all of your analysis and design tasks, including small day-to-day problems. Complex Models can be generated and meshed with powerful built in templates. Integrated design code features can automatically generate wind, wave, bridge, and seismic loads with comprehensive automatic steel and concrete design code checks per US, Canadian and international design standards.

CHAPTER 3

RESEARCH METHODOLOGY

3.0 INTRODUCTION

This chapter will briefly explain about the important facts regarding the approach used to conduct this thesis. The analysis process of the open temporary canopy structure have been carried out using Integrated Solution for Structural Analysis & Design software (SAP2000) to measure the parameter of the lateral wind loading or in simply word the wind speed that can contribute to the overturning mechanism that the major cause of the failure to canopy. For the entire process of the thesis, flowchart will be used to explain from the beginning of the project till the end.

3.1 SEQUENCE OF RESEARCH METHODOLOGY

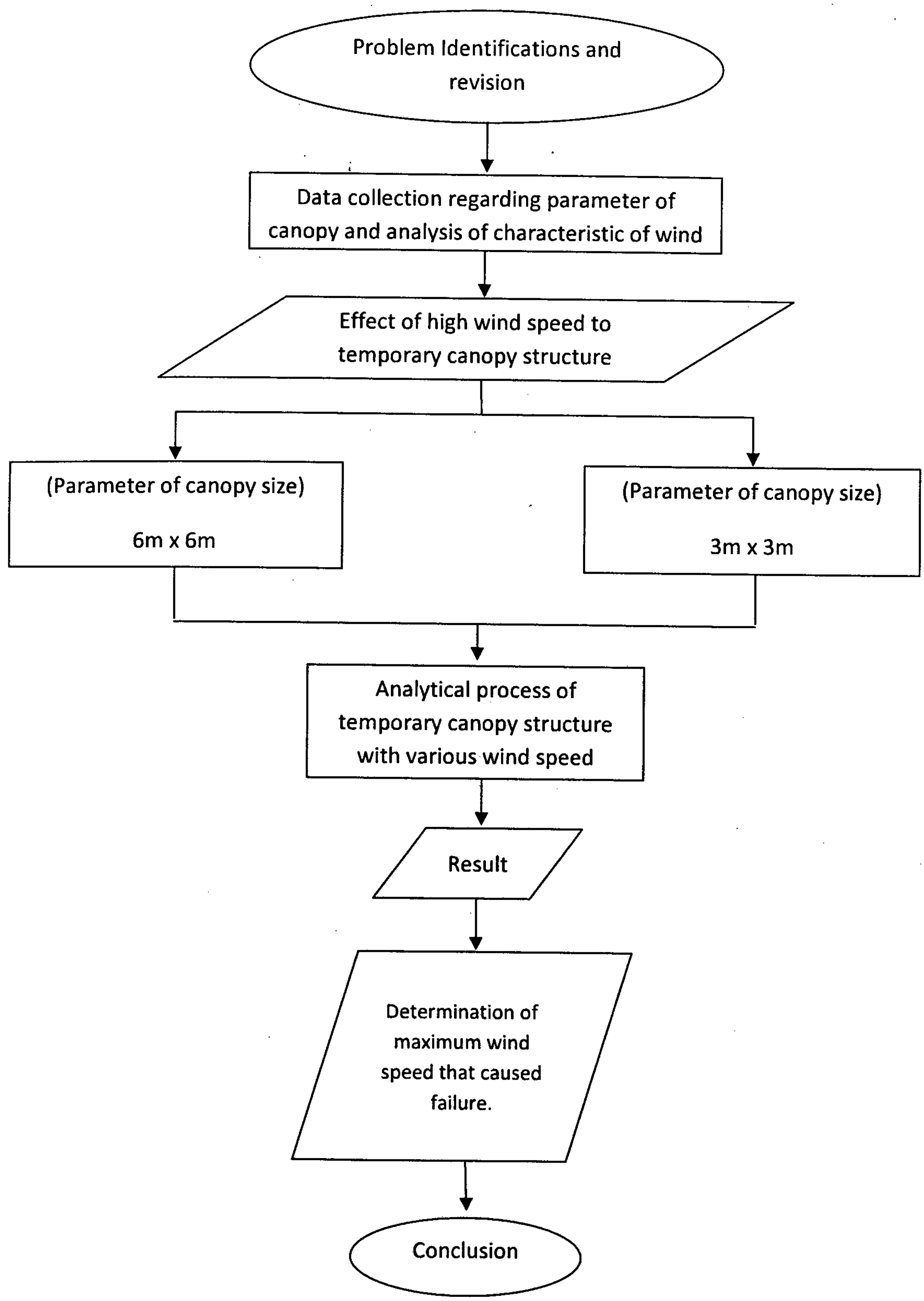

Figure 3.0 : Methodology sequence of the study

3.1.1 Problem Identification and Revision

The purposed of this phase is to identify the problem arise due to design of the temporary open canopy structure specifically on the wind loading. Method of analysis of these open canopy structure were using simplified method. The lack using of this simplified method were they not fully give indication about the design information and for engineers, this situation limit their abilities to carry out the analysis regarding to their structure.

3.1.2 Data Collection Regarding Parameter of Canopy and Analysis of Characteristic of Wind

Data collection of the canopy's parameter were carried out in order to indentify which most suitable sizing of canopy will be used for simulation in SAP2000 software.. Several sizing of the canopy were recorded as a reference. The characteristic of the wind behavior including uplift load, shear load and lateral load were also collected in order to carry out the analysis on the selected temporary open canopy structure.

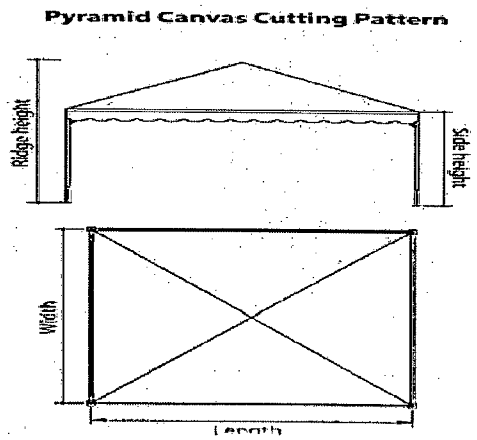

Figure 3.1 : Overall outline dimension of Temporary Canopy Structure