ANALYSIS OF THE WIND EFF. NING) STRUCTURE IN MALAYSIA

NUR'ATIKAH BT AB RAHMAN

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ABSTRACT

Recently numbers of the damage and injuries due to wind hazard on the patio cover structure increases in Malaysia. Patio cover is defined any overhead covering constructed in an elevated position over a patio or deck with the intent to provide shade or rain coverage for the patio area. In Malaysia, this structure is constructed using steel structure and commonly notified as awning. Most of the awning structures are not well design. Therefore, the study are conduct to indicate the possibly of failure due to wind load. The typical type of patio cover used in Malaysia had been discovered as model 1, model 2 and model 3. The analysis carried out covering various loading and geometry configuration. The values that choose from the design that commonly used in Malaysia. From the result, it shows that the awning structure will fail at wind speed 11m/s for a few awning structures. It can be conclude that any structure needs to design properly to withstand from wind storm.

ABSTRAK

Kebelakangan ini bilangan kerosakan dan kecederaan akibat angin bahaya kepada struktur perlindungan teras meningkat di Malaysia. Penutup teres ditakrifkan mana-mana meliputi dibina dalam kedudukan yang tinggi lebih teras atau dek dengan niat untuk memberi bayangan atau hujan liputan bagi kawasan teres. Di Malaysia, struktur ini dibina dengan menggunakan struktur keluli dan sering diberitahu sebaik awning. Kebanyakan struktur awning tidak reka bentuk juga. Oleh itu, kajian ini adalah untuk menunjukkan tingkah laku yang mungkin disebabkan oleh kegagalan untuk menggulung beban. Jenis-jenis biasa perlindungan teras yang digunakan di Malaysia telah ditemui sebagai model 1, model 2 dan model 3. Kajian yang dijalankan meliputi pelbagai loading dan konfigurasi geometri. The nilai-nilai yang memilih daripada reka bentuk yang yang biasa digunakan dalam Malaysia. Dari hasil yang, ia menunjukkan bahawa struktur awning akan gagal pada kelajuan angin 11m / s untuk a struktur-struktur awning beberapa. Ia boleh membuat kesimpulan bahawa mana-mana struktur memerlukan untuk mereka bentuk dengan betul untuk menahan dari ribut angin.

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LIST OF SYMBOLS

qh	Design velocity (uplift) pressure at a specific height above grade
V	Basic wind speed
Kh	Velocity pressure coefficient
Kzt	Topographic factor
Kd	Wind directionality factor
I	Importance factor
$p(t)$	Instantaneous pressure
ρ	Air density
$V(t)$	Instantaneous magnitudes of wind speed
$q(t)$	Velocity pressure
$Cp(\theta(t))$	Mean pressure coefficient for the instantaneous wind direction $\theta(t)$.
$\hat{p}$	Peak pressure
$\hat{V}$	Peak wind speed
$\hat{C}_p$	Peak pressure coefficient.
p_{air}	Density of air
C_{fig}	Aerodynamic shape factor
C_{dyn}	Dynamic response factor

CHAPTER 1

INTRODUCTION

1.0 BACKGROUND OF STUDY

Wind engineering analyzes outcomes of wind in the natural and the built environment and studies the potential damage, nuisance or benefits of wind. In the field of structural engineering it includes strong winds, which may cause inconvenience and also ultimate winds, which may cause extensive devastation. Recent years, the number of damage and injury caused wind hazard. However, awareness of the wind hazard is still lacking among people in Malaysia.

Patio cover can be defined as any overhead covering constructed in an elevated position over a patio or deck with the intent to provide shade or rain coverage for the patio area. Patio covers are either attached to an existing structure or constructed as a free-standing structure. There are some of the types of patio cover such as commonly used such as arbor, sun shade, patio roofing and patio awning. While patio awning has two types which is fixed patio awning and retractable patio awnings. Patio covers are completely independent group of the structure which cannot be interpreted as a subsection of canopies or eaves. Applied design pressure may be simply inadequate. It is mostly light and vulnerable to wind-induced loads which required strict design and considering the safety and economical during construction.

This study is part of research that was conducted to investigate wind speed that can causes failure to patio cover (awning) structures in Malaysia and the wind load effect on that structure. The study includes the description and the results of finite element analysis conducted on patio cover using SAP2000 software .The analysis carried out covering various loading and geometry configuration. The values that choose from the design that commonly used in Malaysia. For this project, the title is Analysis of the Wind Effect on the Patio Cover Structure, it required to know and do an analysis using Finite Element Method by using SAP2000 software. Overall this project involved analyzing the patio cover, wind speed and wind load.

1.1 PROBLEM STATEMENT

Recently numbers of the damage and injuries due to wind hazard on the patio cover structure increases in Malaysia. However, there is no proper estimation of wind speed that can cause failure for patio cover structure because of the less of awareness about this matter in Malaysia. In construction field, analysis of structure is one of the important element should be considered before the process can be proceed to the next level. It is important engineers know the deflection, stress and strain for the structure before design it. The available wind provision includes insufficient information regarding design load for such structural components. Applied design pressure may thus be over conservative or simply inadequate.

1.2 OBJECTIVE

The main objectives of this study are:

1. To analysis wind load effect on patio cover (awning) structure.
2. To determine wind speed that can causes failure to patio cover (awning) structures in Malaysia

1.3 SCOPE OF WORK

The scope works of this research are:

1. Analysis the design of patio covers structure using SAP 2000.
2. Determining the relationship of wind speed and the ratio of the patio cover is taken into consideration along with the size (width) of the patio.
3. Show how wind load, wind uplift and moment will affect the structure.

CHAPTER 2

LITERATURE REVIEW

2.1 WIND

Wind is a phenomenon of great complexity because of the many flow situations arising from the interaction of wind with structures. Wind discomposed of a multitude of eddies of varying sizes a rotational characteristic carried along in a general stream of air moving relative to the earth's surface. These eddies give wind its gusty or turbulent character. The gustiness of strong winds in the lower levels of the atmosphere largely arises from interaction with surface features. The average wind speed over a time period of the order of ten minutes or more tends to increase with height, while the gustiness tends to decrease with height (Mendis.et.al, 2007).

2.2 WIND ENGINEERING

The definition of Wind Engineering provided by Cermak in 1975, "Wind engineering is best defined as the rational treatment of interactions between wind in the atmospheric boundary layer and man and his works on the surface of Earth." Approved by the IAWE General Assembly on July 5, 2007- Cairns, Australia

What is certain is that the study of the actions and effects of wind on built-up and natural environment is today, in the engineering panorama, one of the most relevant and pressing lines of research because of the importance and variety of the scientific, technological and technical problems it concerns. Drawing its principles from several disciplines like physics of the atmosphere and fluid mechanics, meteorology and micro-meteorology, urban planning, architecture and bioclimatic studies, aerodynamics and aeronautics, civil, environmental, energy and mechanical engineering, physiology and psychology, wind engineering develops autonomous concepts and methods which are applied in all sorts of contexts (Augusti and Solari,1998).

It deals with forecasting and mitigating damage caused by storms, which alone are responsible for over 80% of the human casualties and economic losses that the world suffers from natural events, with the representation and measure of the wind and its related meteorological phenomena, the forecasting of weather and climatology, the aerodynamics of constructions and vehicles, wind tunnel experiments, the computer simulation of the flow fields and of actions of wind on bluff bodies, the wind behaviour of all constructions, in particular towers, skyscrapers, bridges, large roofs and all structures whose safety depend on wind, the diffusion of atmospheric pollutants, the quality of air and environmental protection, the use of wind energy and the choice of sites for wind turbines, the land planning in terms of wind problems (Augusti, Solari,1998).

2.3 WIND HAZARD

Most of possibility risk of wind hazard base on recent wind-induced damage to buildings and structures in Malaysia is due to thunderstorm. There are very little emphasizes of design building structure such as roof and cladding to minimize wind induced damage to buildings. Several study had made by previous researchers in Malaysia. From the study made there are several factors are founded to contribute damage to building component. It can be conclude most of the failures cause by lack of the consideration due to wind effect during design stage (Majid.et.al. 2010).

Most probably every year some part of Malaysia will expected of damages caused by the windstorm. The damages will effect either to properties (roof blown off and vehicle destroyed), environment (uprooted tree) and human (people killed and injured). The losses caused by a typical damage value reach from thousand to a million ringgit. The impacts of windstorm also could create social problem such as trauma and homeless to the windstorm victims (Bachok.et.al. 2012).

In general, Malaysian has a good awareness on this disaster. More than 90 % of the respondents agreed the windstorm were among the types of natural disasters that were capable of bringing destruction and should be concerned. Report through newspaper, television, radio and internet about the windstorm damage and proactive step that had been taken by Malaysia Meteorological Department (MMD) by published a detail about windstorm through the department website are believed as the factors that contribute to the increase of windstorm awareness among Malaysian (Bachok.et.al. 2012).

2.4 WIND LOAD

Usually Wind loads on buildings are evaluated using codes and standards whose specifications are generally based on wind-tunnel tests performed on isolated structures and do not take into account interference effects using codes and standards whose specifications are generally based on wind-tunnel tests performed on isolated structures and do not take into account interference effects. As pointed out by Krishna (1995), the knowledge of the mean pressure alone is not adequate to ensure the safety of the building and it is necessary to know the fluctuations and the peak values as well, particularly when severe winds are concerned and where the dynamic response becomes important(Saadae.et al.2002).

Regardless of the type of construction, buildings are subjected to two basic types of loads under high winds. Uplift loads result from air flowing over the roof, causing a suction force. Lateral loads result from wind blowing on the windward wall, as well as wind blowing past the leeward wall. These two lateral forces act in the same direction and combine to create a force that tries to push the building over or slide it in the direction of the wind. Lateral loads can also result from wind blowing on a steep pitched roof (Shackelford and Pryor, 2007).

Shear force must be transferred from the top of the wall to the bottom. It is resisted by nailing panels at their edges to the wall framing (reduced nailing at the panel interior is also provided to resist panel buckling and wind suction loads). By varying the nailing and panel thickness, different levels of shear resistance can be achieved. The amount of shear in each panel depends on the wind speed, exposure, building height (and size in the perpendicular direction), and the amount of sheathing on the shear wall. The more sheathing on the wall, the less each panel has to work. Since current plans often require many openings in the walls, there is less and less sheathing to act as shear walls, so each panel tends to have to resist more force (Shackelford. and Pryor,2007).

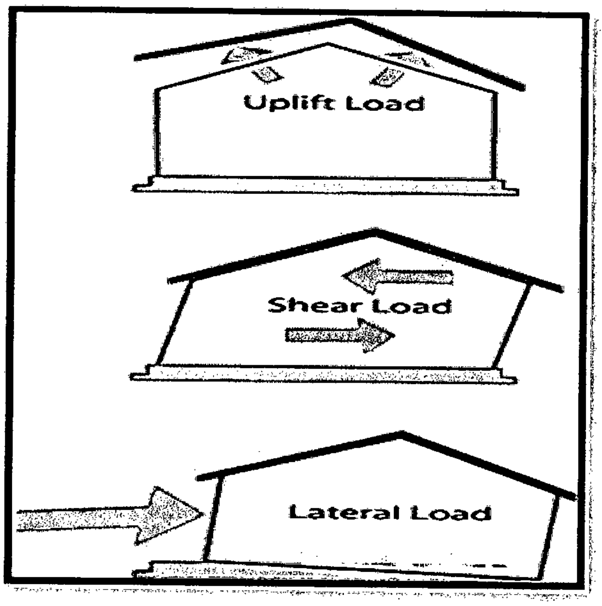

Figure 2.1: Different types of wind load on structures building.

2.5 WIND PRESSURE

According to Ginger and Holmes, 2003, the pressure at i, pi (t) described in terms of the mean pressure averaged over time $t\,\overline{P}_i$, and the fluctuating component $p'i(t)$ is given in Eq. (1). The peak (i.e. maximum and minimum) pressure at i, $\widehat{P}_i$, $\check{P}_i$ can be given by Eq. (2), where gpi is the pressure peak factor and σpi is the standard deviation of pressure fluctuations:

Equation (1)

$$p_i(t) = \bar{p}_i + p'_i(t),$$

Equation (2)

$$\hat{p}_i, \check{p} = \bar{p}_i \pm g_{p_i} \sigma_{p_i}.$$

The correlation coefficient between the pressure at *i* and the pressure at *j* is

Equation (3)

$$r_{p_i p_j} = \overline{p_i'(t) p_j'(t)} / (\sigma_{p_i} \sigma_{p_j}).$$

Peak wind load effects on the tributary consisting of *N* panels are calculated using the "covariance integration" method given in Eq. (4).

Equation (4)

$$\hat{x}, \check{x} = \bar{x} \pm g_x \sigma_x = \sum_{i=1}^{N} \beta_i \bar{P}_i \pm g_x \left[\sum_{i=1}^{N} \sum_{j=1}^{N} \beta_i \beta_j \overline{P_i'(t) P_j'(t)} \right]^{1/2} = \sum_{i=1}^{N} \beta_i \bar{p}_i A_i \pm g_x \left[\sum_{i=1}^{N} \sum_{j=1}^{N} \beta_i \beta_j r_{p_i p_j} \sigma_{p_i} \sigma_{p_j} A_i A_j \right]^{1/2}.$$

Here, βi are the influence coefficients, gx is the peak factor and σx is the standard deviation of the structural load effect, x. The force acting on panel i of area Ai is, $Pi(t)=pi(t)Ai$, and the peak factor for the load effect, gx is estimated using

$$g_x = [\textstyle\sum_{i=1}^{N} \sum_{j=1}^{N} \beta_i \beta_j g_{p_i} g_{p_j} \overline{P_i'(t) P_j'(t)}]^{1/2} / \sigma_x,$$

where:

$g_{p_i}^{+} = (\hat{p}_i - \bar{p}_i) / \sigma_{p_i}$ is used when βi is positive

$g_{p_i}^{-} = (\bar{p}_i - \check{p}_i) / \sigma_{p_i}$ is used when βi is negative, respectively, for the pressure peak factors *gpi*. Effective static wind load distributions for selected load effects are derived using the "load–response correlation" method in Eq. (5), which gives the load on panel *j*, *Pj* causing the peak value of load effect $\hat{x}$, $\breve{x}$:

Equation (5)

$$(P_j)_{\hat{x}} = \overline{P}_j \pm g_x r_{P_j x} \sigma_{P_j}.$$

Here, *rPjx* is the correlation coefficient between the wind load fluctuations at *j* and the load effect *x*, which is dependent on the influence line for the load effect under consideration, and is given by Eq. (6).

Equation (6)

$$r_{P_j x} = \sum_{i=1}^{N} \overline{P_i'(t) P_j'(t)} \beta_i \,/\, (\sigma_{P_j} \sigma_x).$$

According to Mendis.et al, 2007, the characteristics of wind pressures on a structure are a function of the characteristics of the approaching wind, the geometry of the structure under consideration, and the geometry and proximity of the structures upwind. The pressures are not steady, but highly fluctuating, partly as a result of the gustiness of the wind, but also because of local vortex shedding at the edges of the structures themselves. The fluctuating pressures can result in fatigue damage to structures, and in dynamic excitation, if the structure happens to be dynamically wind sensitive. The pressures are also not uniformly distributed over the surface of the structure, but vary with position.

2.6 WIND UPLIFT

According to Graham, 2009, design wind-uplift pressures on roof systems are determined based on a number of considerations, including a specific building's mean roof height and basic wind speed. The fundamental equation for determining the design wind pressure in the field of a low-slope roof area is qh = 0.00256 (Kh) (Kzt) (Kd) (V2) (I).The variable qh represents the calculated design velocity (uplift) pressure at a specific height above grade, which is designated in pounds per square foot (psf). V is the basic wind speed designated in miles per hour. Kh is a velocity pressure coefficient; Kzt is a topographic factor; Kd is a wind directionality factor; and I is an importance factor.

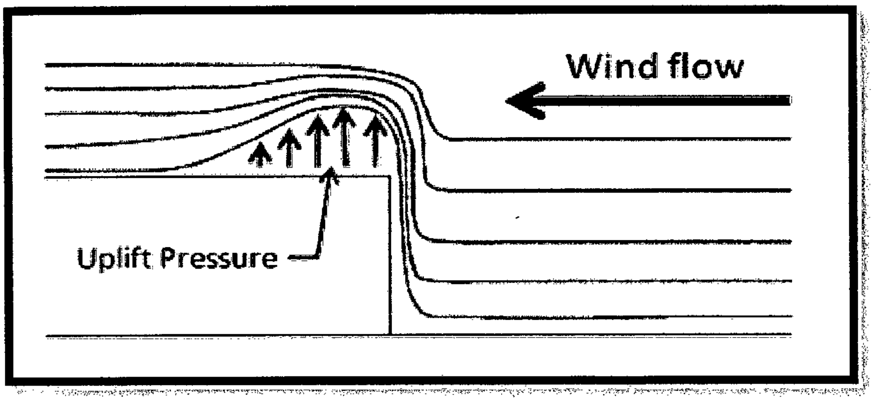

Figure 2.2: The wind flow on structure

2.7 WIND SPEED

There are needs of revised basic wind speed in MS 1553:2002. Malaysia is dividing in to part which the main wind force resisting system shall not be less than 0.65 kN/m2 which is shown from the value 32.5 m/s base on 3 second gust and nears the seaside the code suggested wind speed at 33.5 m/s (Majid.et.al. 2010).

(Uematsu and Isyumov, 1999).In the quasi-steady approach, the pressures on a building respond to atmospheric turbulence directly, as if they were changes in mean wind speed and direction. Thus, pressure variations correspond exactly to wind fluctuations. The instantaneous pressure, *p*(*t*), may be given by the following equation:

$$p(t) = q(t) \cdot C_p(\theta(t)) = \tfrac{1}{2}\rho V^2(t) \cdot C_p(\theta(t)),$$

where ρ=air density; $V(t)$ and $q(t)$ stand for the instantaneous magnitudes of wind speed and velocity pressure, respectively; and $Cp(\theta(t))$ is the mean pressure coefficient for the instantaneous wind direction $\theta(t)$. Assuming that the peak pressure $\hat{p}$ occurs in accordance with the peak wind speed $\hat{V}$ and that the change in wind direction is small, the peak pressure coefficient $\hat{C}_P$.

2.8 TEMPORARY STRUCTURE

Faulty design of temporary structures is not necessarily the fault of the design engineer, the lack of a worldwide standard for designing temporary structures doesn't help. The industry standards today do not give the design engineer enough information to determine loads and other considerations concerning the design without the engineer having to use their best engineering "judgment"(Kleinosky, 2012).

Temporary structures encompass a wide range of items such as concert and theatrical stages, tents, public art projects, temporary roofs and shade structures, lighting and speaker towers, temporary grandstands and bleachers, and many other facilities. Some building codes require temporary structures to comply with the wind-load guidelines applied to permanent buildings, and others leave this to the discretion of the building official. Accordingly, engineers are designing temporary structures to be strong enough to withstand once-a-century hurricanes when in fact these structures will be used for only a short period—sometimes just a day or two. If a hurricane were approaching, though, you would not erect a temporary structure, nor would you have it sheltering people during a heavy storm. In fact, strong winds would likely keep people away from the event altogether and may well prompt event owners to cancel or postpone the event. In any case, the most these structures are likely to face is a thunderstorm, but absent other guidelines, the building codes apparently require us to design for a hurricane, which needlessly drives up costs without increasing safety (Gorlin, 2009).

2.9 PATIO COVER

Patio covers are relatively simple structures compliant the same number of people or even more as those of the building. Very few technical sources exist about patio cover wind design; therefore it is of very well importance to treat these structures for both safeties an economic reason with the appropriate attention (Stathopoulos and Zisis, 2010).

Patio covers are completely independent group of the structure which cannot be interpreted as a subsection of canopies or eaves. Canopies usually are not surrounded by walls and used as covers and. The detailed description, function and geometry of canopy roofs, differs significantly from those of patio covers. Moreover, patio covers cannot be treated as roof extensions or overhangs because it usually at a lower level than building's roof (Stathopoulos and Zisis, 2010).

2.10 SAP2000 SOFTWARE

SAP2000 software developed by Computer and structure, inc. 1995 university, ave. provides excellent features for modeling of building frames with different types of energy dissipating devices. It has capabilities of linear and nonlinear analysis with static as well as time dependent loading. In this example, nonlinear time history analysis is carried out for the building frame. Modeling and analysis of building frame using SAP2000 software involves steps which are create 2D frame using file menu and apply the properties of different member using define section properties and defining link/support properties in the SAP, assign the joint masses/forces using Assign menu and apply time history analysis using past earthquake data. (Dethariya and Shah, 2011).

According to Khapekar and Deshmukh,2013, SAP2000(Structural analysis program) is an integrated finite element analysis program for various structures including static and dynamic analysis, supported by powerful analytical capabilities, representing the latest research in numerical techniques and solution algorithms.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter will discuss the methodology that has been used in this study. It is also describe the typical patio cover structure; wind effect on the structure. The type of the research used is analytical research. An important feature of this type of research is in locating and identifying the different factors (or variables) involved.

3.2 Types of Structure

The typical type of the patio cover structure is used in Malaysia is the patio cover with two supports and attached to the wall of the build or house. As a figure below:

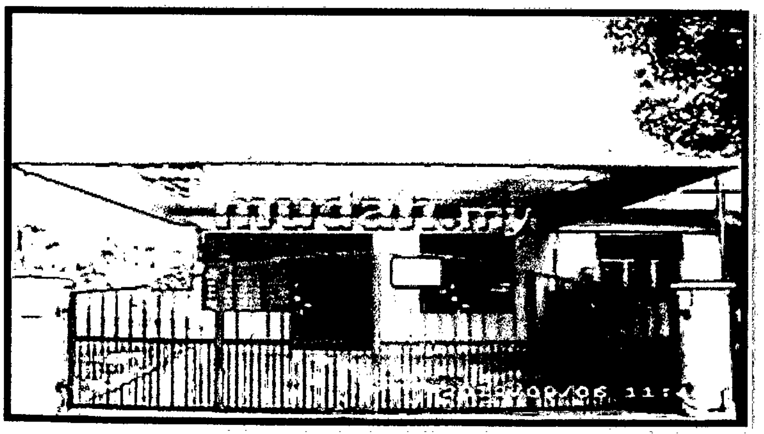

Figure 3.2: Patio Cover with two supports

For the patio cover structure with the two supports or steel column the specification of the structures that commonly used is determined. The range of the projection of this types of structures are greater than or equal 10 feet. Whereas it width is about 10 feet to 15 feet. Based the range of the size, the three combinations of size that usually used in Malaysia is chosen which a projection is times' width:

1) Model 1: 10 ft X 10 ft
2) Model 2: 10 ft X 12 ft
3) Model 3: 12 ft X 15 ft

The other specifications of the fixed which the steel truss and frame used are tube types with sizes 2 ½" X 1 1/2" and 1 ¼" X 1 ¼" .The joint used are bolts size 15 and welding. The weld tolerance is 1".The structure specifications are based on the BS5950 2000.The types of the materials used are steel with tensile yield strength, 345MPa and tensile ultimate strength, 450MPa. Wind is caused by differences in atmospheric pressure

3.3 Produce Design Patio Cover Structure

SAP2000 is a general purpose finite element program which performs the static or dynamic, linear or nonlinear analysis of structural systems. The SAP2000 is used to model, analyze, design, and display the structure geometry, properties and analysis results. The analysis procedure can be divided into three parts which are pre-processing, solving and post processing for analyze the patio cover structures. The model used is 2D truss structure.

In the preprocessing parts, the specifications and information such as choosing the units for this project, setting up geometry, defining material and member section properties, assigning member section properties and element releases, defining load cases, assigning load magnitudes and assigning restraints are needed.

Then, in the second part for producing design patio cover structure using SAP 2000 software is solving. In this part the SAP 2000 software will assemble and solve the global matrix. The various phases of analysis process are progressively reported.

The last part is post processing. Post processing involves the process of displaying the deformed shape, displaying the member forces, Printing the results, designing the structural members and checking the safety of a design and modifying the structure.

3.4 Wind Speed

The wind speed that causes failure to structure will determine when the patio cover is starting to undergo overstress condition. Then, the model that can withstand the highest and lowest wind speed can be determined. When a difference in atmospheric pressure exists, air moves from the higher to the lower pressure area, resulting in winds of various speeds. Therefore, the structures are applied with differences wind load based on the wind speed. The calculation used is based on the Ms 1553:2002 code of practice on wind loading for building structure, section 2.4.1.Refer to the Ms 1553:2002 the minimum wind load design is 0.65kN/m2. The values is decreased till the structures is hit the maximum speed it can resist. If the structures still can resist the minimum wind load design, the values is increased till the structures start to fail. The structures being apply with gravity and uplift force.

The capacity ratio is compared with limit ratio which is 0.95, on the BS5950:2000 section 4.8.3.3.1-2.If the capacity ratio is greater than limit ratio; it means based the structures are experienced overstress condition and deflection, which means the structure, is fail. Therefore, the patio cover structures which are have difference sizes of projection and width can be figured till how much of the wind speed it can withstand. The effect of the uplift force and downward/gravity force can be determined based on the axial load design. The structure will experience compression or tension. .