THE RISK ASSESSMENT OF ROOF TRUSS STRUCTURE IN MALAYSIA DUE TO WINDSTORM

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A report submitted in fulfillment the requirement for the award of the degree of

B.Eng (Hons.) Civil Engineering

Faculty of Civil Engineering & Earth Resources

UNIVERSITI MALAYSIA PAHANG

JANUARY 2015

ABSTRACT

Recently the pattern of wind in Malaysia is unpredictable which there are increasing the number of damage and injuries due to wind hazard. The most possibility risk of wind load damage to buildings structure in particularly roof structure. Roof structure is form of roof trusses and roof coverings. The durability of the roof structure is closely related to material selection and design process. Fortunately in Malaysia, there are many options to get the good material to build roof trusses either wooden or steel. However, there is some weakness in the design process where engineer only consider the wind acts as downward pressure to roof structure. Pervious study had shown that the wind loads are not only act in downward pressure but it also act in uplift force which is caused by suction pressure. Therefore, this study will discuss the risk possibility of roof truss in Malaysia due to windstorm. A typical roof truss system is evaluated due to various wind effect which is wind pressure, wind suction and simultaneous of wind pressure and suction at the same time. From the result, it clearly shows that the roof truss structure failed at wind suction effect and simultaneous wind pressure and wind suction effect. Therefore, there is lack of the wind effects consideration during design process due to poor knowledge about the wind hazard that caused the failure of roof structure.

ABSTRAK

Kebelakangan ini corak angin di Malaysia tidak dapat diduga yang terdapat peningkatan jumlah kerosakan dan kecederaan akibat bahaya angin. Risiko kemungkinan sebahagian besar kerosakan daripada beban angin untuk struktur bangunan terutamanya struktur bumbung. Struktur bumbung adalah bentuk kekuda bumbung dan penutup bumbung. Ketahanan struktur bumbung adalah berkaitan rapat dengan pemilihan bahan dan proses reka bentuk. Mujurlah di Malaysia, terdapat banyak pilihan untuk mendapatkan bahan yang baik untuk membina kekuda bumbung sama ada kayu atau keluli. Walau bagaimanapun, terdapat beberapa kelemahan dalam proses reka bentuk di mana jurutera hanya mempertimbangkan angin bertindak sebagai tekanan kepada struktur bumbung. Kajian lampau telah menunjukkan bahawa beban angin tidak hanya bertindak tekanan tetapi ia juga bertindak dalam gaya beban angkat yang disebabkan oleh tekanan sedutan. Oleh itu, kajian ini akan membicarakan kebarangkalian risiko kerangka bumbung di Malaysia terhadap rebut angin. Satu sistem kekuda bumbung yang tipikal adalah dinilai terhadap pelbagai kesan angin yang tekanan angin, sedutan dan serentak tekanan angin dan sedutan angin pada masa yang sama. Daripada keputusan itu, ia jelas menunjukkan bahawa struktur kekuda bumbung di kesan gagal semasa sedutan angin dan serentak tekanan angin dan sedutan angin. Oleh itu, terdapat kekurangan pertimbangan kesan angin semasa proses reka bentuk kerana kurang pengetahuan tentang bahaya angin yang menyebabkan kegagalan struktur bumbung.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Wind engineering study the effects of wind in the natural and the human-made surroundings and analyze the potential damage, disruption or advantages which may produce by windstorm. In the field of structural engineering, it is includes various type of wind which may cause inconvenience and also ultimate wind which may result to extensive devastation. Recent years, there is increasing number of damage and injury that caused by wind activities as shown in Table 1.0, the recent occurrence of windstorm in Malaysia. The most affected structure was roof structure which is clearly show that most of the incidents caused the damage to either roof sheeting or roof trusses. Besides that, the uprooted can lead to power outages due to tree branches disrupting the flow of energy through power lines. However, there is lack of awareness about wind hazard among the people in Malaysia either less knowledge or poor technology. This situation is very worrying since the authorities in Malaysia do not take any action or improvement to either reduce or overcome this situation.

Table 1.0: Windstorm Occurrences in Malaysia (2012-2014)

Date	Place	Damage	Total Damages
26 September 2012 (Noon)	Butterworth, P. Pinang	Roof and truss	Several houses and shop lots
29 September 2012 (1430)	Bukit Jelutong, Shah Alam	Roof, signboard, uprooted tree	Commercial centre, car porch and highway signboard
21 October 2014 (Noon)	Pandamaran, Klang	Roof and truss, uprooted tree	2 block Pangsapuri PKNS, houses
24 May 2012 (0145)	Balik Pulau, Pulau Pinang	Roof and truss, uprooted tree	150 houses
26 June 2013 (0130)	Putrajaya	Roof and truss	Quarters Block
22 July 2014 (1700)	Temerloh, Pahang	Roof and truss	200 houses and halls
30 October 2012 (0130)	Miri, Sarawak	Roof, uprooted tree	2 houses
30 March 2014 (1950)	Kuala Kedah, Kedah	Roof	16 houses
1 September 2014 (1800)	Gua Musang, Kelantan	Roof	6 houses
12 October 2014 (1630)	Pasir Gudang, Johor	Roof pedestrian bridge	Pedestrian bridge, 2 cars

Source: Berita Harian Online(2012-2014)

As we all know, the constructions of buildings were start from design process which is a methodical series of steps that engineers use in creating functional products and processes. The steps tend to get articulated, subdivided, and illustrated in variety of different ways, but regardless, they generally reflect certain core principles regarding underlying concepts and their respective sequence and interrelationship. The most highly exposed structure that related to wind is roof structure which is form of roof sheeting and trusses system. Therefore, it is desire to taking into account all load from wind effect during design process. Further study on wind effect to truss is necessary since the increasing of roof truss damages.

Roof truss system is an important part of a building, be able to support the weight of roof covering which provide shelter to the buildings. Truss has been used for centuries to help construct building besides bridges and frame. Early truss was made out of wood s but with constrains to get the quality wood, nowadays truss were use steel as the main material. A truss structure comprising one or more triangular units constructed with straight members whose ends are connected at joints referred to as nodes. External forces and reactions to those forces are considered to act only at the nodes and result in force the members which are either tensile or compressive force. Moments are explicitly excluded because all joints in a truss system are treated as revolute. The two basic trusses are pitched truss and parallel chord truss. The common used truss is pitched truss which is characterized by its triangular shape. Mostly this type of truss is used in construction for roof structure. Usually truss is named according to their web configuration. The most common type of trusses used in construction is pratt truss and howe truss.

This study is part of research that was conducted to study the action of wind affect on building which is various load effect on structure especially roof trusses and evaluate the risk possibility to existing roof truss system in Malaysia due to windstorm. The study includes the description and results of finite element analysis conducted on roof truss using SAP2000 software. The analysis carried out by consider various loading on the existing roof truss. The title of this research is The Risk Assessment of Roof Truss Structure in Malaysia due to Windstorm, which required to study the wind load and analyzing the roof truss structure using finite element method.

1.2 PROBLEM STATEMENT

Recently the direction and pattern of wind in Malaysia is unpredictable that lead to wind hazard. The number of damages and injuries due to wind hazard on roof structure increases in Malaysia. Most of the roof structure fail due to extremely wind blow besides poor design process that less focus on wind load either on wind downward force and wind uplift force. Roof structure consists of roof truss and roof sheet. Roof truss may be either from wood or steel. The lightweight truss that widely applied nowadays was cold formed steel truss which better among their class in quality aspect and durability that is important characteristics in selecting materials. Poor performance of building roofs especially during rainstorm was largely due to failures of roof connections, then leading to partial or full roof structural failure. During high wind events, buildings and their components connection may be subjected to simultaneous uplift and downward forces. Malaysia is a country that is located under the climate monsoon tropical. There is northeast monsoon on November to December that cause the exposed areas such as the east coast of Peninsular Malaysia, Sarawak west and the northeast coast of Sabah experiences heavy rainfall with windstorm. These phenomena lead to thunderstorm disaster that caused a lot of damage to the community such as land slide, flood and destruction of property. The loading from wind load that imposed to roof sheet will be transmitted to roof trusses. Therefore it is important to know the risk of roof truss due to various wind loads actions.

1.3 OBJECTIVE

The main objectives of this study are:

1. To study the wind load effects on building structure.
2. To analyze the roof truss structure due to variation wind load effects.
3. To check the possibility of roof truss failure due to wind load.

1.4 SCOPE OF WORKS

In order to ensure the objectives are achieved, several scopes needed to be stated so that the research does not turn aside from the real purpose of this study. This study will be focus on wind load affect on building structure. The design practice that purpose for Malaysia is MS1553:2002 Wind Load for Building Structure that will set out the procedure for determining wind speed and resulting wind actions to be used in the structural analysis.

An existing roof truss structure from a hip roof type will be used as model. In this study it will be involve the usage of SAP2000 software to analyze the element capacity for the whole truss system. Furthermore for the effect of variation wind load actions, the truss will have to withstand the wind pressure and wind suction. The conventional design that practiced in Malaysia only consider wind load act as wind pressure. The results from SAP2000 software will be analyze to achieve the goal of this study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A literature review is the most important things to describe in detail on related subjects. It is a text of a scholarly paper, which includes the current knowledge including substantive findings as well as theoretical and methodological contribution that related to a specified topic. Instead organize the literature review into sections that present themes or identify trends, including relevant topic. Literature review can be simplified as a study on related article or journal in order to pave the way for a better research. In this research, the literature review will focus on previous study about wind, the roof truss structure, the methodology of the research and other related issue to the research.

2.2 WIND

As the sun shines on the earth, different parts of the land and sea heat at different speeds. This will results in high and low pressure areas and leads to the lift and fall of air that passes across the entire globe. Due to the angle of the earth while rotating, the majority of the heat falls upon the middle of the world equator and much less towards the ice caps of the northern and southern hemisphere. This means that as the warm air rises on the equator, the cold air is pulled in from the ice caps. This spreads the warmth across the globe and results in moving air patterns. 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 order of ten minutes or more tends to increase with height, while the gustiness tends to decrease with height (P.Mendis.et.al, 2007). On a rotating planet, air will also be deflected by the moving objects effect except exactly on the equator.

2.3 WIND HAZARD

An extreme wind is a wind gust which is strong enough to be dangerous for people, or cause significant damage to buildings and property. The most risk possibility of wind hazard based on recent wind-induced damage to buildings and structures in Malaysia is due to extreme wind which known as windstorm. There are very little emphasizes of design buildings 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 consideration due to wind effect during design stage (T.A.Majid.et.al.2010).

The consequence of wind damage not only affected building, but it also create social problem. This is supported by Bachok.et.al. (2012), the impact of windstorm also could create social problem such as trauma and homeless to the windstorm victims. Most probably every year Malaysia experienced windstorm that caused damages. The damage either affected to properties (roof blown off and vehicle destroyed), environment (uprooted tree) and human (people killed and injured). The loose caused by a typical damage value reach from thousands to millions. The government spend large amounts every time disaster, even has established National Security Council which is responsible for managing the disaster and post-event time.

Malaysia is a country that experienced various type of disaster which include flood, windstorm and extreme weather such el nino.and la nina. Generally, Malaysian has a good awareness on the various disasters since the government use various medium to convey information to residents. More than 90% of respondent agreed that the windstorm was among the type of disasters that 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

According to Yukia Tamura, 2009, the damage to roof truss structure occurs either directly or is triggered by breakage of openings as shown in Figure 2.1. Most damages to roof themselves are caused by local high suction and large pressure fluctuation around the roof periphery and protruding portions. These local failure enable wind to enter under the roof members, thus increasing the underneath pressure and rapidly increasing lift force.

Local roof damage can lead to total roof destruction. Total roof lift-off can also be triggered by damage to openings at wall such as windows, allowing wind into room and increasing the underneath pressure.

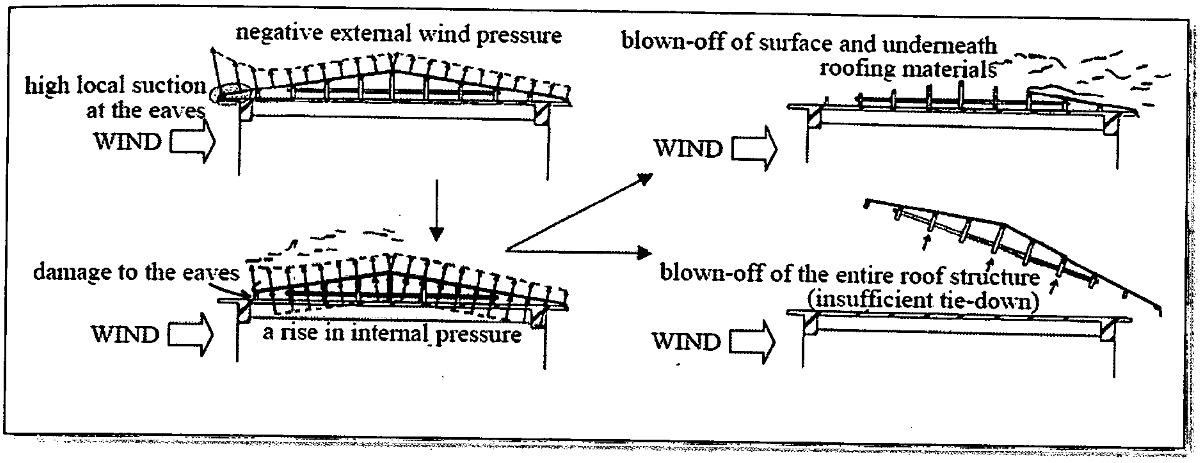

Figure 2.1: Wind Damage Correlation (Yukio Tamura.2009)

Wind will cause various action on building either pressure or suction. Most of damage seems caused by wind suction as we cans see the flying debris that fall apart from its original place. This statement supported by Craig R Dixon and David O. Prevatt, 2010, as ground level wind flow encounters a building's face, it forced to go up and over the structure. Unless the roof slope is too high, would be usually uplift force perpendicular to the roof, due to suction effect of the wind blowing over the roof. Otherwise uplift pressure result from the separation of flow from the roof.

Wind loads on roof also depend on the roof shape. On a pitch roof with a slope exceeding approximately 35 degree, there will be pressure on the windward part of the roof and suction on the leeward part of the roof. While flat roofs and pitch roofs with slope of less than 15 degree, suction effect on the whole roof (Islam, Hamza and Dudek.2013). As the leeward is the direction downwind from the point of reference and windward is the direction upwind from the point of reference.

2.5 WIND PRESSURE

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

The pressure of wind load on the surface must be taken as one of main important in order to construct building and any other part of building that can withstand the effect of wind. Besides that cost also is the major reason, it is because the cost in order to assess the best design of wind load uses a lot of money such as wind tunnel test. Therefore, thorough consideration must be taken if want to construct a building that is complex and have dynamic characteristic of wind in the design, although the wind effect cannot be predicted to precise design load. The proper design should be done to avoid the high maintenance cost which is very expensive when it include to the structural damages.

2.6 WIND UPLIFT

Wind directions are not always normal to the building and most importantly, wind flow is dynamic. Upwind surface roughness disrupts the wind flow creating turbulence as shown in Figure 2.2. This phenomenon have confirmed by wind tunnel studies, showing that these pressure vary both temporarily and spatially with the highest pressure near corners and edges of the roof (B.A. Baskaran, T.L. Smith.2005). A roof system must resist these dynamic loads while maintaining weather tightness.

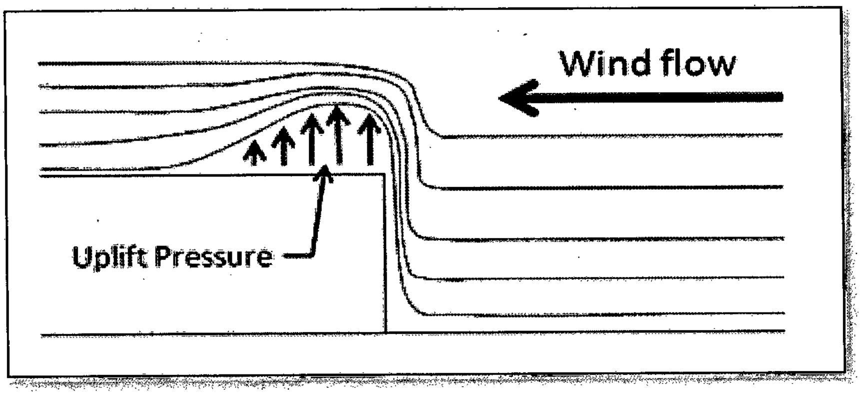

Figure 2.2: Wind suction

According to Graham, 2009, design wind uplift pressure 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;

$$Q_h = 0.00256K_hK_{zt}K_dV_2I \quad \text{(Equation 1)}$$

The variable Q_h represents the calculated design velocity for uplift pressure at a specific height above grade, which is designated in pounds per square foot. V is the basic wind speed designated in miles per hour. K_h is a velocity pressure coefficient, K_{zt} is a topographic factor, K_d is a wind directionality and I is an importance factor.

2.7 WIND SPEED

The calculation of wind load was based on the basic wind speed which in Malaysia is subjected to Malaysian Standard. There are needs of revised basic wind speed in MS1553:2002, Malaysia is a dividing in to part which the main wind force resisting system shall not be less than $0.65kN/m^2$ which is shown from basic wind speed of 32.5m/s based on 3 second gust and nears the seaside the code suggested basic wind speed at 33.5m/s (T.A. Majid.et.al.2010). This value will be take consideration in design process as pressure acting downward to roof structure.

According to 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;

$$p(t) = q(t)\,C_p(\theta(t)) = \frac{1}{2}\rho V^2(t)\,C_p(\theta(t)) \qquad \text{(Equation 2)}$$

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

2.8 DESIGN OF PRACTICE

In this study, the design practice that applicable in Malaysia is MS 1553:2002 that will set out the procedures for determining wind speed and resulting wind actions to be used in structural design. The procedures are specified for calculation of wind pressure on buildings which limited to regular buildings that are not more than 200m height and structure with roof spans less than 100m. It also applicable for structure other than off shore structures, bridges and transmission towers.

$$P_s = 0.5\rho_{air} V_{des}^2 C_{fig} C_{dyn} \quad \text{(Equation 3)}$$

ρ_{air} = density of air which can be taken as $1.225 kgm^{-3}$; and

$0.5\rho_{air}$ = 0.613 (This value is based on standard air conditions and typical ground level atmospheric pressure)

C_{fig} = aerodynamic shape factor

C_{dyn} = dynamic response factor which shall be taken as 1.0

$$V_{des} = V_{sit} \times I \quad \text{(Equation 4)}$$

The site wind speed, V_{sit} is defined by expression

$$V_{sit} = V_s(M_d)(M_{z,cat})(M_s)(M_h) \quad \text{(Equation 5)}$$

The value of Vs is obtained by refer zone map which is 33.5m/s Zone I and 32.5m/s Zone II respectively. Station wind speed for all directions based on 3-second gust wind data is given in Table 2.1 for the region shown in Figure 2.3. Importance factor, *I* gained in Table 2.2.

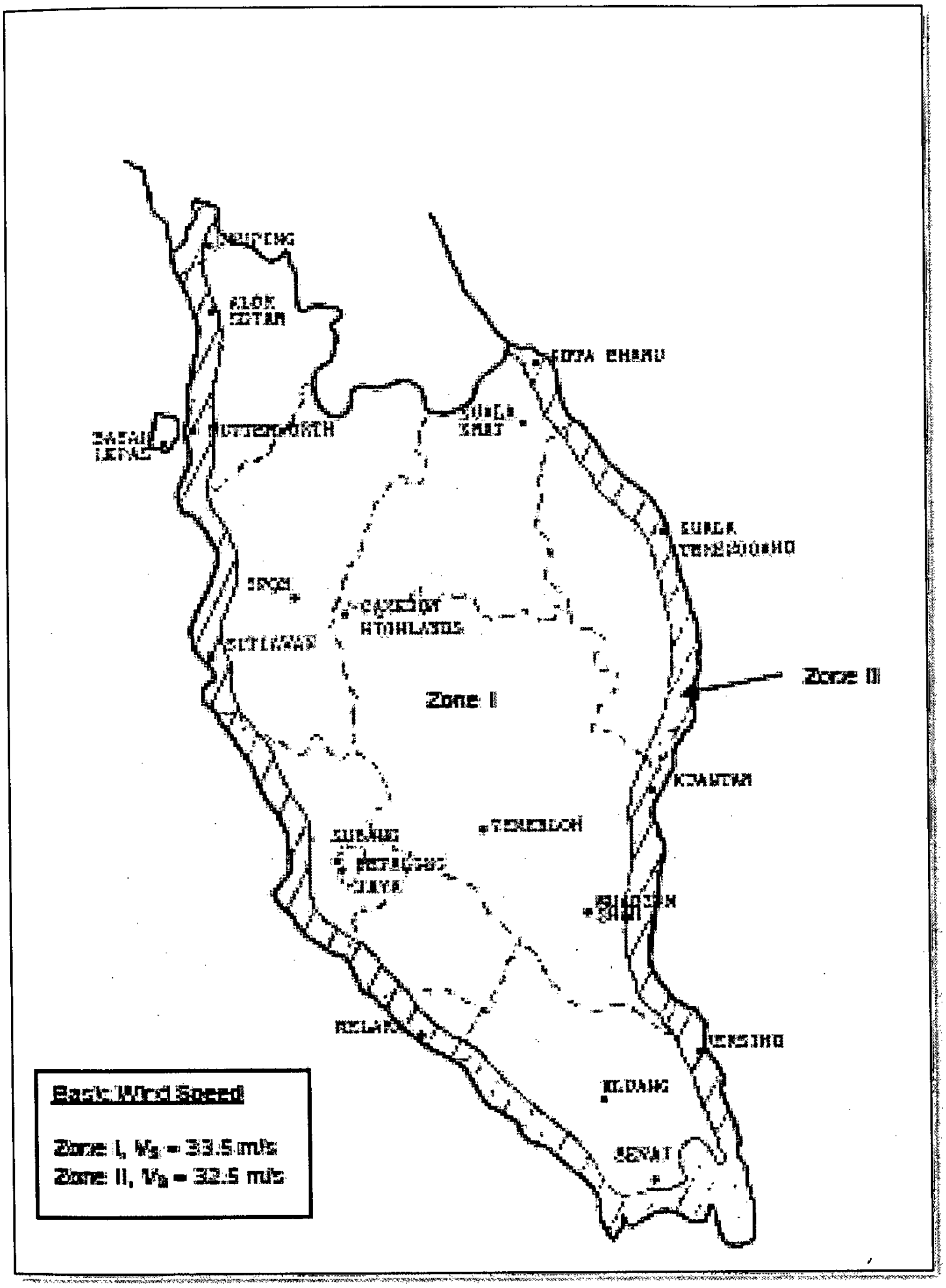

Figure 2.3: Basic wind speed (MS 1553:2002)

Table 2.1: Wind speed for various return periods (MS 1553:2002)

Station	20 years return period (m/s)	50 years return period (m/s)	100 years return period (m/s)
Temerloh	25.1	27.4	29.1
Tawau	24.6	26.6	28.1
Subang	29.2	32.1	34.3
Sri Aman	27.6	30.2	32.4
Sitiawan	23.3	25.3	26.7
Sibu	27.0	29.3	31.0
Senai	26.9	29.1	30.7
Sandakan	23.4	25.8	27.7
Petaling Jaya	28.8	31.4	33.4
Muadzam Shah	22.6	24.4	25.8
Miri	26.9	29.0	30.5
Mersing	29.5	32.0	33.8
Melaka	26.7	29.4	31.3
Labuan	26.0	27.7	29.0
Kudat	27.1	29.1	30.6
Kuala Terengganu	25.5	27.2	28.5
Kuantan	27.5	29.8	31.6
Kluang	29.6	32.6	34.9
Kuala Krai	27.2	29.5	31.3
Kuching	29.5	32.6	24.9
Kota Bharu	30.0	32.4	34.2
Kota Kinabalu	28.3	30.5	32.2
Ipoh	30.6	33.5	25.7
Chuping	23.8	25.6	27.0
Cameron Highlands	25.2	26.8	28.0
Butterworth	24.6	26.4	27.7
Batu Embun	25.3	27.5	29.2
Bayan Lepas	25.6	27.5	28.9
Bintulu	23.9	25.9	26.9
Alor Setar	27.2	25.9	31.8