DETERMINATION OF DIRECTION FACTOR, Md FOR MS 1553:2002 WIND LOADING FOR BUILDING STRUCTURE

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ABSTRACT

Current records from the Malaysia natural disaster studies show that windstorm causes damages to building. Even though Malaysia has developed own code of practice on wind loading for building structure to support Malaysian Standard in 2002, ongoing research is still being carried out to update the data in the codes. Currently, in Malaysia is refer to Malaysian Standard, MS 1553:2002 that do not have the value of direction factor, M_d. Most of design methods in Malaysia are not considering the effect of wind direction. Significantly, building orientation on design stage can reduce the wind load impact. Wind speeds data from eights Meteorological Station over the peninsular Malaysia are used in this study. Extreme wind speed are examined by statistical technique namely Gumbel method. The extreme wind speed data are considered into two conditions, (i) Non-Direction Method, (ii) Directional Method. By using this method, extreme wind can be determined at 8 stations in Peninsular Malaysia which are Kuantan, Kuala Terengganu, Mersing, Senai, Subang, Bayan Lepas, Chuping, and Melaka. From the result, the direction factor, M_d at each station was found and the values are recommending in MS 1553:2002. The results also have shown that, at some direction of extreme wind predicted stronger than non direction method. Furthermore these values can give guideline to the designer to orientate the building in facing high wind speed. It is also can reduce factor failure due to the extreme wind in Malaysia.

ABSTRAK

Dari data-data bencana yang direkodkan di Malaysia, angin merupakan salah satu bencana yang menyebabkan kerosakan pada bangunan di Malaysia. Kod piawai Beban Angin terhadap bangunan telah dibangunkan bagi memenuhi kehendak Piawai Malaysia MS. Pada tahun 2002, kajian terus dijalankan bagi mengemaskini piawai yang sudah ada. Pada masa kini, di Malaysia adalah merujuk kepada Piawai Malaysia, MS 1553:2002 yang tidak mempunyai nilai faktor arah, Md. Kebanyakan kaedah rekabentuk di Malaysia tidak mempertimbangkan pengaruh arah angin. Pentingnya, orientasi bangunan pada tahap merekabentuk adalah ia dapat mengurangkan kesan beban angin. Data kelajuan angin dari lapan buah Stesen Meteorologi di Semenanjung Malaysia telah digunakan dalam kajian ini. Kelajuan angin yang terlampau diperiksa dengan menggunakan teknik statistik iaitu kaedah Gumbel. Data kelajuan angin terlampau ini boleh dipertimbangkan kepada dua keaadaan, (i) Kaedah Non-directional, (ii) Kaedah Directional. Dengan menggunakan kaedah ini, angin terlampau dapat ditentukan di setiap 8 stesen di Semenanjung Malaysia iaitu Kuantan, Kuala Terengganu, Mersing, Senai, Subang, Bayan Lepas, Chuping, dan Melaka. Dari keputusan tersebut, faktor arah, Md dalam setiap stesen ditemui, kemudian nilai itu boleh dicadangkan kepada MS 1553:2002. Keputusan kajian juga menunjukkan bahawa, pada beberapa arah angin terlampau dianggarkan lebih kuat melalui kaedah non-directional. Disamping itu juga, nilai-nilai ini dapat memberikan panduan kepada pereka bentuk untuk mengorientasikan bangunan dalam menghadapi kelajuan angin yang kuat. Ia juga dapat mengurangkan faktor kegagalan angin terlampau di Malaysia.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background

Wind is natural phenomena, it has advantages and disadvantages. It had been used by people as an energy source to benefit mankind. However, it also causes property damage even loss of life. In fact, in last decades much more losses have been caused by severe windstorm if compared to other disasters. Recently, some building in Penang and Selangor had severe damaged due to strong wind. (MMS, 2002)

Wind load has a great deal of influence on building design and the design of other kinds of civil engineering structure. Many whole structures or parts of structures fail because of inadequate consideration given to wind action at the design stage.

Buildings and structures in Malaysia are also affected by wind action. As a result Malaysia has developed her own code of practice MS 1553:2002 on wind loading for building structure. The MS: 1553:2002 has been adapted from Australia Standard AS 1170.2 due to similarity of wind climate (Sundaraj, 2002). The code was developed using data from 23 meteorological stations all over Malaysia and the basic wind speed for Malaysia was established.

Beside the basic wind speed map, the code must also have information on parameters such as terrain height multiplier, shielding multiplier and hillshape multiplier.

1.2 Problem Statement

Analysis of wind effects has become an integral part of design. Wind induced structural vibration can caused severe structural damage and failure. However structures such as communication tower, transmission tower and skyscrapers such as Petronas Twin Tower and Kuala Lumpur Telecommunication Tower are high rise building. They require appropriate wind loads for the design the structure according to the height to make sure the structures safe.

According to International Disaster Database (OFDA/CRED, 2004), wind storm are listed top 10 natural disaster affecting Malaysia. On 6 of November 2004, wind storm has affected 40000 people in east coast of Peninsular Malaysia. Another wind storm event on 26 of December 1996 has killed 270 people in Sabah. Windstorm at all times has been the headlines of newspaper in Malaysia. A lot of building destroyed or damaged due to wind storm.

Utusan Malaysia Newspaper has highlighted the windstorm events. In year 1999, on 12 of February windstorm has hit Kuala Lumpur. Several houses and buildings structures has been damaged and destroyed by wind. Losses are estimated to be more than RM 250,000. On 19 of February 2005, 38 numbers of house damaged due to windstorm in Sungai Siput, Perak. Twenty vehicles have damaged because roof of apartment fell down on them as shown in Figure 2.1. It happened at Bukit Mertajam, Seberang Perai on 16 of August 2004. The location of this event is closed to Seberang Jaya Telecommunication Tower. Eight days after that Penang was once again hit by windstorm. It caused not only serious damages to 25 houses but also injuries to people.

Figure 1.1: Apartment Roof Falling Down on Vehicles (Arkib Utusan, 2004)

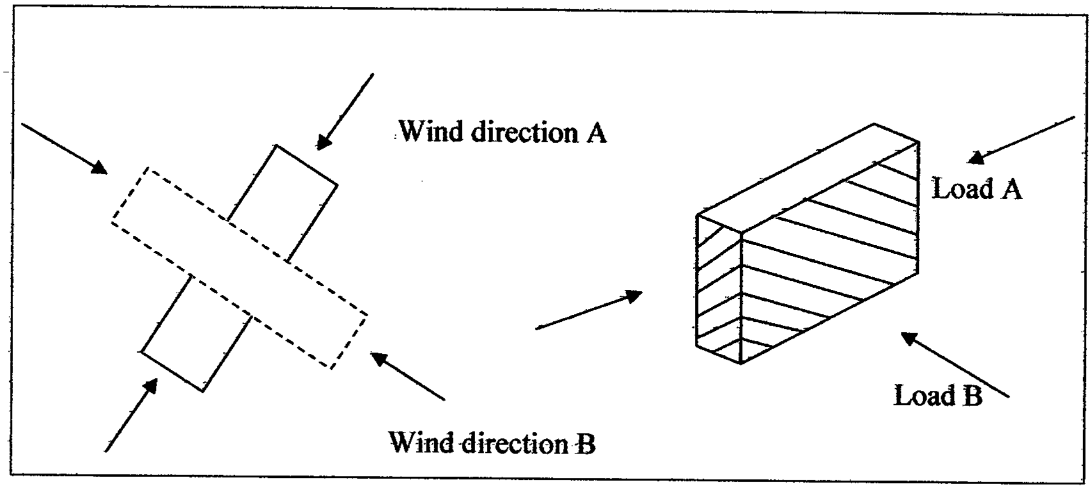


Figure 1.2: Building orientation

Orientation strongly relates a building to the natural environment—the sun, wind, weather patterns, topography, landscape, and views. Decisions made in site planning and building orientation will have impacts on the energy performance of the building over its entire life cycle. Refer to figure 1.2, the wind from A direction will cause the load to the building surface A increase and if the wind is come from B direction, the load at building surface B will increase. Wind will affect tall buildings more than low structures. Design for wind direction—admitting favourable breezes and shielding from storms and cold weather winds. Wind information is often available from airports, libraries, and/or county agricultural extension offices. In cold climates, locate pedestrian paths and parking lots on south and east sides of buildings to enable snow melting, but in southern climates locate these on the less sunny east or north sides of the building.

In conclusion, this study effort will be focus to find the best method in order to determine the basic wind speed and wind direction for best Malaysia. There is having several methods to determine the basic wind speed.

1.3 Objectives

This study consists of the following specific objectives:

I. To determine the basic wind speed using non directional method and directional method.

II. To determine the direction factor, Md

1.4 Scope of Work

The scope of this project is determining the basic wind speed of 12 stations at Malaysia area. The actual data obtained from the Malaysian Metrological Department (MMD). Gumbel method is used in this research to determine the basic wind speed by considering Non- Directional and Directional method.

I. Analysis the basic wind speed data from Malaysian Metrological Department (MMD).

II. Determine basic wind speed based on direction and non direction.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A simple method is proposed for defining directional design wind speeds. In evaluate wind loads on buildings, it is important to evaluate wind directionality for both wind speed and aerodynamic properties of buildings. For design winds in mixed wind climate regions like Japan, directional wind speeds are evaluated using a simulation method for typhoon winds and a statistical method for non-typhoon winds. Then the equivalent wind speed and its return period, called equivalent return period here, are identified in every direction that gives the same wind load as the design considering wind directionality. Assuming the general procedure of adopting a maximum wind load calculated for respective wind directions, directional design wind speed is evaluated using the minimum equivalent return period. It is shown that the effects of structure shapes and orientations are small for these wind speeds.

Winds load have great deal of influence on building design and the design of other kinds of civil engineering structure. Damage to buildings and other structures by wind has been a reality of human life. For many centuries, damage from wind speed force acting on building has been considered as act of god (Senin, 2000). Only after the 18 century, wind characteristic has become the area of interest by many scientists and researchers. A lot of structure or parts of structure fail because of inadequate consideration given to wind action at the design stage. Trial and error has played an important part in the development of construction methods to construct building structures to resist wind loads. Therefore wind speed impact is among major load that must be considered in the design.

The directional design wind speed may exceed the non-directional design wind speed even though they have the same exceedance probability. In design practice, designers sometimes want to orient the building according to the directional characteristics of wind speeds at the construction site. Only a few codes, e.g. BS6399.2 and AS/NZS1170.2, provide directional design wind speeds (Masahiro Matsui, 2005). The growth of modern approach replaced trial and error theory. Probabilistic and statistical methods become the basis to study wind characteristic based on historical recorded data. The determination of appropriate design wind speed is a vital step towards the calculations of design wind loads for structures.

In order to evaluate the wind load effect considering wind speed directionality, it is necessary to know the wind speed probability and the directional wind speed-load effect relationship. If only the wind directions and wind speeds are taken into account regardless of the load effect, for a certain wind direction, an irrational result may be obtained. For example, the directional design wind speed may exceed the non-directional design wind speed even though they have the same exceedance probability. This paper describes a procedure for evaluating wind loadings on buildings considering both the directional effect of wind speeds and the aerodynamic properties of the building.

On the other hand, consists of directional wind loading probabilities and results in their extreme value distribution. The wind speed directionality, however, is not easy to evaluate. This method is expected to give more realistic and rational values. The directional method requires two types of directionality: wind speed directionality and directional aerodynamic properties of the prototype building (Holmes, 1990).

2.2 Basic Wind Speed

Basic wind speed (V_s) can be defined as maximum wind speed that will occur one in a recurrent interval year (X_T), where X is the wind speed and T is year. Always T is taken as 50 years and 100 years. The basic wind speed, Vs at 10 m height from ground level at all meteorological stations are used as reference wind speed that will be considered in the calculation design load to building structure. In several international codes and standards, basic wind speed is based on averaging time 10 minute to 1 hour (Zhou and Kareem, 2002). In some cases averaging time is taken as 3 second as listed in Table 2.1 below. Averaging time is wind speed measured over an interval time to provide basic wind speed.

Table 2.1: Average Time of Basic Wind Speed (Zhou and Kareem, 2002)

Country	Code	Averaging Time
-	ISO 4354	10 minutes
European Country	ENV 1991-2-4	10 minutes
United States Of America	ASCE 7-98	3 seconds
Japan	AIJ 1996	10 minutes
Australia	AS 1170.2	3 seconds
United Kingdom	BS 6399: Part 2	1 hour
Canada	NBCC 1996	1 hour
Malaysia	MS 1553:2002	3 seconds

Design wind speed is derived from site wind speed multiplied with some parameter such as terrain categories and type of building. This design wind speed is used in deriving the wind loads or also referred as equivalent static wind load.

2.3 Equivalent Static Wind Load

For many structures, the wind induced resonant vibrations are negligible and the fluctuated wind responses can be calculated using procedure applicable to static load. Since the majority of buildings belong to this category i.e. the natural frequency is not more than 1.0 hertz, the so called static wind load is very important in connection with stress calculations and design (Dyrbe and Hansen, 1996). Newton first law says that force, F can be calculated from mass and acceleration as follows.

$$F \quad = \quad ma \tag{2.1}$$

Where, m (mass) is equal to volume x density (ρ) and a, acceleration is equal to changing wind speed over an interval of time. From equation 2.1 forces can be calculated, Equation 2.1 also relates between wind speed and force. Winds have its own density and the acceleration can be calculated by measuring the wind speed changes within a specified interval of time. Another equation introduced by Bernoulli give more accurate assumption in calculation of static wind load.

$$p + 0.5\rho V_s^2 \quad = \quad 0 \tag{2.2}$$

Where p is sum of static pressure, ρ is air density and V is velocity. This equation is called *hyrodynamica*, which specifies that the sum of static pressure, p and the velocity pressure, $0.5\rho V_s^2$ is constant along streamline. From equation 2.2 design wind speed pressure can be measured by:

$$q \quad = \quad 0.5\rho V_s^2 \tag{2.3}$$

Equation 2.3 has been used until now as a guideline to calculate static pressure from basic wind speed. Equation 2.3 also has also been adopted ISO 4354 as a guideline for drafting national codes of practice.

2.4 Power Law Profile

Power law profile is an alternative way to expressed wind speed profile. It is more popular equation and has been used all over the world in most of the major codes of practice. The equation describes wind speed profile as a function of height above the ground which can be computed by

$$V(z) = V_s\, b(z/z_{ref})^{\alpha} \qquad (2.5)$$

Where V_s is basic wind speed, b and α are constants depending on terrain type, z is height above the ground surface and z_{ref} is reference height at which basic wind speed are measured, always taken as 10 m elevation from ground surface. For exposed open terrain type, b is considered as 1.0. Nevertheless many researchers and meteorologists have neglected b in the power law equation, where b is always considered as 1.

2.5 Gumbel Method

There are two types of calculation in Gumbel method. Those are directional and non- directional method. The Generalized Extreme Value Distribution (G.E.V.) introduced by Jenkinson (1955) combines the three Extreme Value distributions into a single mathematical form:

$$F_U(U) = \exp\{-[1 - k(U - u)/a]\ 1/k\} \qquad (2.6)$$

Where $F_U(U)$ is the cumulative probability distribution function of the maximum wind speed in a defined period (e.g. one year).

In equation (2.6), k is a shape factor and ***a*** is a scale factor. As k tends to 0, equation (2.6) becomes equation (2.7) in the limit. Equation (2.7) is the Type I Extreme Value Distribution, or Gumbel Distribution.

$$F_U(U) = \exp\{-\exp[-(U - u)/a]\} \tag{2.7}$$

Where u is the mode of the distribution, and **a** is a scale factor.

The return period, R, is directly related to the cumulative probability distribution, $F_U(U)$, of the annual maximum wind speed at a site as follows:

$$R = \{1/[1 - F_U(U)]\} \tag{2.8}$$

Substituting for $F_U(U)$ from equation (2.8) in (2.7), we obtain:

$$U_R = u + a\{-\log_e[-\log e(1 - [1/R])]\} \tag{2.9}$$

For large values of return period, R, equation (2.9) can be written:

$$U_R \equiv u + a\log_e R \tag{2.10}$$

2.5.1 Incorporation of wind direction effects

Increased knowledge of the aerodynamics of buildings and other structures, through wind-tunnel and full-scale studies, has revealed the variation of structural response as a function of wind direction as well as speed. The approaches to probabilistic assessment of wind loads including direction can be divided into those based on the parent distribution of wind speed and those based on extreme wind speeds. In many countries, the extreme winds are produced by rare severe storms such as thunderstorms and tropical cyclones, and there is no direct relationship between the parent population of regular everyday winds and the extreme winds. For such locations (which would include most tropical and subtropical countries), the latter approach is more appropriate. Where a separate analysis of extreme wind speeds by direction sector has been carried out, the relationship between the return periods, Ra, for exceedence of a specified wind speed from *all* direction sectors and the return periods for the same wind speed from direction sectors $\theta 1$, $\theta 2$, etc. is given in the following equation:

$$(1-[1/R2]) = {}^{N}\prod_{i=1} (1-[1/R_{\Theta}]) \tag{2.11}$$

Equation (2.11) follows from the assumption that wind speeds from each direction sector are statistically independent of each other and is a statement of the following:

Probability that a wind speed U is *not* exceeded for all wind directions =

(probability that U is not exceeded from direction 1) ×
(probability that U is not exceeded from direction 2) ×
(probability that U is not exceeded from direction 3)......etc.

2.5.2 Wind directionality factor

When the records are divided into 8 sectors of azimuth, each sector have very few typhoon data, so sampling error is very large. Thus, typhoon effect should be considered when wind directionality factor is determined. There are two types of wind directionality factors. One defines a wind directionality factor that changes with direction, as shown in BS6399.2 and AS/NZS 1170.2, except for the cyclone-prone regions. And the other one is defines a constant reduction coefficient regardless of wind direction, as in the ASCE standard. For the latter, it is hard to reflect directional design wind speeds in design practice. In these recommendations, wind directionality factor was defined for each direction as for the former type, so as to achieve reasonable wind resistant design.

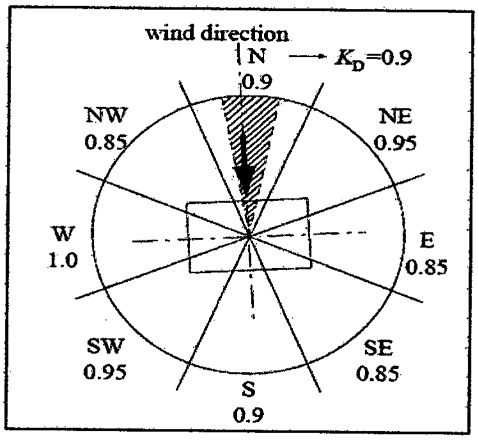
Wind directionality factor was provided on the assumption that the wind load is calculated according to the following procedure:

i- Where the aerodynamic shape factors for each wind direction are known from appropriate wind tunnel experiments, the wind directionality factor K_D, which is used to evaluate wind loads on structural frames and components/cladding for a particular wind direction, shall take the same value as that for the cardinal direction whose 45 degree sector includes the wind direction. In this case, the wind tunnel experiments should be conducted for detailed change of directional characteristics for the aerodynamic shape factors of the structure.

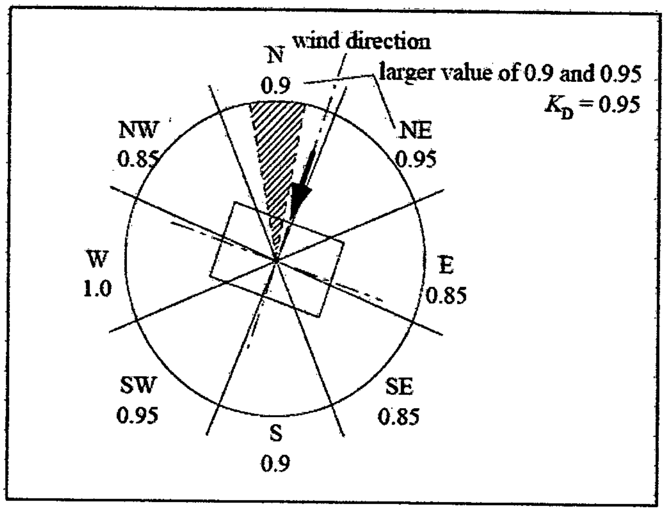
ii- Where the aerodynamic shape factors are used. When assessing the wind loads on structural frames, two conditions are considered: whether or not the aerodynamic shape factors depend on wind direction.

Where the aerodynamic shape factors are dependent on wind directions, four wind directions should be considered that coincide with the principal coordinate axis of the structure. If the wind direction is within a 22.5 degree sector centered at one of the 8 cardinal directions, the value of the wind directionality factor K_D for this direction should be adopted. If the wind direction is outside the 22.5 degree sector, the larger of the 2 nearest cardinal directions should be adopted. When assessing wind loads on cladding according to the peak wind pressure coefficient, those obtained under the condition of $K_D = 1$ should be used for design because the maximum peak pressure coefficient of all directions is shown in these recommendations.

For a building with rectangular horizontal section, the wind force coefficients for the wind directions normal to the building faces are given by these recommendations. When the wind direction considered is at an intermediate position between two cardinal directions shown in the table, the greater value of the two neighboring directions is adopted.



a) Where the wind direction falls in a 22.5 degree sector



b) Where the wind direction does not fall in a 22.5 degree sector

Figure 2.1(a-b): Selection of the wind directionality factor (when using the wind force coefficient of buildings with rectangular horizontal sections defined in these recommendations)

2.5.3 Directional method

The directional method consists of directional wind loading probabilities and results in their extreme value distribution (Figure 2.1). This method is expected to give more realistic and rational values. The directional method requires two types of directionality: wind speed directionality and the directional aerodynamic properties of the prototype building. The directional aerodynamic properties are easily obtained by conducting wind tunnel tests. Wind speed directionality, however, is not easy to evaluate. Improved techniques will be shown in a later section for evaluating directional wind speed probability.