COUNTRY REPORT : WIND LOADING FOR STRUCTURAL DESIGN IN MALAYSIA

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ABSTRACT : Some general discussions on the climatic and wind speed distribution around Malaysia are presented. The structural design practices in Malaysia which accounts for wind actions are described. Typical design problems for buildings in Kuala Lumpur are also highlighted. Generally, Malaysia experiences low wind speed and the assumption of wind loading in accordance to the code requirements will normally be considered safe for any simple building. However, in densely populated building areas, designers have to undertake critical measures at the design stage to examine the consequential effects of winds and ensuring that a safe and economical design is achieved.

KEYWORDS: Wind loading, Wind analyses, Low Rise Buildings, High-rise building, Wind Speed, Structural Design

1 INTRODUCTION

In order to fully comprehend the adequacy or inadequacy of a building, designers must have an accurate estimate of the wind speeds to which the construction was subjected. Wind speed databases provide data necessary to the development of other tools to further our understanding and preparedness for natural disasters. Such efforts can help us to better understand the nature of hurricane force winds and their impact on structures.

Additionally, with the general expansion of structural design, the need for widely available data on design wind speeds for all countries has become more obvious. Currently, there exists a multitude of national wind loading codes and standards with a range of defined averaging periods and return periods. Not withstanding the fact that there are also a large number of publications publicly available such as in published papers and reports, national wind codes and standards, that a designer, or consultant, can use for structural design purposes [1].

However, to date, there is no single document that provides world-wide data on extreme wind speeds at present. Holmes [2], summarized briefly the sources of basic design wind speeds for 56 countries, and classified these countries or territories into five levels, with respect to the magnitude of their extreme wind speeds. Design wind speeds for the Asia-Pacific Region have been summarized by Holmes and Weller [3], based on national codes and standards and a five-level zoning system. Eurocode 1: Wind actions on Structures [4] provides a harmonized code for winds but the basic design wind speeds is provided by the national application documents of respective European member countries.

This paper describes the distribution of wind speed and wind loading analyses for structural design considerations in Malaysia. Typical design problems on wind engineering for buildings in Kuala Lumpur are also highlighted.

2 LOCATION AND GENERAL CLIMATIC CONDITIONS

Malaysia is situated in the tropics, between 1º N and 6º N. It consists of West Malaysia, a peninsula south of Thailand, and East Malaysia (Sabah and Sarawak) in the northern part of the land mass of Borneo, Figure 1. The country is mountainous, with peaks rising to over 6500ft (2000m). Malaysia is situated near the equator and has a tropical climate with high temperatures and rainfall all year round. Rainfall is heavy and usually occurs in the form of thunderstorms.

Figure 1. Location of Malaysia

The main differences of climate within the country are due to differences of altitude and the exposure of the coastal lowlands to the alternating North-East and South-West monsoon winds. The North-East monsoon and the South-West monsoon winds form the dominant winds in Peninsular Malaysia. The South–West monsoon winds blow from April- September while the North-East monsoon occurs from November-February. March and October are the transition months between the monsoons, characterised by light and variable winds.

The North-eastern coasts of Malaysia experience very wet weather conditions during the North-East monsoon season as they are exposed to the North-easterly winds. These are wetter than when the south-western coasts are exposed to the southwest monsoon. However rainfall occurs throughout the year and falls on 150-200 days of the year almost everywhere.

Temperatures do not differ much from month to month, and there is no large daily range of temperature. Night-time temperatures can be oppressive due to high humidity. Conditions are cooler in the hills but this is balanced by higher humidity and rainfall, and less sunshine. Although Malaysia has a warm and humid climate, severe heat stress is rare. The transition months (March and October) can be uncomfortable because winds are light and humidity may be higher. In the afternoons, conditions on the coast are often relieved by sea breezes.

3. WIND SPEED AND DIRECTIONS AT STRATEGIC LOCATIONS IN MALAYSIA

The wind speed at various meteorological stations in Malaysia is shown in Figure 2. The data was collected on hourly period however the height of anemometer varied from station to station. No wind speed correction is made as most of the height ratio is small and therefore only small velocity variation is expected [5]

The highest wind speed area was recorded in Mersing followed by other East coast areas, i.e Kuala Terengganu and Kota Bharu.. In general, the West Coast areas experienced lower wind speed, mostly below 2 m/s [5].

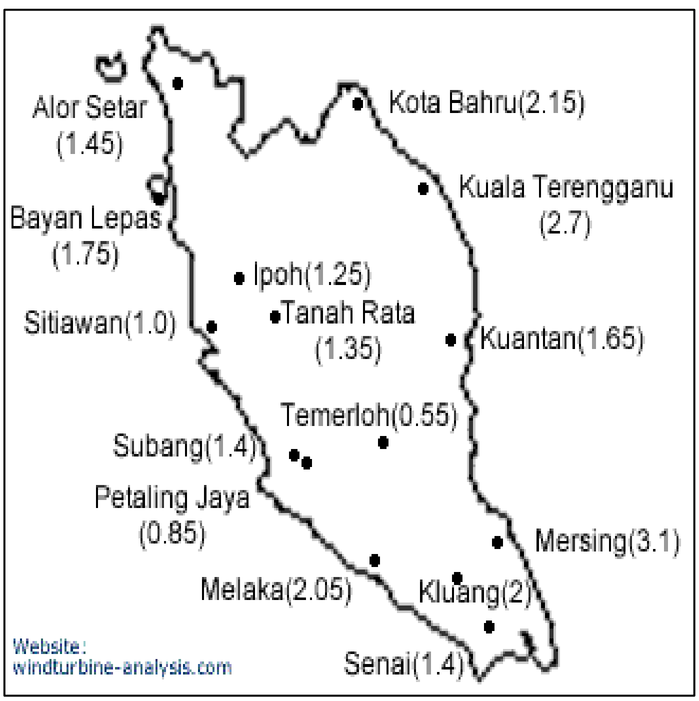

Figure 2. Annual wind speed at 18 meteorological stations in Peninsular Malaysia (after windturbine-analysis .com)

Table 1. shows the winds directions at selected towns and cities in Malaysia. According to these records, the directions varies and could occur all within a day [5].

Locations					
Month	*A.Star*	*K.Lumpur*	*K.Bharu*	*Mersing*	*B.Lepas*
January	NE/E	NE	E/NE	N/NE	Variable
February	NE	NE	E	N/NE	Variable
March	NE	Variable	E/NE	N/NE	NE/N
April	Variable	Variable	E/NE	W	SW/W
May	W	Variable	SW/S	W/SW	SW/W
June	W	S	SW/S	SW/W	Variable
July	W	S	SW/S	SW/W	Variable
August	W	S	SW/S	SW/W	Variable
September	W	S	SW/S	SW/W	SW/S
October	Variable	Variable	SW	W/SW	SW/S
November	NE	W	E/NE	W	Variable
December	NE	NE	E/NE	N/NE	N/NE

Table 1 : Variable wind directions at selected locations in Malaysia

4 WIND LOADING ANALYSIS

4.1 Design Codes for Wind Loading

The estimation of wind loading for structural design in Malaysia is based on MS1553: Code of Practice on Wind Loading for Building Structures, 2002 [6]. The code is an adaptation of the Australian / New Zealand Standard , AS/NZS 1170.2: Structural Design - General Requirements and Design Action [7].

MS1553:2002 specifies the procedures to determine wind speed and resulting wind actions to be used in the design for structures subjected to wind actions other than those caused by tornadoes and typhoons. The standard covers structures within the criteria of (i) buildings of less than 200m high (ii) structures with roof span less than 100m and (iii) structures other than offshore structures, bridges and transmission lines.

4.2 Design Practices

Similar to most other national design codes for wind loading, the scope of MS 1553:2002 is limited to a small range of standard geometries, structures for which wind loading does not control the design. For the majority of conventional building structures the use of wind loading information in codes is perfectly adequate. However, for structures with an unusual geometry or with non-standard structural properties, it is often not possible to obtain accurate wind loading data from codes to achieve a reliable design. In these cases specialist studies are required to obtain the information required for safe and efficient design.

Typical calculations of design wind speeds for a site are based on estimated measured data or basic wind speed information in the design codes. The variation with direction and height is determined using established techniques based on the roughness and topography of the site.

As highlighted above, Malaysia experiences low wind speed however this does not mean that constructed buildings or structures are free from the consequential and adversarial effects of winds. For cities in Malaysia, particularly Kuala Lumpur, wind loads have become particularly significant because of increasing number of high-rise buildings. Other factors have also contributed to importance in wind design such as lightweight low-slope roofs, curtain wall construction and appearance of special structures having aerodynamic shapes. Recent events such as wind forces which blown off anchored lightweight roofs, and roofing materials (lifted by local suctions) and eventually peeled from large areas of roofs are new concerns faced by designers of high-rise buildings. These and many other problems have emphasized the importance of a clearer understanding of wind and its effect.

5. DESIGN CONSIDERATIONS

5.1 Tall Buildings

As buildings become tall and complex, it becomes imperative to account for wind loads. A close look will show that wind not only affects the load distribution pattern on buildings but it also influences various design parameters.

Wind effects are an extremely important aspect in the design of tall buildings. Wind loading can often be the dominant load case, with significant increases in loading due to dynamic effects Holmes, 2001 [2]. Dynamic response can also lead to high accelerations and swayed excessively in strong winds thus affecting occupant comfort. In addition, tall buildings tend to deflect high-level winds down to ground level, affecting the local wind environment at the base of the building.

Since wind is a complicated phenomenon due to its turbulent flow and erratic motions, architects and engineers are concerned with and responsible for not only structural design, but also the choice of exterior claddings and components, operation of mechanical services such as heating and ventilation equipment, and with details of openings to limit infiltration. Wind has important effects on each of these aspects of design.

The simplified approach assumes a uniform lateral pressure on windward side of a building and suction on leeward wall to represent the total effect of wind. Simplified rules were also used to calculate pressures or suctions on roofs. Only horizontal shear and overturning moments were calculated. For low or medium height buildings, such simple methods may have been reasonably satisfactory., but for tall buildings, the greater importance of wind loading calls for more accuracy [8].

Often, besides computer aided simulations, model scaled tall buildings are tested in commercial wind tunnels during design stage to determine the likely loads under both service-level and extreme wind events.

The Petronas Twin Towers, currently the second tallest buildings in the world, standing at 452 m in height with an aspect ratio of 8.64 were designed using design wind speed for Kuala Lumpur area i.e. 35.1m/s (65 mph) , peak 3-second gust at 10m (33ft) above grade for a 50-year return period. The structural properties, mass and damping of the building were carefully designed to eliminate occupant perception of wind movements and accelerations. The 10-year return peak total accelerations on the upper floors is in the range of 20milli-g, which are well within acceptable criteria.

5.2 Low Rise Buildings

Various interviews with designers in Kuala Lumpur indicated equal concerns for wind loadings on low rise buildings. Recent trend in the use of fabric structures or other unconventional low rise buildings has resulted in unusually increased of the used of boundary layer wind tunnel tests to verify design pressures. Of main concerns are the damages to the roofs of these less engineered structures under extreme winds. Holmes and Reardon (1997) made various references and highlighted the importance of wind effects upon the design of low rise buildings.

5.3. Effects of Neighbouring Buildings

Like any other urban areas and major cities, the number of high rise buildings in Kuala Lumpur have increased quite considerably in the past two decades. The construction of new building developments can have a significant effect on the surrounding wind climate due to the change in the local wind flow caused by the building. In some cases high-speed winds are deflected down to ground level resulting in uncomfortable wind conditions for the users of the building and the pedestrians in the surrounding streets. The impact of the local wind environment is dependent on the intended use of the external areas surrounding a development. For example, a space intended for recreational activities will be far more sensitive to frequent high winds than an area intended for general access. Because of the complexities of wind flows in the built environment, wind environment is not covered by design codes. Consequently, special studies are required to assess the impact of major building developments on the local wind environment.

Wind loads on buildings which were surrounded by neighbouring buildings may be considerably different from those measured on isolated buildings. Harris [9] found that the torque on the Empire State Building in New York would be doubled if two building blocks are built across the two streets adjacent to the building. Other works included attempts to determine the general relationships between wind-speed and the distribution of wind-speed and the distribution of wind pressure over slope, flat and stepped roofed building under exposed conditions and when in close proximity to other buildings. Other studies include shielding effects of upstream buildings, aero-

dynamic interference due to tall buildings, interference effects due to groups of buildings and flow visualization studies to explain the phenomenon of interference [10].
Although a considerable amount of works were undertaken there were only a few comprehensive and generalised set of guidelines for wind loading modification caused by adjacent buildings. The lack of guidelines may be due to. firstly, the complex nature of the problem even for a single additional building. Secondly, the scarcity of experimental data. Thirdly, the widely held notion that wind loads on buildings are expected top be less severe if surrounded by other structures compared to in isolation. The last reason is argumentative where only two or three buildings interact, since several other studies indicated adverse effects de structures which can change the air flow directly depending upon the relative location of these buildings. The parameters which cause wind induced interference effects include shape of the buildings, wind velocity and direction, type of approach terrain, arrangements of buildings and the location of proximity of neighbouring buildings [11]..

With the complexity of wind phenomena on buildings designers often have to rely on wind tunnel tests in order to achieve an economical design for the project. Accommodating the forces due to wind acting on the cladding is a major factor in the design and budget for building projects. In accounting for the wind forces, design engineers have to choose between simplified calculation methods provided in local building codes or the more accurate approach of wind-tunnel testing. The economics of simple projects may benefit from the application of code calculations. However, more complex and for those with non-standard design features can benefit from wind tunnel testing, often reducing the overall project cost while increasing confidence that a safe design will be achieved.

CONCLUSIONS

The structural design practices in Malaysia accounts for wind actions described in MS1553: Code of Practice on Wind Loading for Building Structures, 2002. Due to low wind speed and corresponding low wind loading, generally, buildings in Malaysia do not experience extensive damages due to extreme wind events. In urban areas, design of major projects focused on the impacts of winds due to neighbouring structures as these have critical effects on the safety of buildings and economics of the projects. Concerns on low rise design are also increasing as many of these less engineered buildings suffered damages during extreme winds.

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