“I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Mechanical Engineering (Thermal-Fluid)”

Signature : ....

Name of Supervisor : Mr. Cheng See Yuan

Date : 29/5/06

STUDY OF WIND PRESSURE DISTRIBUTION AROUND LOW-RISE BUILDING BY USING CFD METHOD

FAIZUL BIN AHMAD

This thesis is submitted to Mechanical Engineering Faculty in partial fulfillment of the requirements for the award of Bachelor Degree in Mechanical Engineering (Thermal-Fluid)

Faculty of Mechanical Engineering
Kolej Universiti Teknikal Kebangsaan Malaysia

May 2006

"I hereby declare that this thesis entitled "Study of wind pressure distribution around low-rise building by using CFD method" is the result of my own research except as cited in the references"

Signature : ....

Name : Faizul Bin Ahmad

Date : 29/05/2006

A special thanks to my project supervisor Mr. Cheng See Yuan, my beloved family and all my beloved friends for your guidance, strong support and encouragement…

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ABSTRACT

This project is all about the study of wind pressure distribution around low-rise building by using CFD method. The objectives of this project are to determine the effects of low-rise building configuration on the wind pressure and to predict the wind pressure distribution around low-rise building by using CFD. There are some variables that can effects the wind pressure distribution around low-rise building such as wind speed, wind direction, type of the roof, shape of the building and the shield around the building. The simulations were running in different model design based on the variables to find the pattern of wind pressure distribution. Simulations were running by using Ansys CFX-5.7. The results showed that there are different pattern of wind pressure distribution and wind speed flow pattern for each models. The windward area will show the high pressure value than the leeward area which the leeward area was the negative pressure is because of it was the suction are.

ABSTRAK

Projek ini merupakan kajian mengenai taburan tekanan angin di sekeliling bangunan rendah dengan menggunakan kaedah CFD. Objektif projek ini adalah untuk menentukan kesan konfigurasi bangunan rendah terhadap taburan tekanan udara dan untuk meramalkan taburan tekanan angin di sekeliling banggunan rendah dengan menggunakan kaedah CFD. Terdapat beberapa pembolehubah yang boleh memberi kesan kepada taburan tekanan angin di sekiling rumah rendah seperti halaju angin, arah angin, jenis bumbung, bentuk bangunan dan halangan di sekeliling bangunan. Simulasi dijalankan dengan menggunakan model yang berbeza berdasarkan kepada pembolehubah untuk mendapatkan corak taburan tekanan angin. Simulasi dijalankan dengan menggunakan perisian Ansys CFX-5.7. keputusan yang diperolehi menunjukkan perbezaan corak taburan tekanan angin dan corak aliran halaju udara bagi setiap model. Kawan yang menghadap arah angina akan menunjukkan nilai tekanan yang tinggi berbanding kawasan lindungan yang mempunyai nilai tekanan negatif disebabkan kawansan tersebut merupakan kawasan sedutan.

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LIST OF SYMBOL

SYMBOL	DEFINITION
P	Pressure
v	Velocity
ρ	Density
q	Kinetic Energy

LIST OF ABBREVIATION

ABBREVIATION	DEFINITION
CFD	Computational Fluid Dynamics

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CHAPTER I

INTRODUCTION

1.1 Project Background

In this project, the effects of low-rise building configuration on the wind pressure are need to determine and the wind pressure distribution around low-rise building by using CFD simulation is needed to predict.

1.1.1 Wind Pressure

Wind is caused by pressure gradients which the change in air pressure with distance. Wind is an attempt to equalize the pressure differential. This differential is the result of unequal heating of different portions of the Earth's surface. Wind acts in all directions because the atmosphere is a gas. In the atmosphere as air is heated it expands. Because it expands it becomes less dense and therefore, rises. This creates an area of low pressure at the surface. As the warm air rises it begins to cool, eventually causing it to sink back to the surface creating an area of high pressure. In general, air flows towards areas of low pressure and away from areas of high pressure.

The principal wind characteristics are speed and direction [1]. The direction of a wind is the direction from which it blows. A north wind comes out of the north and blows southward, while a west wind comes out of the west and blows eastward. Wind direction is best described by its azimuth, measured clockwise from north from 0° to 360°. An approximate means of expressing wind direction that is usually quite accurate enough is to use points of the compass in the wind rose.

There are 8 points could be used: North (N), North East (NE), East (E), South East (SE), South (S), South West (SW), West (W), North West (NW). Four points is a bit too crude; N, E, S and W. Wind direction is measured with a rotating vane.

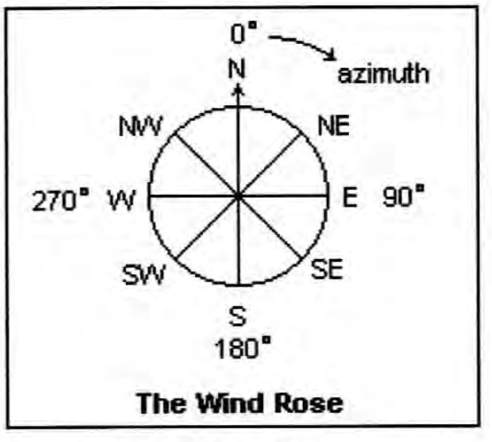

Figure 1.1 : The Wind Rose

Wind is one of the significant forces of nature that must be considered in the design of buildings. Structural loads applied by high winds are readily appreciated, even if the method of determining them is not so easily understood. Other effects that can be caused even by moderate breezes are commonly overlooked, however, because very often there is no obvious link between wind and the behavior of a building [8].

Wind pressures exerted on a structure depend on the speed of the wind as well as the interaction between the air flow and the structure. Since wind is air in motion the pressures it can exert are related to its kinetic energy. The kinetic energy will transformed into pressure then the resulting increase is given by the expression

$$\text{Kinetic Energy, } q = \tfrac{1}{2}\rho V^2$$

where ρ is the mass density and V the velocity of the air. This is called the "stagnation pressure" and is the maximum positive increase over ambient pressure that can be exerted on a building surface by wind of any given speed. It is the basic pressure to which all other pressures over the structure are referred.

When wind strikes a simple structure such as a free standing wall, the streamlines in line with the wall are forced, to diverge and pass around the edges. The direction and magnitude of the original wind velocity are therefore altered by the encounter and cause changes in pressure [6].

Pressure is not usually constant over a wall or roof surface; but to simplify design procedures an average coefficient is specified for a given surface; when multiplied by the area and the basic pressure it gives the total force on the surface. The net force on the free standing wall would of course be the result of both the pressure on the windward side and the suction on the leeward side. Correspondingly, for an exterior wall of a building the net pressure on the wall would be the difference in pressures outside and inside the building, the inside pressure being a function of openings, as is discussed later [7].

Figure 1.2 illustrates a more complicated shape and the flow lines associated with it. For buildings with flat and low-sloped roofs the windward wall is the only surface subjected to pressure; all other surfaces are located in the wake where pressures are below the ambient.

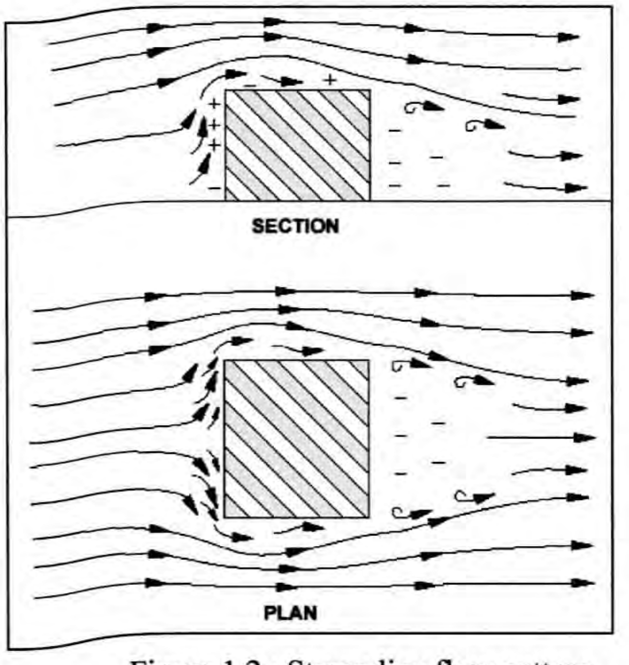

Figure 1.2 : Streamline flow pattern

The reason for this is again that the flow lines deflected around the windward edges are unable to "cling" to the building surfaces as they pass around the sharp corners and a separation occurs between the wind and the building. Figure 1.3 is a cross-section of the pressure distribution on the building. It A should be noted that the pressures are not uniform and that, in particular, certain small areas experience suctions much higher than the average.

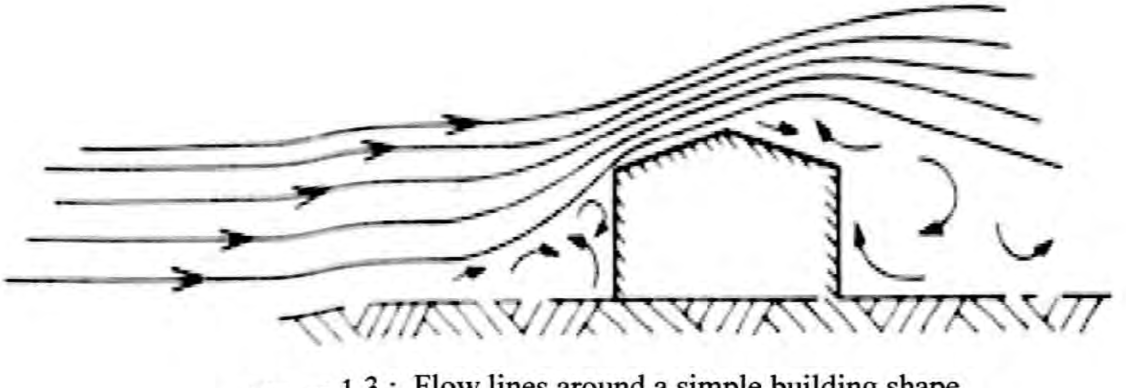

Figure 1.3 : Flow lines around a simple building shape

Some variables that can effect the pressure distribution are:

- The shape of the building.
- The size and location of openings such as windows and doors.
- The wind direction.
- The increasing of wind speed with height of building.
- The shielding around the building such as other building, trees, and similar large objects.

Building Shape

Pressures on certain parts of a structure are rather sensitive to changes in the shape of the building. The suctions on the windward roof slope, for instance, vary considerably with the slope of the roof, the ratio of height to width, and the ratio of width to length of the building. Suctions on the leeward wall, on the other hand, are not greatly affected by such variables.

Openings

The size and location of openings such as windows and doors determine the internal pressure that must be considered in the calculation of net forces on walls and roofs. Internal pressures tend to take on the values appropriate to the exterior of the wall in which the openings predominate.

Wind Direction

The orientation of a building to the wind has a marked effect on pressure distribution, particularly on suction maxima, which occur over a small area near the leading edges of roofs.

Increase of Wind Speed with Height

Since the wind speed and consequently the velocity pressure increase with height above the ground, a height factor is applied to the basic pressure in the design of buildings.

Shielding

Other buildings, trees and similar large objects in the immediate vicinity have a bearing on pressure distribution. The shielding provided is usually difficult to estimate, and model tests provide the most convenient means of determining design values. The assignment of reductions for shielding is complicated by the fact that conditions could change during the life of the structure. Shielding does not always have a beneficial effect, and in some cases suction coefficients should be increased because of the proximity of a neighboring building.

There also have some variable can effecting the pressure distribution from type of designing, structure or various parts of building such as roof, windward slope, local suction, wall and shielding.

Roofs

The roof is usually the critical area in the wind design of low buildings, particularly residential structures. Where it is made up of light-weight components particular attention must be paid to anchorage details because of the suction condition prevailing over most, if not all, of it.

Local Suctions

Local suctions are most serious for wind at an angle (usually about 45 degrees) to the side of the building. Local pressure coefficients of -2.0 are not unusual, and in certain model studies values down to -5.0 have been measured over very small areas near corners projecting into the wind; this indicates the importance of proper fastening of roof coverings at such points.

Walls

For tall, slender structures the design of the walls and the frame, with regard to overturning moment, are likely to be critical. The trend toward high-rise buildings and curtain wall construction may lead to greater problems in limiting sway and in specifying the strength of fastenings for wall panels. Although average coefficients for leeward and side walls are only -0.5 to -0.7 high suctions occur just around the corners from the windward edges, and where stagnation pressures are high (near the top of tall buildings) these local suctions may be appreciable (possibly as high as -1.5).

Shielding

Model tests investigating the effects of building proximity have shown that where two buildings are close together rather high suctions may occur on the facing walls if the wind blows parallel to the "alley" between them. Average values of -1.0 have been measured, with local suctions along the windward edges as high as -2.0.

1.1.2 Low-rise Building

Building is either the act of creating an object assembled from more than one element, or the object itself; see also construction. A building is usually a human-created object composed of more than a single element, permanently fixed to the ground that mediates one or more aspects of the environment. Buildings may be as simple as a lone roof providing shelter from the rain for a single occupant, or as complex as a hospital regulating temperature, air flow, light, gas content, bacteria movement, particle flow, pressure, and people movement and activities [5].

In building configurations, shape and surroundings of any building plays a very import role in governing the energy consumption in any building. Such factors may cause heat gain when cooling is required and heat loss when heat gain is required. For any given enclosed building volume, there are numerous ways in which actual dimensions of height, length and breadth can vary resulting in different total surface areas. Thus two buildings, both having the same volume and built of the same materials, may have quiet different surface areas and hence different rate of heat loss and heat gain [6].

The ways the volume and surfaces of the building are oriented also severely affect the heat gain or loss from a building. This is best illustrated when we consider the sol air temperature effect for faces of the buildings in certain orientations. The building configuration may be such that they shade each other mutually. The amount and effectiveness of the shading, however, depends on the type of building clusters. Martin and March (1972) have classified building clusters into three basic types, i.e. pavilions, streets and courts. "Pavilions" are isolated buildings single or in clusters, surrounded by large open spaces. The "street" comprises of long building blocks arranged in parallel rows, separated by actual streets as open spaces. "Courts" are defined as open spaces surrounded by buildings on all sides.

A low-rise building is defined as any occupiable building which is divided at regular intervals into occupiable levels which is lower than a high-rise. To be considered a low-rise building an edifice must be based on solid ground, and fabricated along its full height through deliberate processes (as opposed to naturally-occurring formations) and have at least one floor above ground [2].

Low-rise buildings are generally considered for inclusion in the database when they meet one of the following criteria:

- Buildings associated with major architects or other major building companies.
- Buildings which are especially prominent because of their size or position.
- Any buildings housing commercial uses.
- Buildings added at the request of a company.
- Buildings of significant historical or architectural interest.

General descriptions about low-rise building are:

- Low-rise building is relating to a building having few stories and often no elevators.