FORCE PATTERN IN ROOFING SYSTEM DUE TO WIND LOAD

NADIA FAIRA MAT ZALI

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Faculty of Civil Engineering & Earth Resources
Universiti Malaysia Pahang

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ABSTRACT

Recently there are numbers of records regarding damages of the roofing system in Malaysia due to windstorm. In order to avoid the loss of properties a study had been carried out to avoid damages. The objective of this study is to determine the force pattern in roofing system due to wind load. To resist windstorm wind tunnel testing data are used to examine the roofing system. Result from the study showed that the forces that react to the roof are large in shear force rather than tension force (uplift force). From the results, it can be conclude that roofing system need to be strengthen to resist the shear force. Unfortunately, most designer neglected this factor. Hence, to avoid damages to the roofing system, a guideline in using bolt connection in roofing system had been produced in this study.

ABSTRAK

Dewasa ini, berita tentang kerosakan struktur bumbung yang disebabkan oleh ribut sering diperkatakan. Bencana ini telah mengakibatkan banyak harta benda musnah. Sebagai langkah pencegahan, satu kajian telah dilakukan untuk mengekang kejadian yang tidak diingini ini daripada terus berlaku. Tujuan kajian ini adalah untuk mendapatkan pola daya angin yang bertindak ke atas struktur bumbung. Bagi menahan angin kencang yang di hasilkan oleh ribut, data daripada ujian terowong angin telah digunakan untuk kajian ini. Keputusan kajian ini menunjukkan daya ricih yang bertindak ke atas struktuk bumbung adalah tinggi berbanding daripada daya tegangan. Oleh yang demikian, struktur bumbung perlu diperkasakan untuk menahan daya ricih yang tinggi. Walau bagaimanapun, kebanyakan jurutera yang merangka struktur bumbung telah mengabaikan faktor ini. Hasil daripada kajian ini, satu tatacara penggunaan bolt telah dihasilkan bagi memudahkan jurutera merujuk ketika merangka sistem bumbung pada masa akan datang.

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Roof is the top part of a building. Roof will protect the building from damage, especially water and storm. A proper roof will not only function as shelter and protection from the weather but also will make buildings look aesthetically pleasing. Unfortunately sometimes people do ignore about its capability in resisting load especially wind load. They only concentrate on constructing and designing other member like beam, column and even the foundation. Whereas there are so many damages occurred due to the wind load in roofing system.

As in the media, there are so many cases that been reported due to failure of roofing system due to the wind load especially in rainstorm. People may not note this issues as a big one since the tragedy did not sacrifice life. Yet it is still ruining the property and to fix those things, its need a large sum of money. Prevention is better than cure. Based on that statement it is reasonable and the best way to avoiding the failure of structure especially due to wind load since it is can be avoided just only by designed the roofing system properly.

In this kind of cases, bolts in roofing system do play vital roles. There are many types of bolts that can be used in roofing system structure. There are as shown in table 1.1. A325high-strength carbon steel bolts and A490 steel bolts are been used widely in construction world.

Table 1.1 Types of Bolts (Geoffrey L. Kulak, 2001)

ASTM	Description
A307, Grade A	Low carbon steel bolts and other fasteners
A325	High-strength medium carbon steel bolts, plain finish, weathering steel finish or galvanized finish.
A490	Alloy steel bolts
A449 and A354	High strength bolt such as interference body bolts swedge bolts and other externally threaded fastener or nuts with special locking devices.

1.2 Problem Statement

These recent years, there are bunches of news that saying about failure of structure due to wind loads. To be more specific, it is about failure of roofing system. From the failure, it will take a large amount of money to fix up all the mess. Besides from having a lot of losses, it will also affect the accommodation and will not be safe to be used.

For example, there are a few cases in Malaysia regarding the failure of roofing system due to wind load. First case is involving computer's laboratory in school building. The place has so many innocent lives. When something bad like this happen to this kind of place, it is not secure for school kids to study in here. In fact, the electric short circuit may happen if the roof had been exposed since the raindrop can entered inside the building. Computer class lesson for this school may be interrupted for a while. The kids' lesson may be left behind since the class cannot be done.

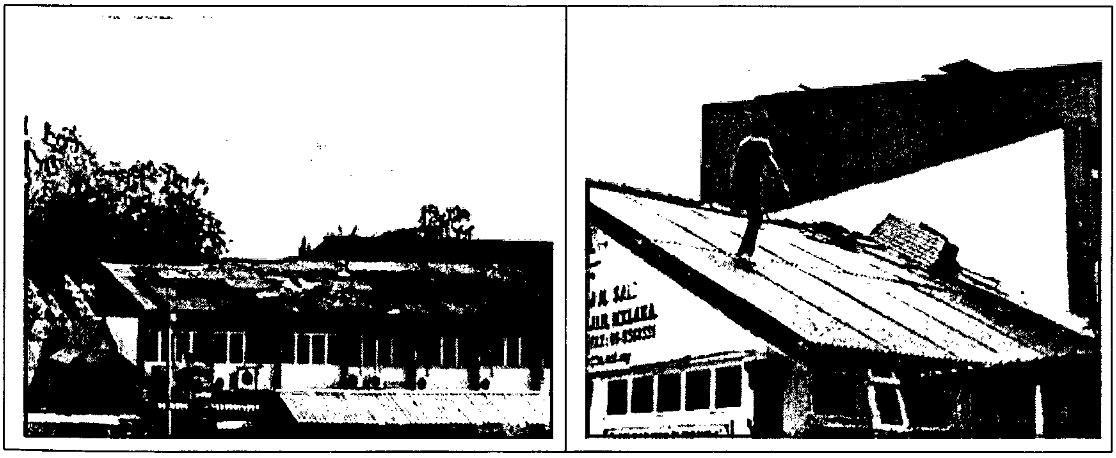

Figure 1.1 Damage Roof (puassmkdds, 2011)

Other than that, residential area also one of the building that commonly been affected by wind load in windstorm. Ii is very harmful to the residence. All the material that had been flew away will be scattered all over the places. The worst part is the thing flew and will hit any individual that passing through the area. Besides, when the roofing system fails, it will trap people inside the building. Here, if the roof fell on the individual in that building, it will make the person injured. So it is very unsafe to be in the building with poor roofing system.

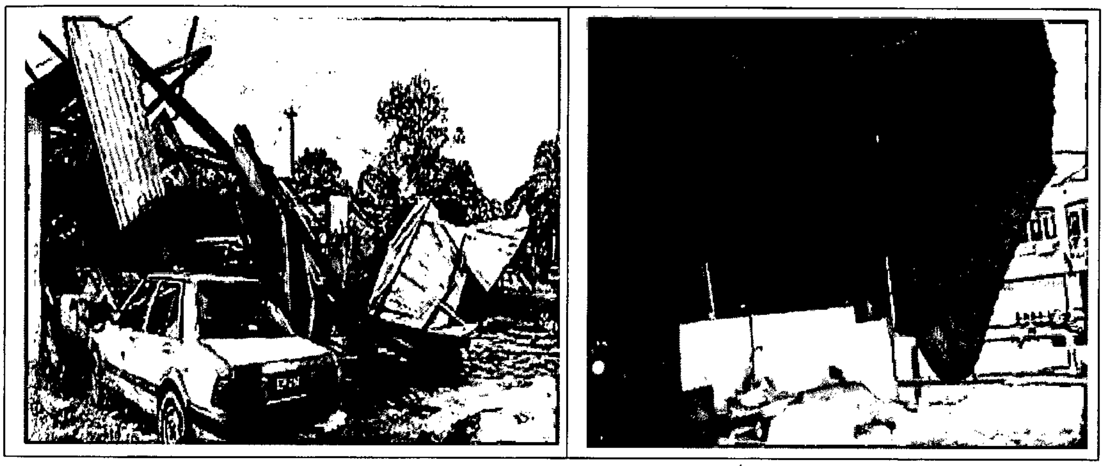

Figure 1.2 Damage Roof (Berita Harian, 2011)

1.3 Objectives

Analysis of wind effect to the structure has become a vital scope in designing. As in Malaysia, there a not much nature disaster and the least one is only windstorm. When this phenomenon happen, structure that always been effected is roofing system. Basically roofs of the building, for instance houses or shop lots roofs will flew away by that strong wind load. It is better if these incidents do not repeated over and over again.

This study do consist several objectives. There are:

i. To determine the load pattern of roofing system due to the variation of wind load.

ii. To produce a guideline in fixing bolt connection in roofing system.

1.4 Scope of Work

The scope of this study is to find a way to complete the objectives. This study will concentrate in determining the maximum uplift force due to wind load in typical roof truss. It is about the relation between the strength of the joint and its length and also the roof slope. The strength will be determined using sap2000 software. The entire maximum load that the bolt can resist will be taken from previous research. All the specific strength of the join in roofing system will be taken from the previous research that had been done by others.

1.5 Significant of Study

Based on the previous research, researcher already studies about the pull-out strength of the bolt. Since the objectives of this study is to determine the effect of wind load due to the variation of wind speed to the roofing systems in Malaysia, it can helping people in increasing the factor of safety of the roof. Besides, this study also will produce a guideline for the bolt strength. As a conclusion, the guideline will help people to determine the suitable strength of the bolt and its capability.

1.6 Structure of Thesis

This thesis consist five chapters. First chapter is about the introduction of the study. It is also defining background of the study and the entire objectives. Second chapter is literature review. This chapter is discussing on previous study which is quite related to this study. Third chapter is about methodology. In this middle chapter all the process and flow to gain results will be discussed. Chapter four will shows all the results that had been gained from this study. Discussion about the results also will be concluding in this chapter. Last chapter is for conclusion and several recommendations will be suggested.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss about damages due to the wind hazard. In these past years, many damages and injuries come from windstorms. Wind is complicated phenomenon which its existence cannot be predicted. People may not realize about wind hazard had become one of the contributor in natural disaster. As in Malaysia wind hazard is very rarely immolate life. By having that fact people do not realize that windstorm do demolish belongings and assets. Those assets are including building structure. Sometimes, people only alert when the damages are in huge scale. When the damages are only a part from the structure, people just take it for granted as it is not harm to them. In the reality when natural hazard occur, all risk should be considered. There is a scale in determining level of structure damage.

Table 2.1 Wind Storms, Damages and Guidelines Measures
(Dr. N.M. Bhandari, 2003)

Structure / Scale	Marginal	Medium	Heavy	Total
Roof of non-engineered and semi-engineered construction and walls with thatch AC sheets and other sheets.	A few connection loosened or damaged	Roof cladding in bad condition or blown off partially (< 50%), wall posts titled, and sagging of roof	Roof cladding blown off with damage to runner, bracing of walls and posts	Roof totally damage
Damage to wall made of mud, reinforced mud, and brick/ stone/ cement concrete block masonry.	Minor cracks in walls, plaster peeled off, moisture penetration noticed on inside wall	Large cracks in wall, no tilt, plaster peeled off, wall material weathered at reaction locations	Wall titled with or without cracks, portion of wall damaged or partial collapse.	Failure of the wall.
Foundation	Few settlement cracks below plinth level.	Large settlement cracks below plinth level, posts titled with gap noticed in soil, noticeable cracks in tie beams.	A portion of foundation fully separated, large tilting/pull out of posts, separation between tie beam and pile, pile tilted.	Failure of foundations.

Roof of industrial structures with AC/metal sheet cladding	A few J bolts disturbed/corroded, sheet broken over small area.	Large number of J bolts disturbed, a few sheets (<25%) blown off, some elements of truss/buildings bent, noticeable sagging of roof truss.	AC sheets blown off, a few trusses bent/out of alignment, failure of a few joints.	Failure of a few trusses
Columns of industrial sheds	A few bolts in built up columns are loose/corroded, bed plates between truss and column or foundation and column not fully matched, minor cracks in reinforced concrete columns.	A few ties/braces in built up columns are corroded, a number of bolts in connection corroded, opening up of mating surfaces at top and bottom with clearly visible separation, structural cracks in reinforced columns exceeding 0.3mm crack width, no tilt of column.	Column tilted inward or outward, large deformations with elongation of holes in ties/braces, failure of a few braces, excessive cracking in reinforced concrete columns, deformations of anchor bolts.	Large tilt or total failure of columns.

2.2 Malaysia's wind speed

Malaysia is located in tropics area in Southeast Asia. Its mainland is bordering with Thailand and its northern is one-third of the island of Borneo which is bordering Indonesia, Brunei, south of Vietnam and also the South China Sea. Malaysia's geographical coordinates is 2 30 N, 112 30 E. The total area of Malaysia is 329750 sq. km. It's been covered with 328550 sq. km land area. Malaysia is mountainous surface and is peak is about 2000m. In addition the country is surrounded by the sea so that it received a lot of rain in a year. "The rainfall is heavy and usually occurs in the form of thunderstorm."(Faridah Shafii, 2006).

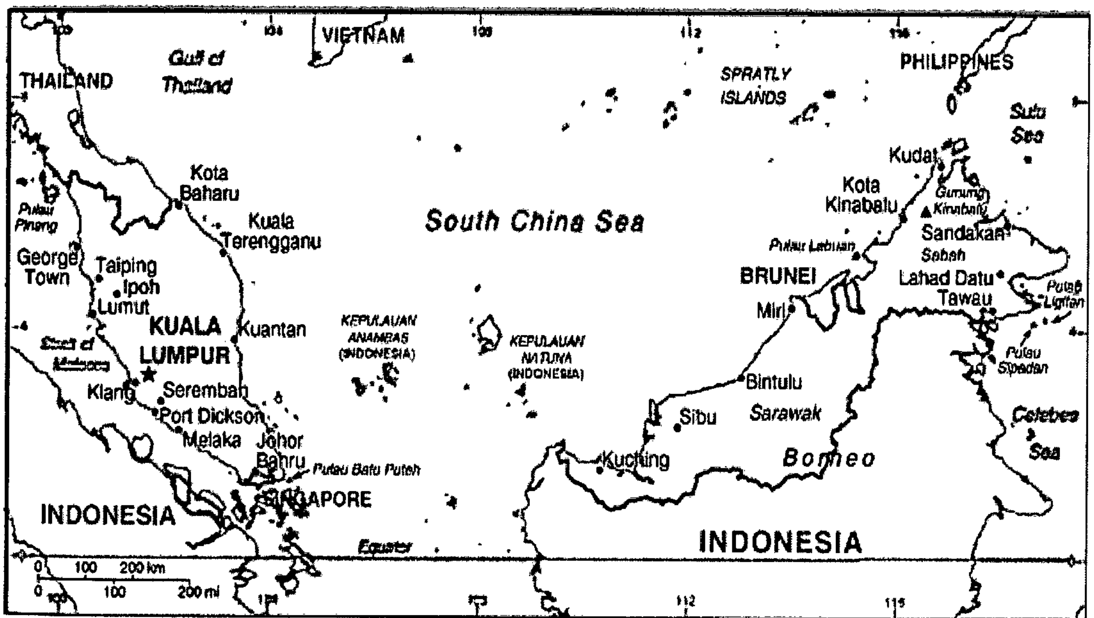

Figure 2.1 Map of Malaysia
(Source: http://www.malaxi.com/malaysia_map.htm, 2011)

Malaysia does have generally light wind flow. However this light wind flow may change due to the monsoon seasons and Malaysia does have two different monsoon seasons. There are southwest monsoon and northeast monsoon. Besides there is also two shorter periods of intermonsoon seasons. During these two intermonsoon seasons the wind is generally light. Southwest monsoon is typically occur in the half end of May or early June and end up in September. The normal wind flow in this season is below 15 knots. For the other monsoon, northeast monsoon usually begins in early November and will end in March. Basically wind will blow up till 10 to 20 knots. However the wind over the east states of Malaysia's mainland can reach up till 30 knots or more during this period.

In early April till November, typhoon usually occur over the West Pacific and move to the west across the Philippines, southwesterly winds over the northwest coast of East Malaysia and the strength of the wind may reach till 20 knots or more. Malaysia is one of maritime country. Sea breezes can reach up till 10 to 15 knots on the sunny bright afternoon and its can be till several tens kilometers. Land breezes will take place in the nights and it will develop over the coastal area. All These seasons made Malaysia has average temperature around 20-30°C. Tropics mean received heavy rainfall all the year. Malaysia does received plenty rainfall per year. Annual rainfall for Malaysia is 2500mm. Normally rain in here will accompanied by thunder and lightning. When thunderstorms occur, the wind will blow stronger. So when this phenomenon happen, it is normal to have small damage to any structure.

2.3 Design Practice

All design will have its own reference to be referred to. For instance for reinforced concrete design will be referred to BS 1880 and for steelwork in building, BS 5950-1:2000 will be used. As for wind load, Malaysian will used MS 1553:2002. This standard is quite limited to a small range of typical geometries structures. As in designing buildings, design wind speed should be determined. Here is the equation to determine wind pressure;

$$P_s = 0.5\rho_{\mathrm{air}} V_{des}^{\;2} C_{fig} C_{dyn}$$

ρ_{air} = density of air which can be taken as 1.223 kgm^{-3} ; and $0.5\rho_{air}$ is 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

V_{des} = V_{sit} x I

The wind speed, V_{sit} is define by expression

$$V_{sit} = V_s (M_d)(M_{z,cat})(M_s)(M_h)$$

In determining V_s, table and zone map should be used. However, Zone map for Malaysia Borneo has not been provided due to ongoing research.

Station wind speed for all directions based on 3-second gust wind data is given in table 2.1 for the regions shown in figure 2.0 V100 is the wind speed for a return period of 100 years, V50 for 50 years and V20 for 20 years.

I = importance factor (gain be gained in table 2.2)

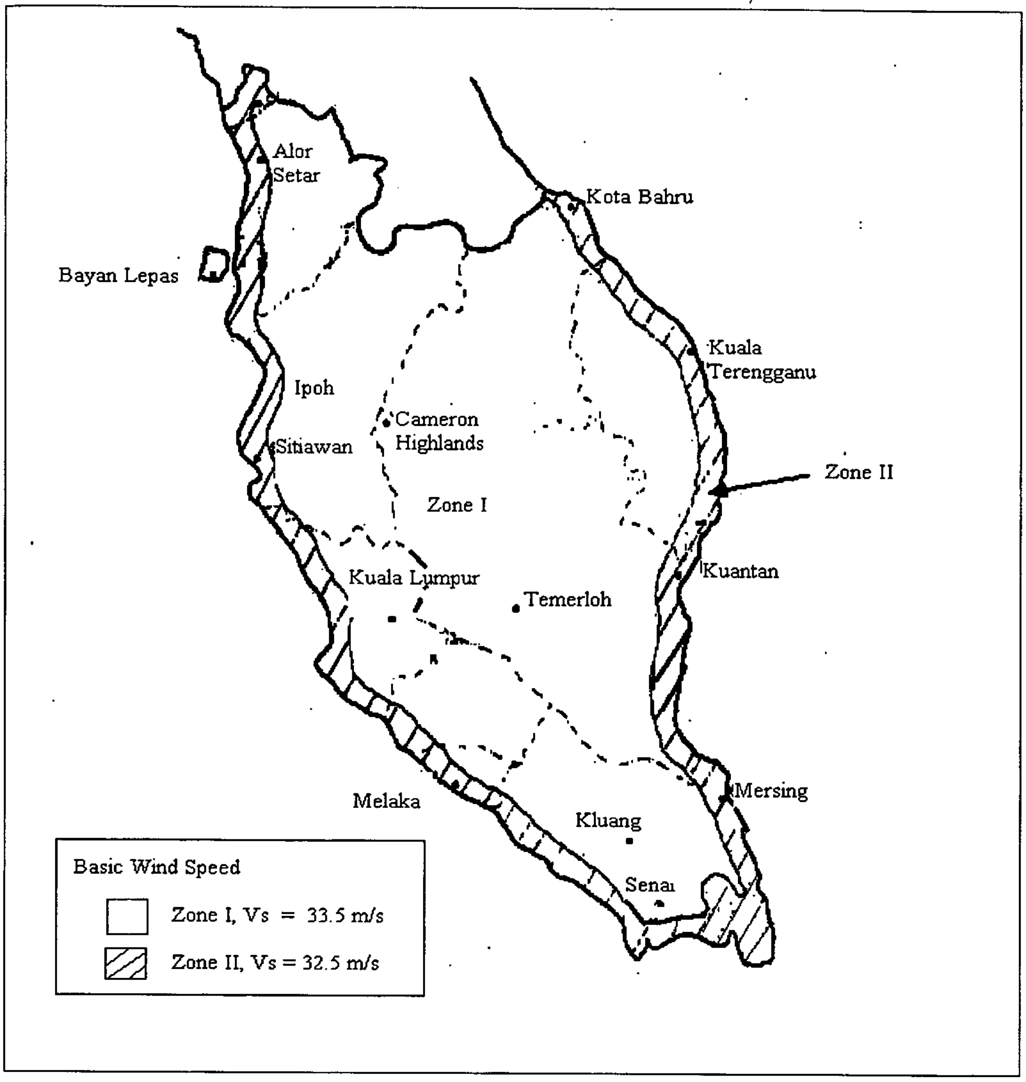

Figure 2.2 Peninsular Malaysia (MS 1553, 2002)

Table 2.2 Wind speed (ms^{-1}) 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)
Chuping	23.8	25.6	27.0
Alor Setar	27.2	29.9	31.8
Bayan Lepas	25.6	27.5	28.9
Butterworth	24.6	26.4	27.7
Ipoh	30.6	33.5	35.7
Sitiawan	23.3	25.3	26.7
Batu Embun	25.3	27.5	28.9
Cameron Highlands	25.2	26.8	28.0
Subang	29.2	32.1	34.3
Petaling Jaya	28.8	31.4	33.4
Melaka	26.7	29.4	31.3
Kluang	29.6	32.6	34.9
Senai	26.9	29.1	30.7
Mersing	29.5	32.0	33.8
Muadzam Shah	22.6	24.4	25.8
Temerloh	25.1	27.4	29.1
Kuantan	27.5	29.8	31.6
Kuala Terengganu	25.5	27.2	28.5
Kota Bahru	30.0	32.4	34.2
Kuala Krai	27.2	29.5	31.3
Kota Kinabalu	28.3	30.5	32.2
Kudat	27.1	29.1	30.6
Tawau	24.6	26.6	28.1
Sandakan	23.4	25.8	27.7
Labuan	26.0	27.7	29.0
Kuching	29.5	32.6	34.9
Miri	26.9	29.0	30.5
Sri Aman	27.6	30.3	32.4
Sibu	27.0	29.3	31.0
Bintulu	23.9	25.6	26.9

Table 2.3 Importance factor, *I* (MS 1553, 2002)

Nature Of Occupancy	Category of Structure	*I*
Buildings and structures that represent low hazard to human life in the event of failure such as agricultural facilities, temporary facilities and minor storage facilities.	I	0.87
All building and structure except those listed in category I, II, III and IV	II	1.0
Buildings and structures where the primary occupancy is one in which more than 300 people congregate in one area	III	1.15
Essential buildings and structures Hospital and medical facilities Fire and police stations, Defense Shelter Structures and equipment in civil defense Communication centers and other emergency utilities	IV	1.15