FAILURE OF ROOF TRUSS DUE TO EXTREME WIND IN MALAYSIA : A STUDY ON CONSULTANT PERSPECTIVE

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ABSTRACT

High wind speeds pose a threat to the integrity of structures, particularly those at exposed sites such as roof truss structure. In any design project for especially for tall structures, accurate estimation of the occurrence of extreme wind speeds is an important factor in achieving the correct balance. The case reported in the Sinar Harian on 1 October 2013, severe damage of properties happen because of the roof truss that made from 65 meters iron at Supermarket Xiri that located at Batu 2 Jalan Kuala Berang was collapsed due to extreme wind. Other than that, Harian Metro also reported the same incident that happened in Kampung Manjoi, Perak on 11 May 2013 at 6.45 PM which is at least about 23 houses damages due to strong wind especially in the roof structure. The major problems that cause this roof failure will be investigate especially on consultant perspective whether the mistake comes from the calculation in design stage or from the construction materials or construction methods that have been implemented over these years. The main objectives of this research is to investigate the roof structure system that frequently fails during extreme wind event and also to determines the problems of the roofing system under extreme wind load in accordance with Malaysian consultation industry practices. For this study, it is taken on the combined quantitative and qualitative approach of research with the use of the survey questionnaire and published literatures. With base SPSS, data collection that get from Google Doc can be manage with case selection, file reshaping, and creating derived data and this research will able to obtain the advantages of both quantitative and qualitative approaches and overcome their limitations. By doing analysing and data findings using SPSS, the result clearly shows the causes of roof truss failure due to extreme wind in Malaysia, the roof truss design consideration and also some effective methods to overcome the problem of roof truss failure due to extreme wind in Malaysia. Determination of the failure whether in design stage or others consultant factors have been done and it can be conclude that the failure is not comes from the design stage but it is comes from the other consultant factors. There are four recommendations which is undertake research to improve the understanding of extreme wind loadings, develop guidelines for the design of roof structures subject to extreme wind loadings, mandatory levels be set for independent third party design review and construction monitoring assisted by appropriately qualified people and structural engineers be required to identify on the drawings collapse critical components of important roof structures subject to extreme wind loading. The research effort produced valuable outcomes that become a references and basis for the study regarding to wind disaster.

ABSTRAK

Kelajuan angin yang tinggi menimbulkan ancaman kepada keteguhan sesebuah struktur, terutamanya struktur di tapak terdedah seperti struktur kekuda bumbung. Dalam mana-mana reka bentuk projek terutamanya bagi struktur yang tinggi, anggaran tepat berlakunya kelajuan angin kuat adalah faktor penting dalam mencapai keseimbangan yang betul. Kes yang dilaporkan dalam Sinar Harian pada 1 Oktober 2013, kerosakan yang teruk telah berlaku kerana kekuda bumbung yang diperbuat daripada 65 meter besi di Supermarket Xiri yang terletak di Batu 2 Jalan Kuala Berang telah runtuh disebabkan oleh angin kuat. Selain itu, Harian Metro turut melaporkan insiden yang sama yang berlaku di Kampung Manjoi, Perak pada 11 Mei 2013 pada 6:45 petang yang sekurang-kurangnya kira-kira 23 buah rumah rosak kerana angin yang kuat terutamanya pada struktur bumbung. Masalah-masalah utama yang menyebabkan kegagalan bumbung ini akan disiasat terutamanya dari perspektif pakar runding sama ada kesilapan yang datang dari pengiraan di peringkat reka bentuk atau dari bahan binaan ataupun dari kaedah pembinaan yang telah dilaksanakan sepanjang tahun-tahun ini. Objektif utama kajian ini adalah untuk menyiasat sistem struktur bumbung yang sering gagal semasa bencana angin yang kuat dan juga untuk menentukan masalah-masalah sistem bumbung di bawah beban angin kuat mengikut amalan industri perundingan Malaysia. Untuk kajian ini, ia dibawa kepada pendekatan kuantitatif dan kualitatif gabungan penyelidikan dengan menggunakan soal selidik tinjauan dan kesusasteraan diterbitkan. Dengan asas SPSS, pengumpulan data yang dapat daripada Google Doc boleh diuruskan dengan pemilihan kes, membentuk fail semula, dan mewujudkan data yang diperolehi dan kajian ini akan mendapatkan kelebihan kedua-dua pendekatan kuantitatif dan kualitatif dan mengatasi halagan. Dengan cara menganalisis dan penemuan data menggunakan SPSS, hasilnya jelas menunjukkan sebab-sebab kegagalan kekuda bumbung kerana angin yang melampau di Malaysia, pertimbangan reka bentuk kekuda bumbung dan juga beberapa kaedah yang berkesan untuk mengatasi masalah kegagalan kekuda bumbung kerana angin yang kuat di Malaysia . Penentuan kegagalan sama ada dalam peringkat reka bentuk atau lain-lain faktor konsultan telah dilakukan dan ia boleh disimpulkan bahawa kegagalan bukan datang dari peringkat reka bentuk tetapi ia datang daripada faktor-faktor perunding lain. Terdapat empat cadangan yang boleh dijalankan iaitu penyelidikan untuk meningkatkan pemahaman beban angin yang kuat, menyediakan garis panduan untuk reka bentuk struktur bumbung tertakluk kepada bebanan angin kuat, tahap wajib ditetapkan untuk bebas pihak ketiga reka bentuk kajian dan pemantauan pembinaan dibantu oleh orang yang berkelayakan dan jurutera struktur diperlukan untuk mengenal pasti lukisan keruntuhan komponen kritikal struktur bumbung penting tertakluk kepada muatan angin melampau. Usaha penyelidikan yang dihasilkan ini sangat berharga dan akan menjadi rujukan serta asas bagi kajian mengenai bencana angin.

TABLE OF CONTENT

LIST OF TABLE

LIST OF FIGURES

LIST OF SYMBOLS

%	Percentage
RM	Ringgit Malaysia
°	Degrees

LIST OF ABBREVIATIONS

SPSS	Statistical Package for the Social Sciences

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

A roof is the covering on the uppermost part of a building or shelter, to provide protection from the weather, notably rain, but also heat, wind and sunlight. A roof is often the most expressive element of the building and functionally important for its capacity to protect the building from the elements. A roof usually consists of an external weatherproof material and an inner layer of thermal insulating material which are supported on a framework of timber rafters or beams. Roofs are regarded as pitched or flat depending upon the amount of slope the surface of the roof has.

For some decades, this uppermost element has been ignored and give more attention on other elements such as beam and column and it seems the incidence of natural hazard resulting in damage to buildings and infrastructure . However, there is some real life report that building has been destroyed by wind related disaster especially on the roof structure. Roof structure is subjected to high wind loads during extreme wind events such as hurricanes and a structural system is needed to resist and transfer the loads. The equipment, structural system, and anchorage connections to the roof members need to be carefully designed to prevent failure during wind storms.

For country that located near the equator like Malaysia, the temperature are high all year round except at altitude and its determined that the climate is dominated by the two monsoon seasons and the inter-monsoon thunderstorms. Throughout these years,there are many cases that related to the roof truss failure due to extreme wind in Malaysia because of the climate change in the world. Due to this tragedy, the roof structure system that frequently fails during extreme wind must be investigate through some research to the wind load effects on the roof truss structure.

Currently in Malaysia, there are so many reports from mass media show that extreme wind events not only blew off roofs, damage the components of the building, uprooted tree but also the affects could possible extend to secondary damage such as cause injury and claim life to the human. Recently, the paperwork is to review extreme wind events occurrences in all over Malaysia from year 2000 to 2013. According to Mohd Fairuz Bachok (2012), summaries of 681 occurrences which contains of 681 locations and dates, 463 times and 147 durations indicated that extreme wind can be expected in Malaysia each year.

1.2 PROBLEM STATEMENT

Roofs are designed to resist the typical wind loads of their location, but no roof is likely to withstand the most extreme wind event. Roof trusses especially steel are light structural members, highly susceptible to instability and lateral torsion buckling without adequate temporary bracings. In between breezes and twisters is a whole range of wind speeds that incrementally damage the roof system. It is important to know the wind flow over houses and the effects on the structure as the individual elements of the structure. Most of the potential damage in an extreme wind event is roof because it's the most exposed in the structure.

On 20 May 2013, twelve people narrowly escaped after the roof of the Masjid Kampung Binjai Kertas in Hulu Terengganu collapsed and in September, a RM6 million mosque in Kampung Tebauk, Bukit Tunggal, also suffered the same fate where this tragedy might be continuous if this matter did not get any priority. Although not involve in death as the cases reported in the Sinar Harian on 1 October 2013, but severe damage of properties happen because of the roof truss that made from 65 meters iron at Supermarket Xiri that located at Batu 2 Jalan Kuala Berang was collapsed due to extreme wind. Harian Metro also reported the same incident that happened in Kampung Manjoi, Perak on 11 May 2013 at 6.45 PM which is at least about 23 houses damages due to strong wind especially in the roof structure.

Reports by the investigation committee highlighted a few factors which could have contributed to the failure of the roof truss structures. It includes the design was inadequate, the roof was not erected properly which is resulting in misalignment, materials and workmanship is not in accordance to specifications and also alternative designs from contractor was adopted without proper analysis. Unfortunately, all this cause will become worse when extreme wind hazard happen.

In all around the world, it is a standard industry practice to maintain structural stability of roof trusses by providing temporary bracings including top and bottom chord lateral and diagonal bracings, and web diagonal bracings during erection until the entire structure has been completed. Due to the lack of adequate lateral and diagonal bracings of top chords, bottom chords, and web members, the installed trusses were in a state of instability and ready to collapse either due to buckling or under any significant lateral and gravity loads. Further, standard industry practice requires that materials should not be placed on trusses during erection unless proper evaluation is done.

In Malaysia, numbers of damage that cause by extreme wind has been recorded and this numbers is constantly increasing yearly with rapid growth of building development. From the previous study carried out, it is found that the most of the failure occurred in structural system especially roof truss is happen when the uplifting of roof system during extreme wind events. To prevent these problems, determination of the probability of roof truss failure whether in design stage, construction stage or materials usage must be done. This research will be implemented especially in the consulting perspective because the design stage is the most important stage in structure development.

Figure 1.1 : Example of Roof Truss Failure In Malaysia

Source: Roof Collapsed 2013

1.3 OBJECTIVES OF STUDY

The prime objectives of this research are as follow:

1. To investigate the roof structure system that frequently fails during extreme wind.
2. To determines the problems of the roofing system under extreme wind load in accordance with Malaysian consultation industry practices.

1.4 SCOPE OF STUDY

Study area for this case is only in Malaysia to determine the roof failure problems that happens over these recent years so that it can be secure in the future. It will be done in consulting engineering scope which is determination of the failure in design stage or others consultant factors. Besides, review the roof failure phenomena that happened due to lack of concern about wind effect to building structure. The research effort produced valuable outcomes that become a references and basis for the study regarding to wind disaster. Numbers of damage in extreme wind will be recorded and produce the suitable practical solution to minimize the wind damages.

For this research, analysis of the data collection will be using Statistical Package for the Social Sciences (SPSS) software because it is the data analysis software package of choice for applied researchers in making inferences. In this study, data collection of consultant companies will be arrangement and analyses by using SPSS software to determine outcomes of this research.

1.5 RESEARCH SIGNIFICANCE

An extreme wind event is not familiar in consultant and construction industry in Malaysia. Further researches about this hazard must be carried out to gather more information for better understanding of extreme wind characteristics especially in consultant stage. Furthermore, most of the codes practices used in Malaysia do not reflect much the structural system and materials used in Malaysia consultation practices.

At the end of this research, the study on consultant perspective will be provided and the factors of the roof truss failure will be determined as awareness to the involved parties. The major problems that cause this roof failure will be investigate especially on consultant perspective whether the mistake comes from the calculation in design stage or from the construction materials or maybe comes from construction work. Besides that, with this information provided the consequence of the roof structure can be detect and it is useful to avoid the tragedy happen again. The aim of this research will be complete which is to provide overview about roof truss failure due extreme wind in Malaysia in consultant engineering perspective.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Many reports and paperwork from mass media review that extreme wind events occurrence in all over Malaysia from year 2000 to 2012. Reports that published from government agencies indicated that extreme wind events can be expected in Malaysia each year and wind storm occurred throughout the year, month with most frequently of occurrences between regions which is Perlis is the most risk district while for main city is Kuala Lumpur. (M.F Bachok.et.al 2012).

According to Dr. Richard Tunner (2013), there is no widely accepted definition for 'extreme wind . In the context of building design, an extreme wind is a wind gust which is strong enough to cause significant damage to buildings and property and also can harm people. In other definition, strong winds from any storm type can damage or destroy vehicles, buildings, bridges, and other outside objects, turning loose debris into deadly flying projectiles.

2.2 WIND ACTION

Wind load are variable loads which act directly on the internal and external surfaces of structure. The intensity of wind load on a structure is related to the square of wind velocity and the dimension of the members that are resisting the wind. Wind velocity is dependent on geographical location, the height of the structure, the topography of the area and the roughness of the surrounding terrain. Wind creates pressure on the windward side of a building and suction on its other three sides. Wind also produces suction on flat roofs, on the leeward side of sloping roofs, and even on the windward side of roofs with a pitch less than 30°.

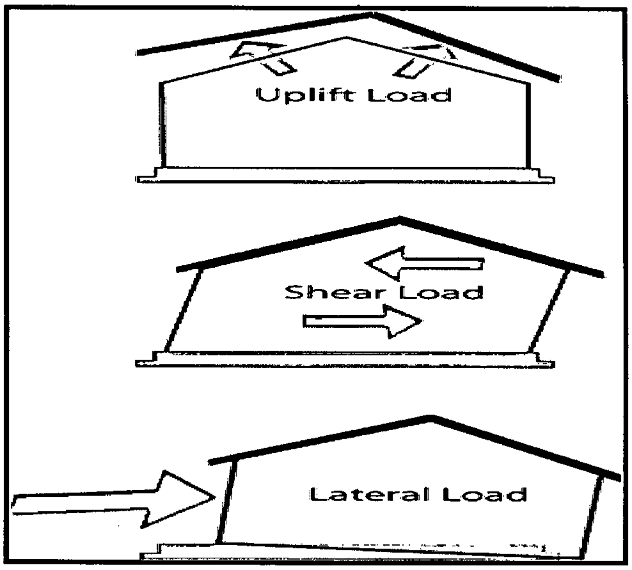

Figure 2.1: Effect of Wind Load on Building

Source: Hazard Resistant 2013

Wind exerts three types of forces on the buildings (Azhar Abdul Aziz, 2011):

- **Uplift load** : Wind flow pressures that create a strong lifting effect, much like the effect on airplane wings. Wind flow under a roof pushes upward; wind flow over a roof pulls upward.
- **Shear load** : Horizontal wind pressure that could cause racking of walls, making a house tilt.
- **Lateral load** : Horizontal pushing and pulling pressure on walls that could make a building slide off the foundation or overturn.

The response of a structure to the variable action of wind can be separated into two components, a background component and a resonant component. The background component involves static deflection of the structure under the wind pressure. The resonant component, on the other hand, involves dynamic vibration of the structure in response to changes in wind pressure.

2.2.1 Factor of Wind Pressure Distribution

There are many factors that can affect the distribution of wind pressure or wind load on buildings, including roof covering or shielding. Stathopoulos stated that the maximum negative pressures which are suction occur at the edges and corners of the roof because of the flow separation. Roof accessory structures can changes the flow pattern on the roof and effectively reducing the wind load on the roof surface and damage to the buildings. In another study, Kopp et al. examined the wind loads and wind effects on the roof parapets of buildings and they found out that the magnitude of wind loads and their distribution largely depend on the architectural detail.

Roof or similar large objects in the immediate vicinity known as shielding have a bearing on pressure distribution. According to Dalgliesh and Schriever (1962), shielding does not always have a beneficial effect and in some cases suction coefficients should be increased because of the proximity of a neighbouring building.

2.2.2 Pressure Distribution on Roof

Wind, as it blows over and around an enclosed building which is it can potentially put very powerful pressure on the outside of the structure in both positives forces (pushing) and negative forces (suction). Roof truss failure happen when a building is internally pressurized which mean a high wind gets inside of the building and try to push the roof up from the inside. Internal pressurization can cause the effective applicable wind pressure to nearly double on the wall and roof of the building.

Nowadays, diversity of structures and random of wind load may affect distribution of wind pressure on roof. Therefore, the studies with the respect to the subject have been conducted a lot in wind engineering field and one of the experiments has been conducted by Holmes. According to Holmes (2000), the result pointed out that high negative pressure zone would be formed at the certain area around the windward slope and the leeward slope of the ridge.

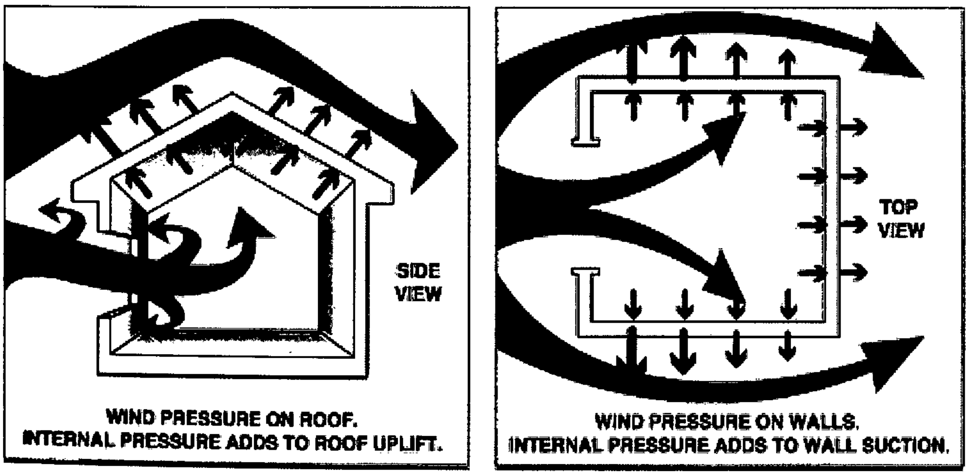

Figure 2.2: Pressuration on Roof Truss

Source: Building Damage 2013

2.3 CONCEPT IN ENGINEERING DESIGN FOR ROOF TRUSS

Generally, roof trusses can be engineered for all types of structures. Roof trusses are a key component to creating a fully engineered, structurally building that usually consists of an external weatherproof material and an inner layer of thermal insulating material. In definition, a roof is the covering on the uppermost part of a building or shelter, to provide protection from the weather, notably rain, but also heat, wind and sunlight (Roof, 2013, para.1). The elements in the design of a roof consists the material, the construction and the durability which is for the roofing materials, there are three important parts:

- 'Built-up' or double layer roofing spanning between secondary members such as purlins.
- Composite panels that also known as sandwich panels spanning between purlins.
- Deep decking spanning between main frames, supporting insulation, with an external metal sheet or waterproof membrane.

For the construction of roof, the same engineering standards and software that are used in commercial construction are used in the residential engineering which is each truss is individually engineered to ensure a strong, yet cost effective, roof system. The most important elements is the durability of a roof because the roof is often the least accessible part of a building for purposes of repair and renewal, while its damage or destruction can have serious effects.

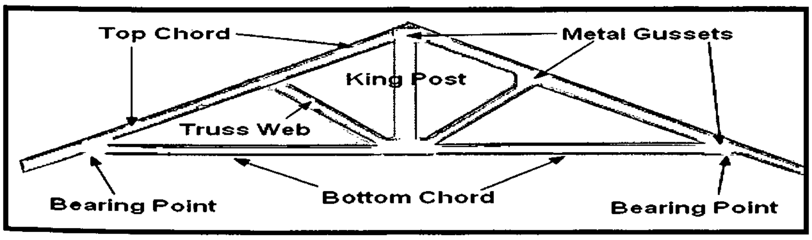

Figure 2.3 : Common Roof Truss

Source: Roof Mount Design Assistant 2013

Steel roofs can be divided into three main types of structure:

- Single roofs.
- Double roofs.
- Trussed roofs.

2.3.1 Single roofs

Rafters of single roofs do not require any intermediate support and this type of roof has a number of limitations which is it can only be used for small spans. If greater spans are required, larger roof sections would be needed. Moreover,if the feet of the rafters are not tied together by means of a binder or roof joist, then this type of roof will have a tendency, under weight,to push the supporting walls outwards at the top causing structural failure of the walls.

According to Community College Hackney (2013), single roofs can be categorised as follows:

- **Couple roof** : These can be used for building with a clear span of not greater than 3m and pitches less than 40°.
- **Collar roof** : These can be used for buildings with a clear span not exceeding 4mm.
- **Close couple roof** : These can be used for buildings with a clear span not exceeding 5.5mm and with pitches less than 25°.

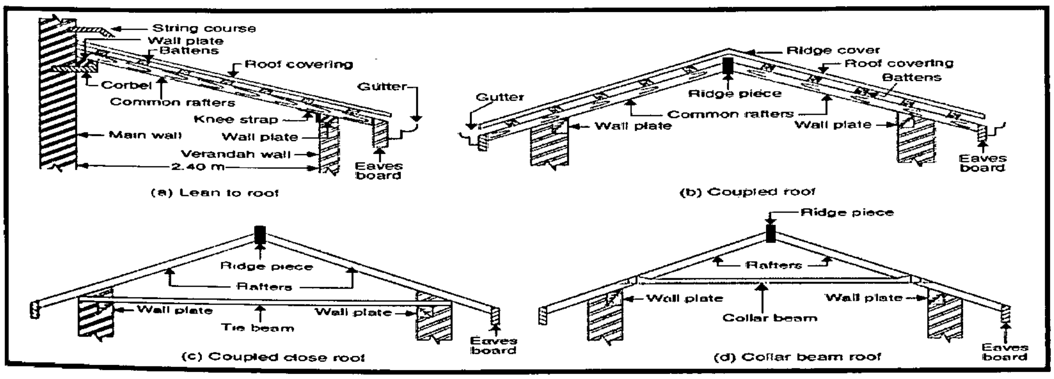

Figure 2.4: Types of Single Roof

Source: Roof 2013

2.3.2 Double Roofs

Definition for double roof is a roof whose rafters are of such a length that are required an intermediate support known as a purlin (Simple Roof Construction,2013). Purlin is usually a beam which is secured under the rafters at a point half way between the ridge and the wallplate. In gable roofs, the purlin is built into the gable wall to provide added support. In double pitched roofs, the purlin is fixed to the rafters in a continuous length, jointed at all the internal and external corners of the roof.

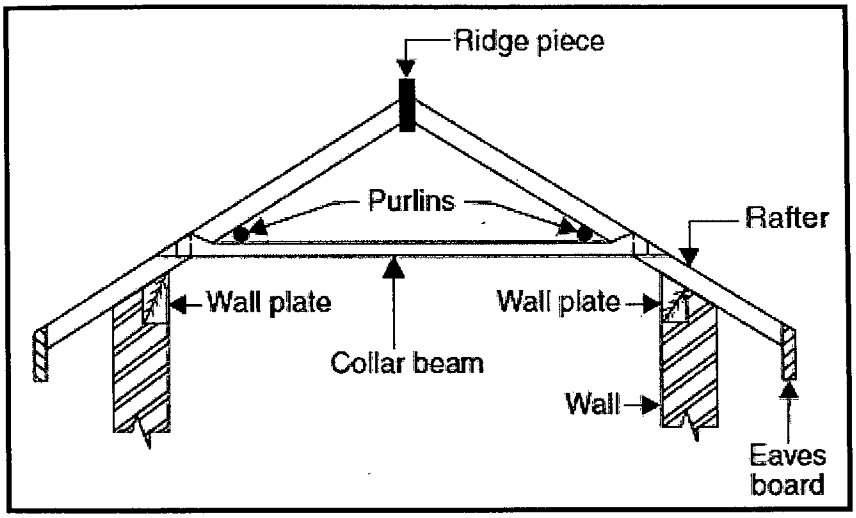

Figure 2.5: Double or Purling Roof

Source: Roof 2013

2.3.3 Trussed Roofs

Trusses is a frame work of slender members are used to support sloping roofs. A number of trusses may be placed lengthwise to get wall free longer halls and purlins are provided over the trusses which in turn support roof sheets. In case of steel trusses joints are made using gusset plates and by providing bolts, rivets or welding. Depending upon the span, trusses of different shapes are used and end of trusses are supported on walls or on column.