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FAILURE OF ROOF STRUCTURE DUE TO WIND LOAD

LEE SID HWA

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Civil engineering (Civil – Structure)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

APRIL 2008

I declare that this project report entitled “Failure of Roof Structure Due to Wind Load” is the result of my own research except as citied in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

There are reported roof failure due to uplifting of the roof structures or roof sheeting during rainstorm has been causing damages to the buildings. Generally, failure occurred at the two points, either at the roof truss's sheeting or at the truss to roof beam connections. There are 2 types of structure are to be analyzed; the different of these two building will be the buildings dimension, meaning that one is a single storey houses and other is a 20 storey apartment. The roof structure's data is extracted from the reported cases for simulation purposes. For a more conservative result, the wind speed is taken as 40 m/s. Due to different aspect for this 2 type of structure, the wind-uplifting force will be determined. The calculated resulting forces transferred at different connection points were compared with the experimental result obtained from laboratory testing. The result of this, is that the connection of both houses and apartment is safe under the wind speed of 40m/s. However, this happen when the proper used of selected material plus all the material is in well condition. To improve the study of this project, the larger scale testing like wind tunnel can provide the more accurate result due to the integrity of the roof structure.

ABSTRAK

Seperti yang dicatat dalam bahan bacaan seperti suratkhabar, kes-kes kepingan atap yang dicabut oleh angin kuat dalam hujan lebat menyababkan kegagalan struktur bumbung. Sebenarnya menurut kajian yang telah dilakukan, biasanya kegagalan struktur bumbung berlaku di 2 tempat, iaitu di tempat sambungan pada komponen-komponen kayu dan paku atau kepingan zink yang dipaku pada gulung gulung. Oleh itu, 2 jenis struktur akan dikaji untuk menyelidik bahawa faktor-faktor ketinggian, saiz, dan lokasi akan menjadi sebab kegagalan struktur bumbung. Perhubungan antara bangunan apartment yang setinggi 20 tingkat dan rumah biasa setinggi satu tingkat. Untuk mendapatkan bacaan yang lebih selamat, halaju angin adalah 40 m/s. Selepas pengiraan untuk kapasiti pada setiap sambungan, kapasiti yand dikaji akan selamat dalam halaju angin 40 m/s. Tetapi keputusan ini adalah benar jikalau semua komponen dalam struktur adalah baik. Pada akhirnya, kajian ini mencadangkan penggunaan Wind Tunnel untuk mendapatkan keputusan yang lebih memuaskan.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The roof is often the most expressive part of a house, symbolic of shelter and functionally important for its capacity to protect the house from the element. However, sometimes we tend to ignore the roof structure and put the concentration on the structural member like beam and column. However, there is some real life report, wind has cause of damage to buildings.

As printed on the newspaper or magazine, there is some cases that related to the failure of roof structure due to the wind blow especially at rainstorm. Due to this tragedy, there is something that can do to reduced or minimize through some study or research to the wind load effect on the roof structure.

Wind damage in rainwater tends to occur progressively, usually starting with damage to one of the components forming the building envelope (typically the roof,

cladding or unprotected windows), and which, if it progresses far enough, can lead to failure of the complete structure. Even in cases where complete structural failure does not occur failure of the building envelope often allows wind-driven rain to penetrate the building leading to damage to the contents as well as loss of function. The loss of roof sheeting is often attributed to the loss of roof sheeting is often attributed to either inadequate nailing.

For roof pitches in the range commonly used for residential structures, wind forces oriented normal to the ridge of the roof will cause wind uplifting forces. Sometimes, there are weakness could extend the damage from wind; these weaknesses involve the attachment of roofing to the roof sheathing. The sheathing attachment to the roof framing, rake overhang details, and attachment of internal partitions to the external walls contributes significantly to the extensive damage and to system failures.

For country that located at near the equator like Malaysia, the temperature is high all year round (except at altitude). In many tropical regions people identify two seasons: wet and dry. Unlike the foreign country, phenomenon like hurricane, snow fall doesn't happen on this area, but when the raining monsoon occurs: a large amount of rainwater will fall, makes the withdrawal of water is crucial to avoid leaking or water spill out. This is why pitched roof is so common compared to flat roof throughout the country. Timber made roof truss has such advantages:

- Lowest overall cost.
- Fast to install.
- Requires ordinary tools and
- Doesn't require skilled labour to install.
- Virtually any roof and ceiling is possible.
- Engineered product.
- No job site waste.

1.2 Problem Statement

Throughout these years, there are some cases that related to the failure of roof structure due to the wind blow especially at rainstorm. Due to this tragedy, there is considered vital if there is a way that can do to reduced or minimize through some study or research to the wind load effect on the roof structure.

For example, there are some real life cases like in the US, wind is the most common, and the most costly cause of damage to buildings. Over a 7 year period from 1986 to 1993 extreme wind damage cost $41 billion in insured catastrophe losses as compared to $6.8 billion for all other natural hazards combined. Reasons given for these losses include: increased development in high risk areas, a lack of awareness of or failure to follow recommended construction practices and the introduction of new and unproven materials. Economic losses include repairing or replacing damaged homes and their contents, while the loss of personal possessions and relocation during reconstruction are common outcomes of residential damage.

Figure 1.1: Some of the common example of roof failure

Uplifting of the roof structures or roof sheeting during rainstorm has been causing damages to the buildings. Generally, failure occurred at the two points, either at the roof frame's sheeting or at the frame to roof beam connections. There are 2 types of structure are to be analyzed; the different of these two building will be the buildings dimension and geographical locations.

Wind damage in rainwater tends to occur progressively, usually starting with damage to one of the components forming the building envelope (typically the roof, cladding or unprotected windows), and which, if it progresses far enough, can lead to failure of the complete structure. Even in cases where complete structural failure does not occur failure of the building envelope often allows wind-driven rain to penetrate the building leading to damage to the contents as well as loss of function.

1.3 Objective of Research

Residential houses located in the countryside region (kampung houses) that were relatively unsheltered from the full force of the storm incurred the decent damage. The damage to these houses presented a unique opportunity to investigate the type and extent of damage to this type of structure.

The objectives of this study are:

a) To investigate the roof structure elements and their tying down system that frequently failed due to wind forces.

b) To determine the minimum wind speed required which causes the uplifting of the roof of various construction and age.

c) To review the safety of the presently practiced construction of roof structure.

1.4 Scope of Research

The scope of this research is to determine the ways to succeed the objectives. One of these was the calculation of connection capacity. For those countryside housing estates, it had presumed that all connection using nails rather than the metal connection plate that used recently due to the age of the existing houses. And so, the weakness in strength is the main focus of the research.

For the worst case environment performance, the experimental circumstances practiced for extreme possibility, means the testing data based on the highest wind speed that occurred before.

Moreover, this research will also determine the effect of the failure pattern of the roof connection that due to strong wind blow condition. The connection part that involved was connection between zinc roof sheeting and purlin; purlin and rafter; and also the rafter and beam.

The result decided through the testing by laboratory equipment or through certain calculation. And through that, the roof structures ultimate storm resistance can be calculated. Data obtained through experiments will be analyzed and suggestions will be given as necessary.

1.5 Significance of the Research

At the end of the research, the wind speed limit, ultimate resistance and effect under severe weather will be provided, as an understanding and awareness to the involved parties. With this, whenever the resident know about the current wind speed, they will know the consequence of roof structure failure. To avoid the tragedy again, repairing and strengthening of roof structure maybe needed.

CHAPTER 2

LITERATURE REVIEW

2.1 Metal Roof Sheeting

Metal roof sheeting is an old material, it has been made for about a century and although it has had it's pro and cons in terms of popularity it has always been the best roofing material for many people. A metal roof is a roofing system made from metal pieces or tiles. They are components of the building envelope. Corrugated roof sheeting or roofing iron has been around since the 1830's in England. It was and still is a significant invention. The simple process or forming corrugations into a flat floppy sheet of thin iron changed roofing for ever. Because of it's lightness and strength, easy transportability, tons of it was shipped all over the world. Corrugated galvanised iron describes the original product that was wrought iron plate coated with zinc and then roll formed into corrugated sheets. However, the corrugated zinc roof sheeting now rare and no longer manufactured in large amount. It has been replaced by some other else material.

Figure 2.1: An example of outstation homestead of using zinc roof sheeting.

The main product that has replaced the old galvanised iron (zinc sheeting) is called "Zincalume". This name being derived from the two main components of the actual coating system, which consists of Zinc 55% / aluminium 43% / silicon 1.6% that coat the steel base. The material is sent from the steel mill in large rolls of flat sheet. The main difference in the coil products are:-

- ***Zincalume*** - This is the natural colour of the sheet that looks similar to the old galvanised iron. It weathers with times and loses it's bright shiny look.
- ***Colorbond*** – Basically it is Zincalume with a paint surface added. It comes in about 20 various colours. It has a plain painted finish to the underside.
- ***Colorbond Metallic*** - A metallic sheen that changes under different light conditions.
- ***Colorbond Ultra*** - For severe coastal and industrial environments.
- ***Stainless*** - For severe coastal and industrial environments.
- ***Thickness*** - For the most part I think that for private house work the 0.42mm thick is the most common. As you can see it is pretty thin stuff, less than half a millimeter most of it.

- ***Galvanised*** - Steel sheeting is still made, but in the thicknesses for roof sheeting it most probably only done as special orders for heritage restoration work. Where I do see it quite a lot is in the form of valley gutters, in thicker gauges, say 2.0mm.

Various companies doing the different type of roll forming. They turn the coils of flat into various standard profiles for which the engineering properties are documented. The types of metal roofing will be as following:

- ***Stainless steel***. - Available for harsh conditions, rollformed and fixed similar to corrugated steel profiles.

- ***Aluminum*** - One of the longest lasting metals, but somewhat expensive.

- ***Copper*** - Usually used for flashing or very small sections like covered entryways. Expensive. If the building were ever to be dismantled the copper would be reused because of its high value and variety of possible uses.

- ***Stone Coated Steel*** - Stone Coated Steel shingle panels are made from pressure formed, zinc/aluminum alloy coated steel with an acrylic, bonded, stone chip finish, which resists fading and UV (Ultra-Violet) penetration. The panels are lightweight (1.5 pounds per square foot) and walkable, and come in a variety of earth-toned colors. They are fireproof and come with a 120-mile (190 km)-per-hour wind rating and have a 50 yr to lifetime warranty against fading, cracking, rusting, curling and de-granulation. Stone Coated Steel panels come in a wide range of solid and Mediterranean blends and are vailable in both tile, shake, slate and shingle style They withstand all extreme environmental elements including Hail, Fire and Wind. Stone Coated Steel is ideal for flat to pitch conversions and can even be installed over existing roofs without the need for tear-off. Structural support is generally not required and can be walked on after

installation, too. Nails are installed horizontally to provide greater resistance against vertical pullout due to high wind conditions.

- ***Inverted Box Rib*** is a low-cost corrugated square-fluted iron roofing used mainly in the South African market. It can be commonly seen all the way from industrial sites to low-income shacks.

From the table shown below, that the shallower the roof sheeting pitch, the deeper the ribs have to be, and also the thicker the material in most cases. There are a handful of other profiles available but those are less common on typical house construction. There are quite a few roof sheeting profiles available, but the main ones for housing are as follows:-

Figure 2.2: Spandek Roof Sheeting.

Figure 2.3: Custom Orb Roof Sheeting.

Figure 2.4: Trimdek Roof Sheeting.

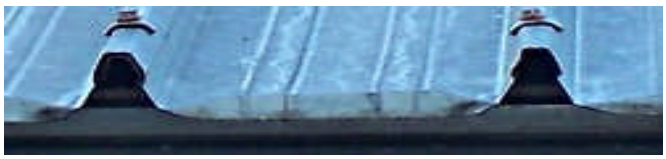

Figure 2.5: Klip-Lok Roof Sheeting.