EVALUATIO[illegible] [illegible]NDER WIND LOAD USING SAP2000

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ABSTRACT

From past record, one of the top ten natural disasters occurred in Malaysia is windstorm. Windstorm has caused many failures to structure especially roof truss. Designer/Engineer tries to avoid the damage by considering the effect of wind to roof truss system. However the understanding of wind behavior to roof truss system is not well defined. Therefore, designer/engineer had try considered the wind load effect to roof truss in gravity direction. Even though the previous study had shown that the wind load are not only act in gravity direction but it also act on uplift direction. Therefore, this study is to evaluate the performance of the roof truss system which neglected the uplift force. The truss system is evaluate with real wind load data. The data are taken from wind tunnel test experiment from Tokyo Polytechnic University. From the result it shows that roof truss is possible to failure due to the real wind load case. The truss system must be considered real wind condition to avoid failure due to wind.

ABSTRAK

Dari rekod yang lepas, salah satu daripada sepuluh bencana semulajadi atas berlaku di Malaysia adalah ribut angin. Angin ribut telah menyebabkan banyak kegagalan untuk struktur terutamanya kekuda bumbung. Pereka / Jurutera cuba untuk mengelakkan kerosakan dengan mengambil kira kesan angin untuk sistem kekuda bumbung. Walau bagaimanapun, pemahaman kelakuan angin kepada sistem kekuda bumbung tidak ditakrifkan dengan baik. Oleh itu, pereka / jurutera hanya menganggap kesan beban angin kepada kekuda bumbung ke arah graviti. Walaupun kajian sebelumnya telah menunjukkan bahawa beban angin bukan sahaja bertindak ke arah graviti tetapi ia juga bertindak ke arah atas. Oleh itu, kajian ini adalah untuk menilai prestasi sistem kekuda bumbung yang mengabaikan daya ke atas. Sistem kekuda dinilai dengan data beban angin yang sebenar. Data ini diambil dari eksperimen ujian terowong angin dari Tokyo Polytechnic University. Daripada keputusan kajian ini menunjukkan bahawa kekuda bumbung mungkin gagal kerana tidak mengira kesan beban angin sebenar. Sistem kekuda mesti dipertimbangkan dalam keadaan angin yang sebenar untuk mengelak kegagalan yang disebabkan oleh angin.

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CHAPTER 1

INTRODUCTION

1.1 Background Of Study

In this era that gone through globalization, most country of nation still does construction as their first priority. To form the structure that can withstand any obstacles it is need to be analysis before the construction process going on. There are many ways to analyze structure of building, material that will be use and the problem that will involves. The history of construction is not only limited to buildings only but it also involve other structures such as bridges.

Structural analysis is the determination of the effects of loads on physical structures and their components. Structures subject to this type of analysis include all that must withstand loads, such as buildings, bridges, vehicles, machinery, furniture, attire, soil strata, prostheses and biological tissue. Structural analysis incorporates the fields of applied mechanics, materials science and applied mathematics to compute a structure's deformations, internal forces, stresses, support reactions, accelerations, and stability. The results of the analysis are used to verify a structure's fitness for use, often saving physical tests. Structural analysis is thus a key part of the engineering design of structures.

SAP2000 is integrated software for structural analysis and design. The SAP name has been synonymous with state-of-the-art analytical methods since its introduction over 30 years ago. SAP2000 follows in the same tradition featuring a very sophisticated, intuitive and versatile user interface powered by an unmatched analysis engine and design tools for engineers working on transportation, industrial, public works, sports, and other facilities. This interface allows you to create structural models rapidly and intuitively without long learning curve delays. The advanced analytical techniques allow for deformation analysis, tension or compression only analysis, buckling analysis , blast analysis, fast nonlinear analysis for dampers, base isolators and support plasticity, energy methods for drift control and segmental construction analysis.

A truss is an important part of a building. A truss is a structure comprising one or more triangular units constructed with straight members whose ends are connected at joints referred to as nodes. External forces and reactions to those forces are considered to act only at the nodes and result in forces in the members which are either tensile or compressive forces. Moments are explicitly excluded because, and only because, all the joints in a truss are treated as revolute. There are two basic types of truss pitched truss and parallel chord truss. The pitched truss, or common truss, is characterized by its triangular shape. It is most often used for roof construction. Some common trusses are named according to their web configuration. The chord size and web configuration are determined by span, load and spacing. The parallel chord truss, or flat truss, gets its name from its parallel top and bottom chords. It is often used for floor construction. The most common type of trusses use in construction is common, pratt and howe trusses.

Wind is air in motion. Structure deflects or stops the wind, converting the wind's kinetic energy into potential energy of pressure, thus create wind loads. The intensity of the wind pressure depends on shape of structure, angle of the induce wind, velocity of air, density of air and stiffness of structure.

1.2 Problem Statement

When designing a truss for wind, it is necessary to abide by the governing building code for jurisdiction where the project is located. The trusses have to stand the load that will be distributed by the wind. From 2010 the trusses that collapse without warning still occur. It is because the lack of taking serious consideration in dynamic load of wind. Furthermore the dynamic load that occurring for years coming will be change according to the type of weather that follows. For now the truss that had been build is only reconsidering the ultimate of wind load can bring and not by reconsidering dynamic load of wind.

1.3 Objectives of Study

i. To determine the load pattern of roof truss structure due to variation of wind angle.
ii. To study the effect of truss failure due to variation of wind angle.

1.4 Scope of Study

In this present study will be focus on the load pattern of roof truss structure and effect of truss failure due to variation of wind angle. In this study it will involve the usage of SAP200 software to check the effect from simulation test. In case for determining the load pattern of roof truss structure due to variation of wind angle, the wind load will be taken from 'Wind Tunnel Test' and follow MS 1553:2002 according to code of practice on wind loading for building structure. Furthermore for the effect of truss failure due to variation of wind angle, the trusses will have to withstand different loading for different area of roof. The typical truss that will be used in this simulation test is pratt truss.

1.5 Significant of Study

The main objective of this study is to determine the load pattern of roof truss structure due to variation of wind angle and study the effect of truss failure due to variation of wind angle. The advantage of this study is to prepare for the outcome disaster that will occur. Besides that from this study it will contribute to the community and other agencies on how to make proper trusses. Moreover from this study it will determine which angle can bring harm to the truss and also can determine the part of truss that is totally affected.

1.6 Expected Outcome

The outcome from this study is the reestablishment of usage wind load and ultimate resistance of the typical truss will be important part to design the trusses. Besides that, trusses problem such as collapsing will be decreasing and the choosing type of trusses use in construction will be important.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter will discuss about the effect of trusses due to the wind load. Trusses are main component before installing the roof in building. The trusses that had been installed must be able to withstand the load that transfer by the roof. Wind load is one of the loads that will be transfer from roof to truss. Thus, from this the wind load will have effect to the trusses strength and workability. Wind is a phenomenon that cannot be predicted. Moreover wind has become one of the top natural disasters that often occur in Malaysia. Disaster than can be brought by the wind such suction load on the building structure. Besides that, wind also can bring uplift force that can lead to failure of truss system.

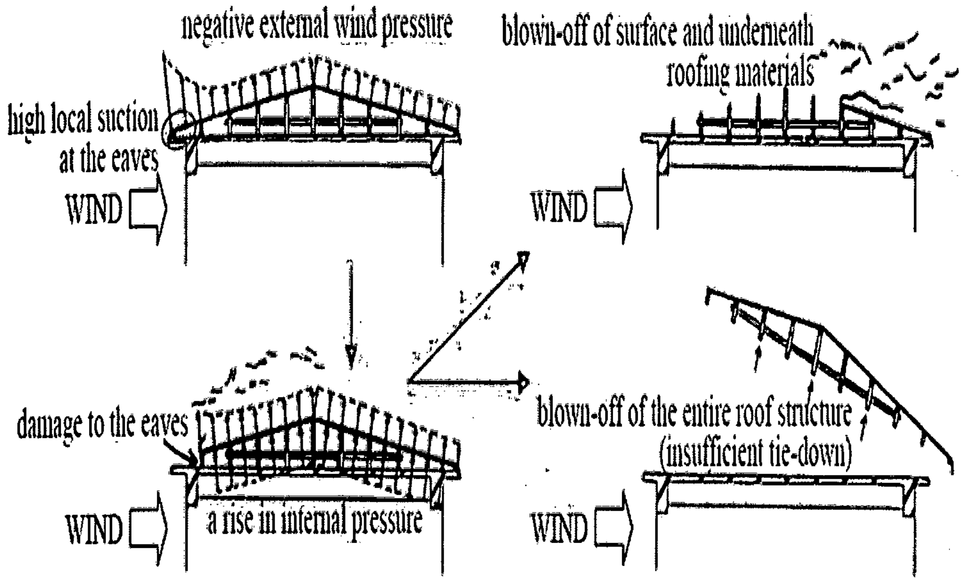

Figure 2.0 : Effect of wind load.

2.2 Types of wind.

Malaysia local climate is equatorial and characterized by the annual southwest climate from April to October and northeast climate from October to February that called monsoons. The temperature is moderated by the presence of the surroundings ocean. Humidity of Malaysia usually high and the average annual rainfall is 250 cm. The climates of the peninsular and east are different. The climate in peninsular is directly affected by wind from mainland, as opposed to the maritime weather of the east. Local climates can be divided into three regions that are highland, lowland and coastal. The wind that blew through cannot be predicted. There are three types of wind that can be classified that is:

i. Common wind.

The common air can be described as the air that moves from latitude to equatorial low pressure.

ii. Monsoons wind.

Winds that acts or release on the ground is hotter in dry season and colder in monsoon season than the air that acts at the sea. Mostly occur at east coast region of Malaysia.

iii. Local wind.

The wind acts accordingly on a season where the temperature and the pressure on the ground also water are the same. The changes occur according to the local effect.

These are the three main types of wind that can be classified. All of these winds occur in Malaysia and it is happen according to the changes of temperature, pressure and local effect. Mostly the problems that occur in wind catastrophic are in monsoons season. Moreover, wind is a complex's phenomenon. "This is because wind speed in Malaysia is usually low and always unpredictable."(Siti Khadijah Najid et al., 2009)

2.3 Consideration in wind design.

2.3.1 Type of wind design.

For structures that are sensitive towards wind, there are types of wind design that must be taken as consideration.

i. Research on environmental wind.
The investigation effect of environmental wind due to the construction of building (e.g. high rise building). This research is important to evaluate the effect of wind to the pedestrians, vehicles, and others types of structure that use public domain and environment structure as their proposal. "Until recently, however, advanced methods of wind load analysis were applied mainly to tall buildings because wind has considerable influence on their design."(W.A. Dalgliesh 1981)

ii. Wind load on the surface.
The pressure of wind load on the surface must be taken as one of main important in order to construct building and any other parts of building that can withstand the effect of wind. Besides that, cost also is the major reason. It is because the cost in order to assess the design of wind load uses a lot of money. So, a fair consideration must be taken if want to construct a building that is complex and have the dynamic characteristic of wind in the design, although that it still cannot predict the precise design load. Wind tunnel experiment must be done to evaluate the design load. By doing this, it will reduce the cost and precisely it is to avoid the

maintenance cost that is expensive if they are related to the damage of structure failure.

2.3.2 Design criteria

In order to design the structure that can withstand the wind effect, the design of structure must be as follows:

i. The strength of the structure must be enough to transmit load without failure for the rest of structure life.

ii. Workability of the structure in which the structure can withstand and stay for the time that had been fixed. These control on building or structure is important to decrease the damage and crack to the unstructured such as wall.

2.3.3 Roof systems

Trusses are triangular frame works, consisting of essentially axially loaded members who are more efficient in resisting external loads since the cross section is nearly uniform stressed. Trusses are extensively used, especially to span large gaps. Trusses are used in in any types of structure. Trusses are also used in horizontal planes of buildings to resist lateral loads and will provide lateral stability. There are plane truss, where in the external loads and the members lie in the same plane or space trusses, in which members are oriented in three dimensions in space and loads may also act in any direction. "Trusses are also used in walls and horizontal planes of industrial building to resist lateral loads and give lateral stability." (Prof. S.R.Satish Kumar and Prof. A.R.Santha Kumar, n.d)

2.3.4 Analysis of trusses.

Generally truss members are assumed to be joined together so as to transfer only the axial forces and not moments and shears from one member to the adjacent members (they are regarded as being pinned joints). The loads are assumed to be acting only at the nodes of the trusses. The trusses may be provided over a single span, simply supported over the two end supports, in which case they are usually statically determinate. Such trusses can be analysed manually by the method of joints or by the method of sections. Computer programs are also available for the analysis of trusses. These programs are more useful in the case of multi-span indeterminate trusses, as well as in the case of trusses in which the joint rigidity has to be considered. The effect of joint rigidity is discussed later in greater detail.

From the analysis based on pinned joint assumption, one obtains only the axial forces in the different members of the trusses. However, in actual design, the members of the trusses are joined together by more than one bolt or by welding, either directly or through larger size end gussets. Further, some of the members, particularly chord members, may be continuous over many nodes. Generally such joints enforce not only compatibility of translation but also compatibility of rotation of members meeting at the joint. As a result, the members of the trusses experience bending moment in addition to axial force. This may not be negligible, particularly at the eaves points of pitched roof trusses, where the depth is small and in trusses with members having a smaller slenderness ratio. Further, the loads may be applied in between the nodes of the trusses, causing bending of the members. Such stresses are referred to as secondary stresses. The secondary bending stresses can be caused also by the eccentric connection of members at the joints. The analysis of trusses for the secondary moments and hence the secondary stresses can be carried out by an indeterminate structural analysis, usually using computer software.

The magnitude of the secondary stresses due to joint rigidity depends upon the stiffness of the joint and the stiffness of the members meeting at the joint. Normally the secondary stresses in roof trusses may be disregarded, if the slenderness ratio of the chord members is greater than 50 and that of the web members is greater than 100. The secondary stresses cannot be neglected when they are induced due to application of loads on members in between nodes and when the members are joined eccentrically. Further the secondary stresses due to the rigidity of the joints cannot be disregarded in the case of bridge trusses due to the higher stiffness of the members and the effect of secondary stresses on fatigue strength of members. In bridge trusses, often misfit is designed into the fabrication of the joints to create prestress during fabrication opposite in nature to the secondary stresses and thus help improve the fatigue performance of the truss members at their joints.

2.4 Configuration of trusses.

Most common types of roof trusses are pitched roof trusses wherein the top chord is provided with a slope in order to facilitate natural drainage of rainwater and clearance of dust/snow accumulation. These trusses have a greater depth at the mid-span. Due to this even though the overall bending effect is larger at mid-span, the chord member and web member stresses are smaller closer to the mid-span and larger closer to the supports. The typical span to maximum depth ratios of pitched roof trusses are in the range of 4 to 8, the larger ratio being economical in longer spans. Pitched roof trusses may have different configurations. In Pratt trusses web members are arranged in such a way that under gravity load the longer diagonal members are under tension and the shorter vertical members experience compression. This allows for efficient design, since the short members are under compression. However, the wind uplift may cause reversal of stresses in these members and nullify this benefit. The converse of the Pratt is the Howe truss. This is commonly used in light roofing so that the longer diagonals experience tension under reversal of stresses due to wind load.

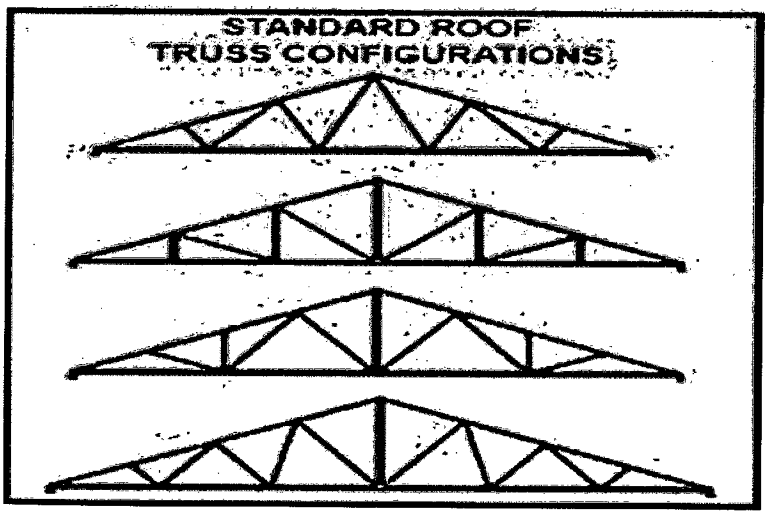

Figure 2.1 Standard roof truss configurations.

The parallel chord trusses are used to support North Light roof trusses in industrial buildings as well as in intermediate span bridges. Parallel chord trusses are also used as pre-fabricated floor joists, beams and girders in multi-storey buildings. Warren configuration is frequently used in the case of parallel chord trusses. The advantage of parallel chord trusses is that they use webs of the same lengths and thus reduce fabrication costs for very long spans. Modified Warren is used with additional verticals, introduced in order to reduce the unsupported length of compression chord members. The saw tooth north light roofing systems use parallel chord lattice girders to support the north light trusses and transfer the load to the end columns. The economical span to depth ratio of the parallel chord trusses is in the range of 12 to 24. The total span is subdivided into a number of panels such that the individual panel lengths are appropriate (6m to 9 m) for the stringer beams, transferring the carriage way load to the nodes of the trusses and the inclination of the web members are around 45 degrees. In the case of very deep and very shallow trusses it may become necessary to use K and diamond patterns for web members to achieve appropriate inclination of the web members.

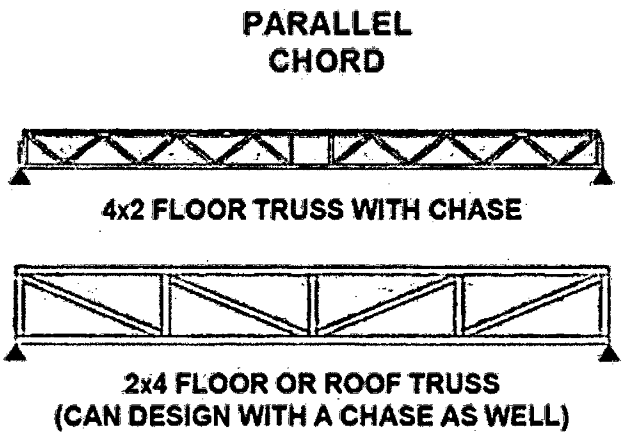

Figure 2.2 Parallel chord truss.

In case of very long span length pitched roof, trusses having trapezoidal configuration, with depth at the ends are used. This configuration reduces the axial forces in the chord members adjacent to the supports. The secondary bending effects in these members are also reduced. The trapezoidal configurations having the sloping bottom chord can be economical in very long span trusses (spans > 30 m), since they tend to reduce the web member length and the chord members tend to have nearly constant forces over the span length. It has been found that bottom chord slope equal to nearly half as much as the rafter slope tends to give close to optimum design.

2.5 Connection of truss.

Members of trusses can be joined by riveting, bolting or welding. Due to involved procedure and highly skilled labour requirement, riveting is not common these days. In railway bridges riveting may be used due to fatigue considerations. Even in such bridges, due to recent developments, high strength friction grip bolting and welding have become more common. Shorter span trusses are usually fabricated in shops and can be completely welded and transported to site as one unit. Longer span trusses can be prefabricated in segments by welding in shop. These segments can be assembled by bolting or welding at site. This results in a much better quality of the fabricated structure.

If the rafter and tie members are T sections, angle diagonals can be directly connected to the web of T by welding or bolting. Frequently, the connections between the members of the truss cannot be made directly, due to inadequate space to accommodate the joint length. In such cases, gusset plates are used to accomplish such connections. The size, shape and the thickness of the gusset plate depend upon the size of the member being joined, number and size of bolt or length of weld required, and the force to be transmitted. The thickness of the gusset is in the range of 8 mm to 12 mm in the case of roof trusses and it can be as high as 22 mm in the case of bridge trusses. The design of gussets is usually by rule of thumb. In short span (8 – 12 m) roof trusses, the member forces are smaller, hence the thickness of gussets are lesser (6 or 8 mm) and for longer span lengths (> 30 m) the thickness of gussets are larger (12 mm).

2.6 Design practice.

In this section, the design practices that propose for Malaysia is MS 1553:2002. Moreover the MS 1553:2002 will set out the procedures for determining wind speeds and resulting wind actions to be used in the structural design for structures that are subjected to wind action. MS 1553:2002 will covers the structure that are within these following criteria:

i. Building less than 200 m high.
ii. Structures with roof spans less than 100 m
iii. Structures other than off shore structures, bridges and transmission towers.

Likewise to the procedures in designing the building structure, the procedures in designing wind speed also have its own steps. In designing wind speed it will use this equation: