



THE EFFECT OF WIND LOAD ON ROOF TRUSS SYSTEM

NUR ALIF BIN ISMAIL

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**FACULTY OF CIVIL ENGINEERING & EARTH RESOURCES
UNIVERSITI MALAYSIA PAHANG**

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ABSTRACT

Nowadays there are lots of constructions that will be constructed in Malaysia. One of the considerations in design is wind load. From the past record, one of the top ten natural disasters occurred in Malaysia is wind storm. However the understanding of wind behavior to roof truss system is not well defined. Numbers of failure cases has been reported in mass media. Wind storm has caused many failures to structure especially to roof truss system. The previous study shows that the maximum load that can be support by each joint is 6.80kN. Finite Element Software was used in this study to analyze and identify the load distribution of the truss system. Two type of typical truss were used in this study. From the result, type 1 wills possibility fails at 30.34 m/s while type 2 able to resist maximum wind speed recommended in MS 1553:2002. Therefore it can be conclude that the arrangement of truss system will be affected to generate damage. Further study needed to be conducted in future.

ABSTRAK

Pada masa kini, terdapat banyak pembinaan yang akan dibina di Malaysia. Salah satu perkara yang perlu diambil berat didalam reka bentuk ialah beban angin. Berdasarkan rekod yang lalu, salah satu daripada sepuluh bencana alam yang berlaku di Malaysia adalah ribut angin. Walaubagaimanapun pemahaman terhadap tingkah laku angin pada sistem kekuda bumbung tidak ditakrifkan dengan baik. Bilangan kes kemusnahan telah dilaporkan didalam media massa. Ribut angin telah menyebabkan banyak kemusnahan pada struktur terutama kepada sistem kekuda bumbung. Kajian yang terdahulu telah menunjukkan bahawa beban maksimum yang boleh sokongan oleh setiap sendi adalah 6.80kN. Perisian "Finite Element" telah digunakan dalam kajian ini untuk menganalisis dan mengenal pasti pengagihan beban pada sistem kekuda. Terdapat dua jenis kekuda biasa yang telah digunakan didalam kajian ini. Keputusan menyatakan bahawa jenis 1 berkemungkinan akan gagal pada 30.34 m/s manakala jenis 2 dapat menahan kelajuan angin maksimum yang telah disyorkan didalam MS 1553:2002. Oleh itu ia boleh disimpulkan bahawa susunan sistem kekuda boleh menjadi punca untuk menjana kerosakan. Kajian berterusan perlu dijalankan pada masa akan datang.

TABLE OF CONTENT

CHAPTER	TITLE	PAGE
	SUPERVISOR'S DECLARATION	iii
	STUDENT'S DECLARATION	iv
	DEDICATION	v
	ACKNOWLEDGEMENT	vi
	ABSTRACT	vii
	ABSTRAK	viii
	TABLE OF CONTENTS	ix
	LIST OF FIGURES	xi
	LIST OF TABLES	xii
1	INTRODUCTION	
	1.1 Background Study	1
	1.2 Problem Statement	2
	1.3 Objectives Of Study	2
	1.4 Scope Of Study	3
2	LITERATURE REVIEW	
	2.1 Climate In Malaysia	5
	2.2 Monsoon In Malaysia	6
	2.3 Windstorm Damage	6
	2.4 Wind Design	8
	2.5 Truss Structure	9
	2.5.1 Roof Truss System	10
	2.6 Cold Formed	11
	2.6.1 Joint Connection	12

3	METHODOLOGY	
3.1	Introduction	13
3.2	Simulation	13
3.2.1	Simulation Models	14
3.2.2	SAP 2000	15
3.2.2.1	SAP 2000 Student Version	15
3.2.2.2	SAP 2000 Version 14	19
3.4	Flow Chart	30
4	RESULT AND DISCUSSION	
4.1	Introduction	31
4.2	Analyses Of Result	31
4.2.1	Stage One of Result Analyses	32
4.2.2	Stage Two of Result Analyses	42
4.2.3	Stage Three of Result Analyses	43
5	CONCLUSION	
5.1	Conclusion	47
5.2	Recommendation	48
6	REFERENCES	49
7	APPENDICES	51

LIST OF FIGURES

FIGURE NO	TITLE	PAGE
1.1	Cases of Wind Load Reaction towards the Roof Truss	4
2.1	Statistic of Damage Due to Wind Storm for Peninsular Malaysia in Jan 2009-June 2012	7
2.2	Apartment Roof Damaged Caused by Thunderstorm	8
3.1	Create a New Model	16
3.2	Edit Grid Lines	17
3.3	Draw Special Joints	18
3.4	Draw Frame Element	18
3.5	Assign Pin Supports	19
3.6	Define Materials (Cold Form)	20
3.7	Assign The Frame Section (Cold Form)	22
3.8	Define the Load Patterns	23
3.9	Assign the Value of Load for Each Load Patterns	24
3.10 (a)	The Reaction for Pressure – Pressure Loads (LOAD 1)	25
3.10 (b)	The Reaction for Suction – Suction Loads (LOAD 2)	25
3.10 (c)	The Reaction for Pressure – Suction Loads (LOAD 3)	26
3.11	Set Analysis Options	27
3.12	Run Analysis	27
3.13	Check the Frame Design	28
3.14	Export the Result to Excel	29
3.15	Flow Chart of Methodology	30
4.1 (a)	The Numbers of Roof Truss Joints for Model 1	33
4.1 (b)	The Numbers of Roof Truss Joints for Model 2	33
4.2	Graph of Maximum Load (KN) against Wind Speed (m/s) for Model 1	44
4.3	Graph of Maximum Load (KN) against Wind Speed (m/s) for Model 2	45
6.1	Map of Peninsular Malaysia	52

LIST OF TABLES

TABLE NO	TITLE	PAGE
3.1	Load Case for Wind Reaction	14
3.2	Number of Grid Surface	15
3.3	Actual Value of Grid Lines	16
3.4	Actual Value of Section Dimensions	21
4.1	The Joints Numbers at the Top Chord for Both Models	34
4.2 (a)	The Forces Reaction When Wind Load is 0.20 KN/m ²	34
4.2 (b)	The Forces Reaction When Wind Load is 0.35 KN/m ²	35
4.2 (c)	The Forces Reaction When Wind Load is 0.50 KN/m ²	35
4.2 (d)	The Forces Reaction When Wind Load is 0.65 KN/m ²	36
4.3 (a)	The Forces Reaction When Wind Load is 0.20 KN/m ²	37
4.3 (b)	The Forces Reaction When Wind Load is 0.35 KN/m ²	38
4.3 (c)	The Forces Reaction When Wind Load is 0.50 KN/m ²	39
4.3 (d)	The Forces Reaction When Wind Load is 0.65 KN/m ²	40
4.4	The Maximum Loads at the Joints for Model 1	43
4.5	The Maximum Loads at the Joints for Model 2	43
6.1	Wind Speed (m/s) For Various Return Periods	51
6.2	Important Factor, I	53

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

Malaysia is a country that known as tropical rain forest due to its located at equator. This country also is placed between South China Sea and Strait of Malacca. All this fact shows that Malaysia can easily exposed to the wind load especially during monsoon season. The monsoon in Malaysia can be categorized into two types which are the Southwest Monsoon from late May to September, and the Northeast Monsoon that will occur from November to March (MOSTI, 2013). During inter monsoon, wind storm are likely to occur and this will contribute high wind load to the building structure. By refer to the EM-DAT in 2010, wind storm are listed as top ten natural disasters in Malaysia which is 22.2%.

Nowadays there are lots of constructions that will be constructed in Malaysia. This is because Malaysia is one of developing country in this world. Building structure is highly contributing in construction compare to others structures like bridge. One of the considerations in design is wind load. This because extreme wind load can cause failure to building structure, therefore to make sure all building structure can withstand from this load, the structure analysis must be conducted carefully by considering the real effect of wind load in the analysis.

Usually the common structures in building structures that easily get damage by wind storm are roof truss structure. This because the weakness of connection at joint of

truss. Besides that, roof truss structure is the upper part of building structure so that mean there is less resistance at the roof to reduce the wind load during the wind storm.

Therefore structure analysis is the key word in civil engineering design to make sure all structure can support all load from dead load and life load so it can guaranty that no structure failure will occur during or after the construction. The structure analysis very important because their function is studies of all the factors or components define an organization or technique, to get their particular interrelationships and comparative magnitude within the understanding of the objectives or goal.

This wind load causes many wind disaster to the building structure that widely reported in Malaysia. This disaster caused death and injury to the people so as a precaution to reduce the number of injury and death, this research will be conducted to produce a suitable guideline for the future design in construction.

1.2 PROBLEM STATEMENT

From the past record, one of the top ten natural disasters occurred in Malaysia is wind storm. However the understanding of wind behavior to roof truss system is not well defined. Numbers of failure cases has been reported in mass media. Wind storm will cause a lot of damage to the structure especially to the roof truss structure. Usually the roof truss fail is due to the weakness at the joints of truss. The strength of this joints is depended on the numbers of screw and the numbers of plate that been used to connect two or more member at each joint.

1.3 OBJECTIVES OF STUDY

- To analyze the typical roof truss system due to wind load.
- To identify the potential of wind load that can cause the failure on truss joints.

1.4 SCOPES OF STUDY

This present study will be focus on the effect of wind load on roof truss system. This study will carry out by conduct the simulation only. The simulations should be conducted to produce the data of element joints force for the each joints of roof truss based on the various value of wind load (0.20 KN/m², 0.35 KN/m², 0.50 KN/m² and 0.65 KN/m²). Every each value of wind load will be run the simulation separately but every simulation will be contained three differences cases of wind load reaction towards the roof truss structure. The value of wind load is obtained from this formula:-

$$\text{Wind load} = 0.613 (V_s^2); \quad \text{when } V_s \text{ is the value of wind speed.}$$

The wind load reaction that has been mentions before mean the characteristics of winds when react with the surface of roof such as pressure load and suction load. From this two characteristics of wind reaction, there are three possibilities will occurred during the wind storm to the both sides of roof truss structure. These three possibilities are represented as figure below:-

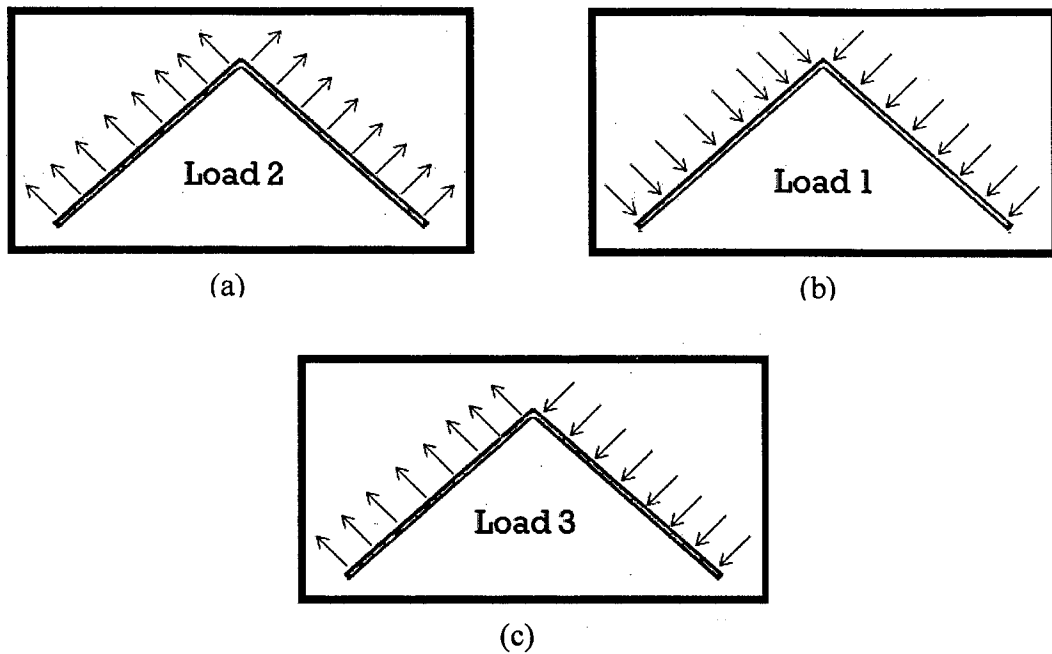


Figure 1.1: Cases of Wind Load Reaction towards the Roof Truss

All the simulations are conducted by using SAP2000 software. The results that produced by simulation is known as the real force of roof truss joints. This study is not complete yet when the results of all simulations are comes out, this because the simulation process cannot tell when this roof truss structure will be fail. Therefore to complete this study, the result that has been study from the previous researcher will be used as a guideline to produce the final result for this study. The result from the previous researcher shows that the maximum load that can be support by each joint of roof truss is 6.80 KN. From the result of simulations, the graphs of maximum load of joint against the speed of wind will be produced and these graphs will insert 6.80 KN as a limitation value of the maximum load at the joints.

CHAPTER 2

LITERATURE REVIEW

2.1 CLIMATE IN MALAYSIA

Malaysia is located in the central of South East Asia, bordering to the Indonesia at the south and west, Singapore to the south and Thailand in the north. It is comprises of Peninsular Malaysia and the states of Sarawak and Sabah. Malaysia has a few characteristics features of climate. Due to its location near to the equator, Malaysia climate categorized as high humidity, uniform temperature and over rainfall throughout the year. Malaysia has a tropical climate, with very warm during day and uniformly cool at nights. Average temperature holds at 30°C and during at night temperatures rarely drop below 20°C. In 2014, the average rainfall trend for Peninsula, especially the Northern and East Coast area has received rainfall more than 60% below the normal average. However for Central of Peninsula were received rainfall amount were over average (MOSTI, 2014).

2.2 MONSOON IN MALAYSIA

Even though Malaysia has light wind and variable, however, some of the periodic changes the wind flow pattern. These differentiate the type of monsoon, namely the northeast monsoon, southwest monsoon and two shorter periods of inter-monsoon seasons. Malaysian Meteorological Department (MMD) state that southwest monsoon usually occur in the later half May or early June and end in September and it blows slightly tranquil. The northeast monsoon season usually merged in early November and ends in March and it brings in more rainfall compared to the Southwest Monsoon. However, inter-monsoon occurs in March and October and during this period, thunderstorm frequently occur. Although thunderstorms are normal phenomena, however, it produced significant strong and gusty surface wind.

2.3 WINDSTORM DAMAGE

Windstorm defined as a wind that is strong enough to cause at least light damage to structure, buildings and trees and may or may not be accompanied by precipitation. In Malaysia, thunderstorms are a common phenomenon occurring all year round with highest mean 211 days annually (MMD, 2010). Despite their small size, all thunderstorms are dangerous. Every thunderstorm produces lightning which the potential to kill people. News on reporting the windstorm damage through mass media helps to increase the awareness among people. Previous research has proved that 91.2% of the respondent agreed that windstorm is one of the factors that contribute to the destructions towards environment and to people (Habibah *et. al.*, 2011).

The winds from thunderstorm are stronger and more turbulent than those monsoon winds. From the research done by Majid *et. al.*,(2012) in, Figure 2.1 indicates that 20 cases damage event happen due to wind storm in 2012 and 2010, 18 cases of damage in 2011 and 21 cases in 2009.

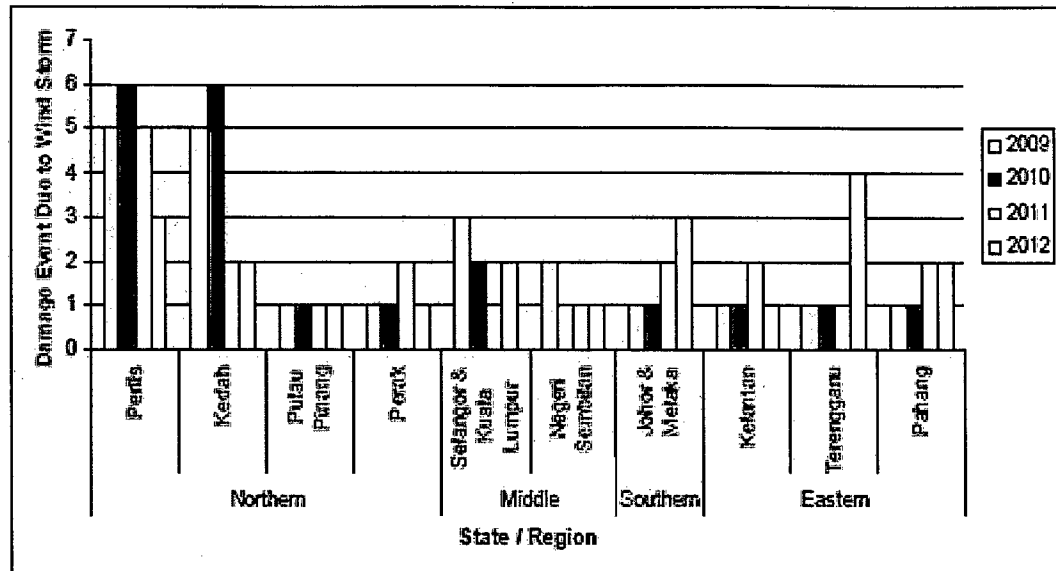


Figure 2.1: Statistic of Damage Due to Wind Storm for Peninsular Malaysia in Jan 2009- June 2012 (Majid *et. al.*, 2012).

The consequences of occurrences windstorm give the impact to building structures. From 80 damage cases about thunderstorm in Peninsular Malaysia, it is identified major contribution of damage occurred related to roofing system. Research done by Majid *et. al.*,(2011) and Lee *et. al.*,(2008) shows damage in steel sheet roofing system contribute highest amount with 47% followed by damage on truss system 30%, other related damage 20% and least contribution is damage of roof tiles with 13%. Figure 2.2 shows the thunderstorm that damages apartment roof at Shah Alam, 2012 (Nadirah, 2012).



Figure 2.2: Apartment Roof Damaged Cause by Thunderstorm,
(Nadirah, 2012).

2.4 WIND DESIGN

In Malaysia most of the roof design only considered wind load acting as a pressure load to the roof structure. However from the many research done it seem that wind also can cause suction load to the building structure. Most damage to roofs themselves is caused by local high suctions and large pressure fluctuations around the roof periphery and protruding portions. (Ramli *et. al.*, 2010)

Based on MS 1553; 2002, the maximum wind speed that has been occurred in Malaysia is 32.5 m/s. This maximum value of wind speed has been taken from 50 years V_{50} , return period of wind speed and the station wind speeds for all directions based on 3-second gust wind data. This data can be seen in the appendices.

2.5 TRUSS STRUCTURE

Wood Solution stated that, truss would be the construction that is made at least 5 triangular items because truss is basically any triangulated system of straight interconnected structural things. The individual elements are usually connected at nodes; your cable connections can be assumed to get nominally pinned. The 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.

Besides that, Wood Solution also mentioned the effectiveness of any truss is based on the triangulation involving banding users which communicate to help the advantage of the overall structure. With regard to trusses, compression users frequently stipulate the size of sun and rain, so models that contain small compression users or even discipline towards horizontal attachment are usually extremely effective compared to trusses having longer compression users.

The planar truss is actually one wherever all of the users and nodes lay in just a two dimensional airplane, while a space truss features users and nodes extending directly into a few size. The superior beams in a truss are generally referred to as major chords and tend to be inside compression setting, the underside beams are generally referred to as bottom level chords and tend to be inside anxiety.

The common use of trusses is at structures, exactly where assist for you to attics, the actual floor surfaces and also inside packing for example providers and also hanging ceilings, are easily provided. The leading reasons are: (Davison *et. al.*, 2012)

- Long span
- Lightweight
- Controlled deflection
- Opportunity to support considerable loads.

2.5.1 Roof Truss System

Education Holed have stated that the roof trusses, which are structural the different parts of homes or even commercial complexes, support the weight of roof. Typically, they are made out of items of solid timber or even material which are nailed, bolted, or even pegged together to form some sort of mutually supporting and strong base roof.

Wise Geek have stated that, whenever roofing some sort of developing or even house, adhering to a proper roof truss design is critical. These types of trusses should never end up being eliminated or even improved with no assistance of a structural industrial engineer. If one component of a truss is removed or weakened, the whole roof could give way. The design ought to remember to consider the strength of the actual timbers, if a wooden truss is used, or the steel, if a steel truss is used. Other aspects which might be significant within in roof truss design include the distribution of the load through the truss parts and the connection of the parts.

Normally, roof trusses are widely-used within household in addition to commercial design as an option to conventional stick roof framing. Using trusses rather than stick framing offers builders along with many benefits. For instance, most such trusses are conceived by engineers, who have ensured they meet roof load and building requirements. Through the use of prefabricated trusses, builders can certainly appreciably lower their own full design time.

An additional important benefit to be able to using trusses will be which connected with charge. Wise Geek has mentioned that roof trusses are generally constructed from two through four futures. This kind of stock will be considerably less high-priced versus lengthier framework bits used in conventional stay ceiling framework. Additionally, trusses can certainly generally end up being mounted through less encountered carpenters, allowing builders to save on job costs.

2.6 COLD FORMED

Cold-formed steel framing (CFSF) pertains especially to help customers throughout light-frame building construction which have been made fully of aluminum sheet steel, produced to help several patterns from normal temperature ranges. The most frequent design intended for CFSF members is often a lipped channel, despite the fact that “Z”, “C”, tubular, “hat” and other patterns and also versions are already used. For this study, C-channel of cold formed member has been used.

Cold-formed steel has been thoroughly utilized in noncommercial construction because doing so presented an increased power, cost-effective, non-combustible, completely recyclable, long lasting and also dimensionally dependable cold-formed steel framework results in superior efficiency because the major structural system throughout noncommercial construction, especially throughout high wind. (Xu et al., 2000)

As a result of superior power of cold-formed steel, it can provide affordable alternatives, for example huge clear-spans and also raised or cathedral ceilings, that may not absolutely end up being economically achievable having wood trusses. Steel trusses likewise have rewards throughout quickening your construction method and also lowering labor costs, because light-weight of cold-formed steel like trusses much easier to erect in comparison to wood construction. Alternatively substance to help regular solid wood truss construction, cold-formed aluminum trusses intended for noncommercial roof systems cash in on the many inherent features about of steel and have great potential in both residential and commercial construction.

Systematic investigation has been executed to investigate the performance of cold-formed steel trusses (Harper, *et. al.*, 1995; LaBoube, *et. al.*, 1998; Mobasher, *et. al.*, 1998). The cold-formed aluminum truss design and style typical will be printed (AISI, 1999).

2.6.1 Joint Connection

Many standard ways of linking parts including riveting, bolting, welding, screwing and adhesives material are suitable for cold-formed section. The potency of joint interconnection is very important from the roof truss design and style for the reason that cold-formed C-section were hooked up jointly to be able to shaped member of roof truss program. If the potency of interconnection just isn't powerful sufficient to be able to refrain from this wind load, this roof framework will collapse.

The prior analyst mentioned which, , the result of test on connections showed the experimental values of the load that can be support by the connection are higher by almost double the theoretical value that has been stated in BS 5959. Therefore the maximum load can be resist by joint is 6.80 KN. (Mahmood *et. al.*, 2005).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will fully describe about the process that involved during the preparation of this project until the final result comes out. In succession of this case study, a flow of method was used. The analysis starts off with project planning by using a flow chart. The flow chart acts as a guide to successfully carry out this case study step by step.

3.2 SIMULATION

This project only runs the simulation process to analyze the reaction of the roof truss structure due to the effect wind load by using SAP2000. Therefore before started the simulation, some research has been done to get the maximum value of wind load in Malaysia and this data has been used in this simulation to produce the suitable and acceptable result. Besides that, another research also has been done to know the typical type of roof truss structure that always been used in the construction to be used as roof truss model in the simulation process of this project because this project is not to discover a new things but to solve the problems of roof truss failure that always happen in Malaysia.

The simulation result cannot be used directly to solve the problems of roof truss failure because the simulation process only can produce the result of load reaction at each join and each member but the simulation cannot mention the maximum load that can be support by the roof truss structure before this structure become failure. Therefore the result

from the previous researcher that has been study in Chapter 2 (Literature Reviews) will be used as guideline in this project when running the simulation on roof truss structure by insert the various speed of wind.

3.2.1 Simulation Models

This research has been conducted by simulate two different model of roof truss structure. First model is the command roof truss structure that always used in residential construction that known as HOWE and this model is for experiment. The second model is the same designation of roof truss structure that commonly used for government schools construction and this model is more to case study.

Every each model will be simulate four times due to four different value of wind speed such as 18 m/s, 24m/s, 29m/s and 33m/s. This various value of wind speed is very important to see the pattern of the reaction load at the joints against the wind speed towards the roof truss structure. The each simulation has three case of wind load reactions and this load cases will run together because this three case is the characteristic of wind reaction that usually react to the surface object. There are two characteristic of wind load reaction that reacts to the surface of roof such as pressure load reaction and suction load reaction. This two characteristic will produces the three probabilities during the real situation to the roof surface when windstorm occur. These three probabilities have been translated into three cases in this research. The cases are stated as below:-

Table 3.1: Load Case for Wind Reaction

Load Case	The Wind Reaction on Roof Surface
1	Pressure – pressure
2	Suction – Suction
3	Pressure – Suction

3.2.2 SAP 2000

SAP 2000 is one of the software that has been used widely in civil engineering field today to analyze the structure. There are two type versions of SAP 2000 that needed to complete the simulation of this study. The first version that use in this study is Student Version and this version has cover a few part in the beginner process of simulation only. The second version that use in this study is 14th Version and this version has been used to continues the work that has been done at Student Version until this simulation produce the result.

3.2.2.1 SAP 2000 Student Version

This version has been used to create a new model and produce the roof truss structure models only because this version is easier to the beginner user to create the model compare to other version.

- To create a new model, a few steps must be follow such as state in figure below:-
 1. Change the global units that we want to use during the creating models. For this models “KN-m” has been choose as global units.
 2. Click File > New Model to start create the model.
 3. After that the Coordinate System Definition will pop-up automatically, than insert the values of Number of Grid Spaces at X (horizontal) and Z (vertical) direction only due to create the 2D model.

Table 3.2: Number of Grid Surface

	Number of Grid Space	
	X	Z
Model 1	4	3
Model 2	14	7

4. Click OK.

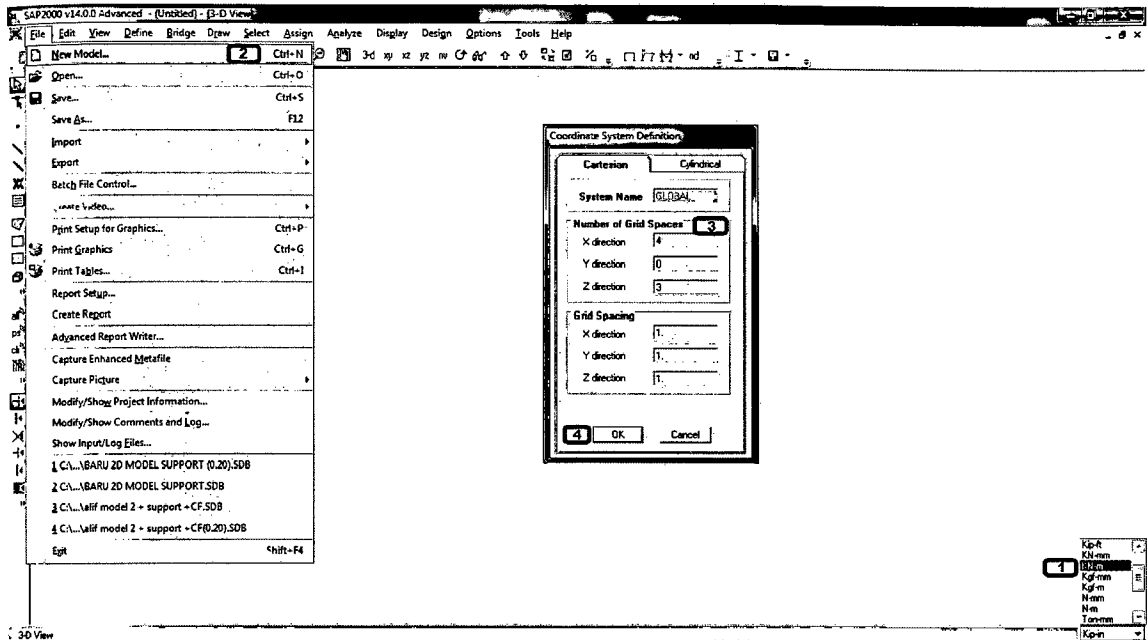


Figure 3.1: Create a New Model.

- To edit the grid, click Draw > Edit Grid, than Modify Grid Lines will pop-up automatically. After that follow a few steps such as state in figure below:-
 - Click at direction X to edit grid line at X.
 - Click Delete All to delete the current value of grid. After that insert the actual value of grid for each model.

Table 3.3: Actual Value of Grid Lines

	Actual value of grid lines	
	Model 1	Model 2
X	0, 4, 8, 12, 16	0, 1.15, 2.3, 3.05, 4.13, 5.21, 6.29, 7.37, 8.45, 9.53, 10.61, 11.69, 12.44, 13.59, 14.74
Y	0	0
Z	0, 2, 4, 6	0, 0.45, 0.9, 1.2, 1.62, 2.05, 2.47, 2.9

- Click Add Grid Line after insert every each value of grid line.
- Repeat steps 1 and 2 by choosing the Y direction and insert the Y value.
- Repeat steps 1 and 2 by choosing the Z direction and insert the Z value.

6. Click OK.

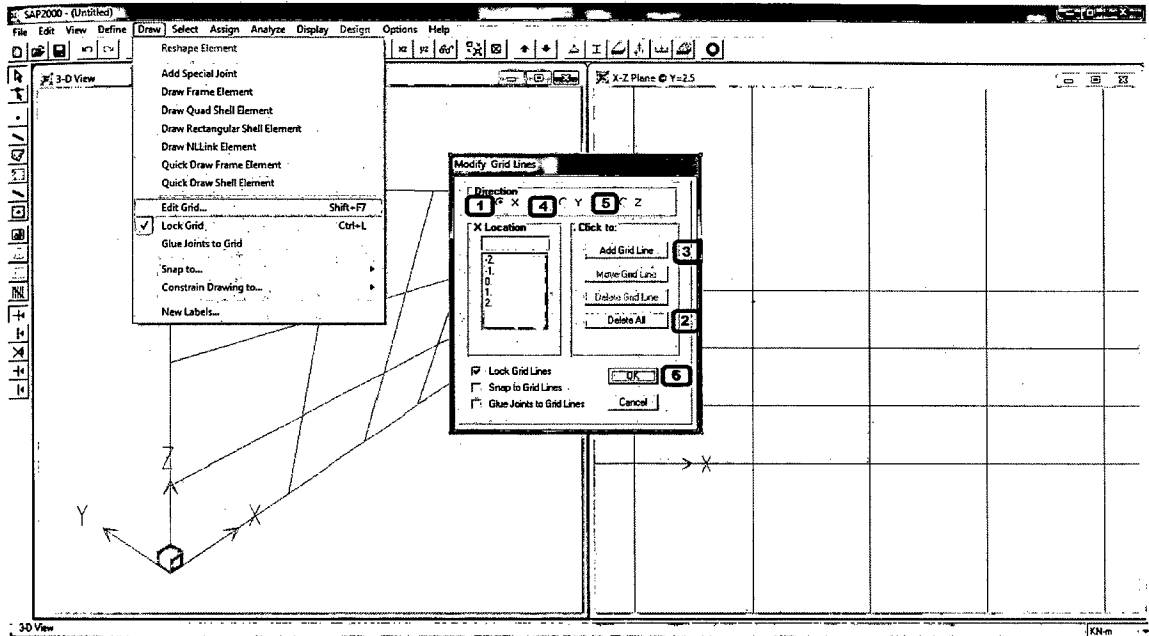


Figure 3.2: Edit Grid Lines.

- To draw special joint, it need to be sketches the roof design first for each models to know the real position of the joint on the each models.
 1. Click the Draw Special Joint at the tools bar
 2. Click at the interceptions of grid lines that require placing the joint by referring the sketches of each roof designs.