Design of Communication Tower and Its Performance

by

Hasmira Binti Sumbiar

Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Civil Engineering)

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Universiti Teknologi PETRONAS

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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

September 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the originality is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken by unspecific sources or persons.

HASMIRA BINTI SUMBIAR

ABSTRACT

This research of "*Design of Communication Tower and Its Performance*" is generally to study on standard design of communication tower and to analyze tower deflection based on acting force of wind load that coming from one direction. There will be two models of square-foot towers of 45m and 76m tall where both towers will be analyzed by using STAAD Pro software. Wind load calculation is based on three codes BS 8100, ASCE 7-05 and MS 1553:2002. This comparison is to find out which code provides the most critical condition for the tower's performance. Some literatures review are done in order to critically discussed on what criteria that related to the topic had been find out by the authors, and also to give some improvement on certain areas corresponding to the research.

ACKNOWLEDGEMENT

The author would like to take this opportunity to thank everyone who has contributed either directly or indirectly to the completion of this dissertation. The utmost gratitude goes to the supervisor, Ap Dr Narayanan Sambu Potty for his endless support and supervision in all the time of study and writing of this thesis. Special thanks to the coordinator, Dr Teo Wee for coordinating the course in a very systematic way. Last but not least, the author was very grateful to her family members and colleagues who continuously encouraged her from the start till the end of the research. Thank you to all.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

With the rapid widening of communication network in Malaysia, a large number of communication towers have been constructed throughout the whole country. Telephone, radio, internet and also television, all these type of communication medium is working fine just if only the system is being installed and monitored comprehensively every day.

The three most common types of communication towers are self supporting, monopole and guyed mast tower. These types of tower differ based on its structural action, geometry of cross section, material of section, and also placement of the tower itself. Tower geometry is generally known to be part of factors that contributing in finding its optimum design.

The importance of these towers is as evident from the communication failures and power blackouts which are due to damages by extreme weather events, vandalism, and etc. Malaysia may have a very huge loss if there is no special emergency plan to be substituted soon after a sudden damage. And therefore, a detailed study on designing a safe communication tower in a case of Malaysia's condition will be carried out.

There will be also a section discussing about the analysis of design comparing between Malaysian, British and American standards, and hence determine which codes provide a better or safer design. The step by step design calculations involved will be put onto the report to assist readers or specifically to graduate engineers to understand more about the exact procedures.

A very crucial part is STAAD Pro modeling where to analyze the structure by using software. It can generate much accurate result and what is more important; numbers of amendments on the design can be made up since the analysis can run in a very short time especially in calculating all the iterative formulas.

1.2 Problem Statement

On August 1st 2009, a huge crisis happened in Pasir Akar, Besut, Terengganu, Malaysia where Menara Mobile Mast (part of the country mega project - wireless-national broadband) collapsed due to strong wind. The project consumed almost up to millions ringgit and completed at September 2008, and unfortunately collapsed a year after. Engineers and even the government had been blamed by most of the citizen for not handling the project well, and even worse they become unconfident with the services of the Malaysian engineers itself. Therefore, this research is done in order to study on how to design a safe communication tower in a case of Malaysia's condition, and also to find solutions in reducing the risk of tower damages. Engineers should be responsible to serve the nation with their good skills and knowledge, and thus to develop the country to a betterment of the social needs.

1.3 Objectives

a) To study two model of square-foot towers of 45m and 76m tall.
b) To study differences of wind load calculation based on three different Codes of Practice (Malaysian, British and American Standard)
c) To carry out STAAD Pro modeling of the two towers.
d) To study on tower deflection based on self weight, wind load and antenna load.

1.4 Scope of Study

Study on communication tower is actually a very huge field, as specification is needed in order to analyze the structure in details. This topic had focused only on the tower design and its performance. The scope of study will be divided into several aspects as followed:

a) Type of tower available in Malaysia
b) Different geometries of tower
c) STAAD Pro modeling and design optimization
d) Wind load calculation based on Malaysian, British and American standard
e) Material used
f) Tower deflection

CHAPTER 2

LITERATURE REVIEW

Communication tower is basically a tower made up of lattice of triangular or square cross section with one or more antennas attached at the top. With height that usually vary in the range of 50 - 250m, this tower can only be fabricated on site if it has a very good engineering design, as the applied load is not only from the mass itself (dead load), but including the live load, wind load and earthquake if any.

A very long research is done in order to collect all the informative literatures available either on the net or in the library. And later on some of the useful information may be used in analyzing the topic however with several additional analyses, so that it can improve the final report.

2.1 Type of Tower

Towers can generally be categorized into three major types which are monopole, guyed mast tower and self supporting tower as refer to the figures below.

Figure 1. Monopole Tower.

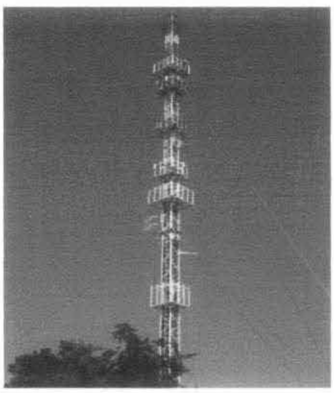

Figure 2. Guyed Mast Tower.

Figure 3. Self Supporting Tower.

Monopoles towers are free standing towers and are most commonly used in cellular and personal communication service (PCS) applications. They are typically constructed of different diameter steel sections either cylindrical or multi sided in shape. Due to its construction, they are expensive to manufacture but simple to erect. And plus, monopole is primarily used in urban environment where there is limited space available for the footprint of the tower base.

Guyed mast towers are generally the least costly however they also require the greatest amount of land to erect due to the area needed for the cable guy wire to be attached on the ground. As a result, guyed towers are most often seen in rural or suburban settings where land is not at a premium.

Self-supporting towers are a free standing tower and it can be constructed with either three or four legs with a lattice frame design. It has a larger footprint than monopoles, but still requires much smaller area than guyed mast tower. These towers are generally the strongest as it can support the largest load which includes wind and ice loads.

The online handout, *http://www.itrainonline.org/trainonline/mmtk/*, *ItrainOnline Multimedia Training Kit (MMTK)*, developed by Alberto Escudero Pascul, May 14th 2006, had mentioned four general considerations when selecting the type of tower, which are:

a) Antenna load: The antenna loading capability of a tower depends on the structure of the tower. The more surface area of the antennas, coaxial cables, brackets and other equipment mounted on the tower and exposed to wind, the more robust tower is required.
b) Tower footprint: The footprint of a tower is the amount of free space on the ground that is required for the installation.
c) Height of tower: Higher height requires adding guying cables to the structure.
d) Budget: The smaller the tower base, the more costly installation budget.

From website *http://www.orps.state.ny.us/sas/valuation/towers.htm*, which has last modified on February 17^{th} 2007, the discussion page which is actually excerpted from the "*Local Telecommunications Taxes and Fees in New York State, Report to Governor George E. Pataki and The New York State Legislature*" highlights other logical points to be counted in considering the type of tower. The highlighted criteria are (1) sand condition, (2) topography and (3) zoning area.

2.2 Geometry of Tower

Most communication towers in Malaysia are using K-bracing for their main structure member. *BS EN1993-3-1:2006, Eurocode 3- Design of Steel Structures, Part 3-1: Tower, masts and chimneys – Tower and masts*, in Section H.3, Bracing Members, has stated that each different pattern has different value of slenderness. Further study is needed in order to check what is the effect on other engineering properties. Figure 4 shows the typical bracing pattern used for tower design.

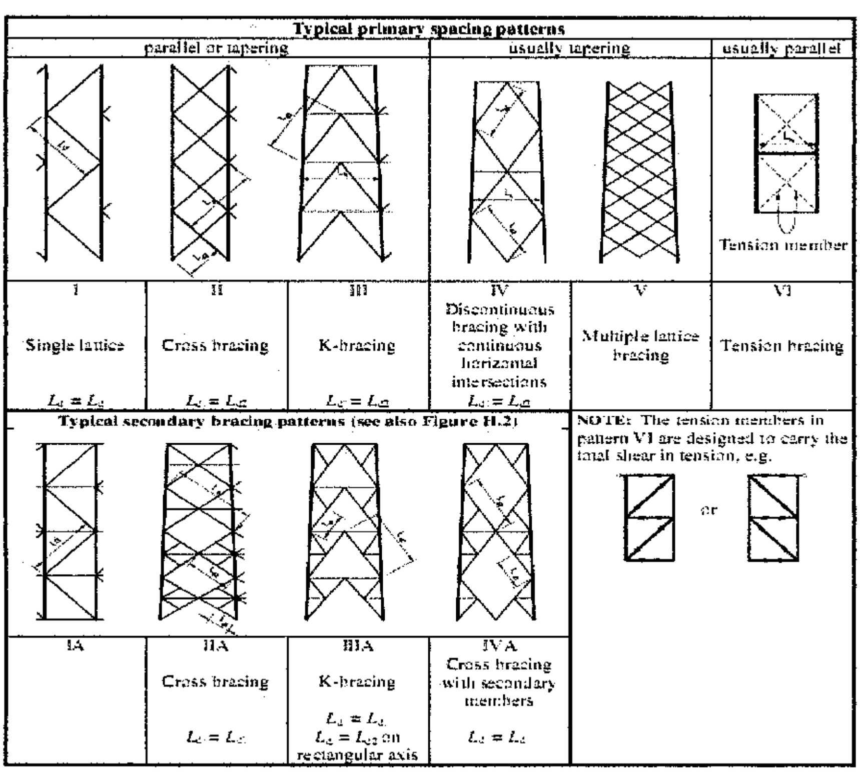

Figure 4. Typical Bracing Pattern. Source: BS EN1993-3-1:2006, Figure H.1, page 72.

2.3 Damages of Tower

As mention before in Chapter 1, Section 1.2 – Problem Statement, on August 1st 2009, a huge crisis once happened in Pasir Akar, Besut, Terengganu where Menara Mobile Mast (part of the country mega project - wireless-national broadband) where it collapsed due to strong wind and heavy rain. Some pictures below are taken from a blogger *(http://teganuku.blogspot.com)* gives a better view on this incident.

Figure 5. Menara Mobile Mast Found Collapsed on August 1st 2009.

All data history on catastrophic collapse of lattice tower at western countries (USA, Germany, Canada, Russia, Sweden, France and Norway) is compiled to analyze the mode of failure of the structure. The record is taken from earliest March 1912 until the latest March 2011. The type of collapsed tower is all basically steel lattices except one in December 2nd 1976 where Pic de Nore Transmitter, Predelles-Carbades in France, due to heavy storm, this concrete tower was collapsed. Besides that, all these towers are also vary in their height in between 45m - 648m. Table 1 is the summary of statistical data for all cases:

Table 1. List of Catastrophic Collapse of Radio Masts and Towers. Source: Wikipedia, http://en.wikipedia.org/wiki/List_of_catastrophic_collapses_of_radio_masts_and_towers

Mode of Failure (Reason for Collapse)		Number of Cases
Natural disaster	Storm	18
	Lightning	3
	Icing	20
	Tornado	7
	Snow	2
	Hurricane	4
	Earthquake	1
Human failure	Construction	4
	Terrorism	3
	Maintenance	9
	Sabotage	4
Structural failure	Material fault	5
	Bad state of guy	6
Accident	Aircraft collision	15
	Fire, fallen tree	2
Unknown	Undetermined factor	3

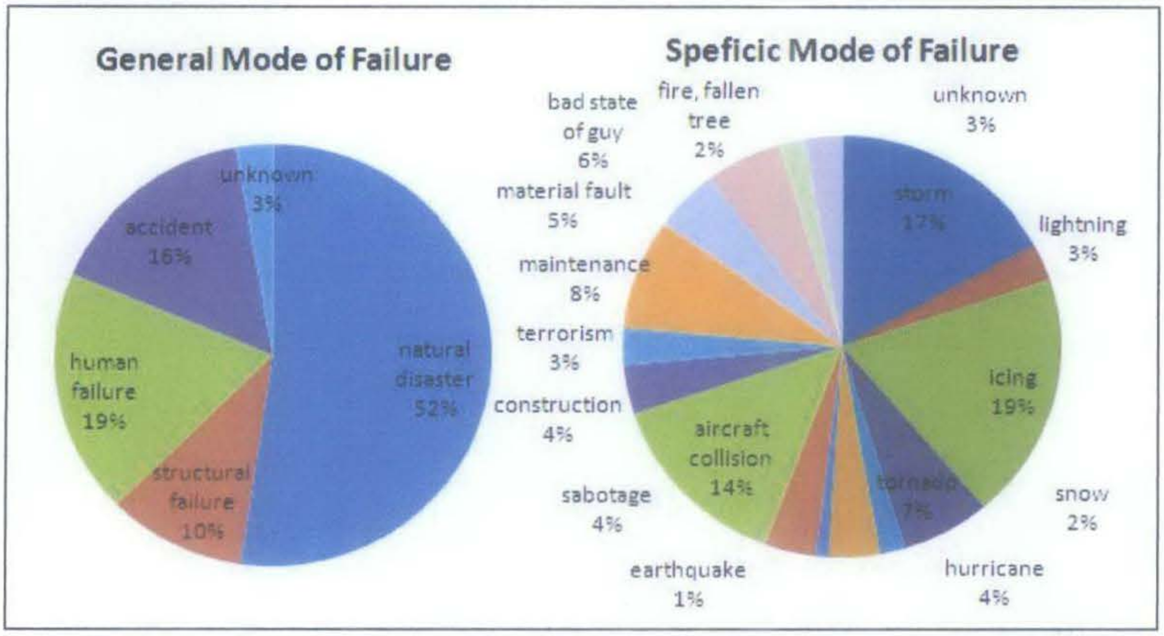

Figure 6. Pie Chart of Mode of Failure of Radio Masts and Towers.

From the pie chart above, it is clearly shown that natural disaster has become the biggest factor on catastrophic collapse of radio masts and towers. With total percentage of 52% which storm is 17%, lightning (3%), icing (19%), tornado (7%), snow (2%), hurricane (4%) and earthquake (1%). It is a fact that this factor is beyond human's control, however it does not mean that engineers especially, cannot solve the problem. Various precautions can be made as a method of reducing the risk to collapse, and further study is thoroughly conducted till the completion of this project.

2.4 Optimizing tower design

In thesis, *Reka Bentuk Dan Analisis Menara Telekomunikasi, Mohd Hafizul Bin Zakaria from Universiti Teknologi Malaysia (UTM)*, had studied the procedures involved in getting optimum design of telecommunication tower. The design was done in 3 stages. For stage 1, only vertical legs of the tower have to be analyzed, followed by analyzing the whole structure including both vertical and slanting legs during stage 2, and final stage is to choose on the most light tower as a model control (result from stage 2) and later it will be modified until it reach its allowable maximum base's width which is 1/7 - height of the tower. However, an improvement can be done here by checking on angle sizing since it can control the tower weight too. Smaller angle provide lighter weight. The summary of the procedures is stated in Figure 7:

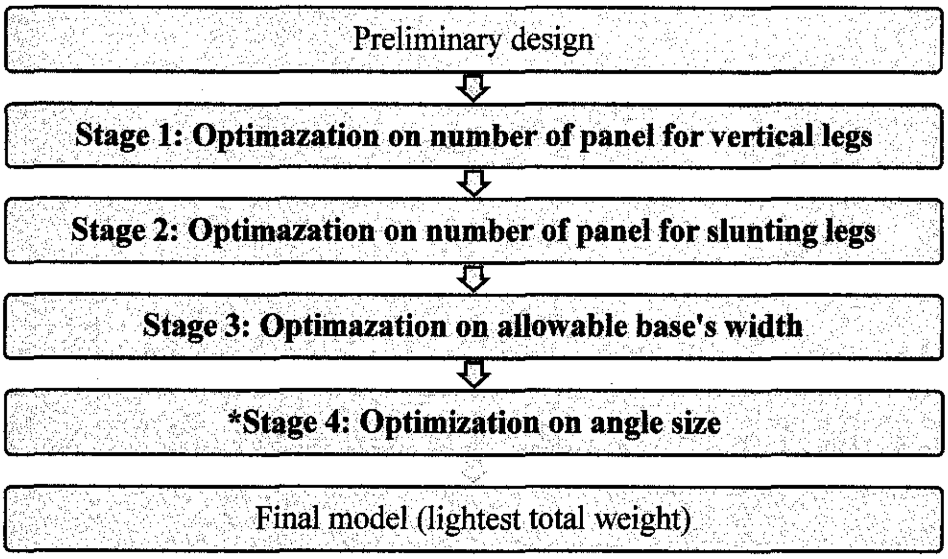

Figure 7. Procedure on Optimum Design of Telecommunication Tower. Source: Thesis Reka Bentuk Dan Analisis Menara Telekomunikasi, Page 40.

Design of Steel Structures textbook, written by *SR Satish Kumar and AR Santha Kumar* is actually a good reference for young engineers to know the step by step procedures on how a communication tower is designed. Here, the authors had explained all the related formulas with several examples of solved case studies, as to make the readers understand the procedures easier. Besides that, in the middle of Chapter 7, there is a section about computer-aided design method. Since the steps are usually iterative (lengthy repeated calculations) and therefore it is obvious that the use of computer is essential. There are two methods available, which the first method is to use a fixed geometry (configuration) and minimizes the weight of the tower, and meanwhile the second method assumes the geometry as unknown and derives the minimization of weight.

2.5 Antenna Load

"Invitation to Register Interest as Universal Service Provider", Appendix 8 - Tower and Site Specifications, 30th Dec 2008, had outlined dimension and weight of TX and GSM type as shown in Table 2. These are the standard antennas that usually being attached at the top of the communication tower. Therefore, some of these antennas will be used as sample design in designing both tower 45m and 76m tall.

Table 2. Dimension And Weight of Antenna. Source: Appendix 8 - Tower and Site Specifications.

Antenna Type	Dimension (m)	Weight (kg)	Area (m^2)
TX	3.6	386	10.18
TX	3.0	245	7.07
TX	2.4	203	4.52
TX	1.8	125	2.54
TX	1.2	77	1.13
TX	0.6	23	0.28
GSM	2.6H x 0.26W x 0.16D	28	0.68

This spefication also provided information on mounting up the antenna at specific height from the tower base. Table 3 and 4 show the position of antenna used for tower 45m and 76m tall. However, this arrangement was designed for triangular not for square-foot tower. So some changes will be done in relocating the antennas to the suitable position on the tower panel. The numbers of the antenna used also differed from the origin data in the specification.

Table 3. 45m Tower Load Chart. Source: Appendix 8 - Tower and Site Specifications.

Mounting from Tower Base (m)	45m Light Duty (LD)	Azimuth in Degrees	45m Medium Duty (MD)	Azimuth in Degrees
	Antenna Type and Position			
44	3 x GSM	60, 180, 330	3 x GSM	60, 180, 330
41	2 x 2.4m Dia	60, 330	2 x 2.4m Dia 2 x 1.8m Dia	60, 180 240, 360
40	3 x GSM	60, 180, 330	3 x GSM	60, 180, 330
38				
37	2 x 1.8m Dia	60, 330	2 x 1.8m Dia	60, 180
			2 x 1.2m Dia	240, 360
36	3 x GSM	60, 180, 330	3 x GSM	60, 180, 330
35				
33	2 x 1.2m Dia	60, 330	2 x 1.8m Dia 2 x 1.2m Dia	60, 180 240, 360

Table 4. 76m Tower Load Chart. Source: Appendix 8 - Tower and Site Specifications.

Mounting from Tower Base (m)	76m Light Duty	Azimuth in Degrees	76m Medium Duty	Azimuth in Degrees
	Antenna Type and Position			
75	3 x GSM	60, 180, 330	3 x GSM	60, 180, 330
72	2 x 2.4m Dia	60, 330	2 x 2.4m Dia 2 x 1.8m Dia	60, 180 240, 360
71	3 x GSM	60, 180, 330	3 x GSM	60, 180, 330
69				
68	2 x 1.8m Dia	60, 330	2 x 1.8m Dia	60, 180
			2 x 1.2m Dia	240, 360
67	3 x GSM	60, 180, 330	3 x GSM	60, 180, 330
66				
64	2 x 1.2m Dia	60, 330	2 x 1.8m Dia 2 x 1.2m Dia	60, 180 240, 360

CHAPTER 3

METHODOLOGY

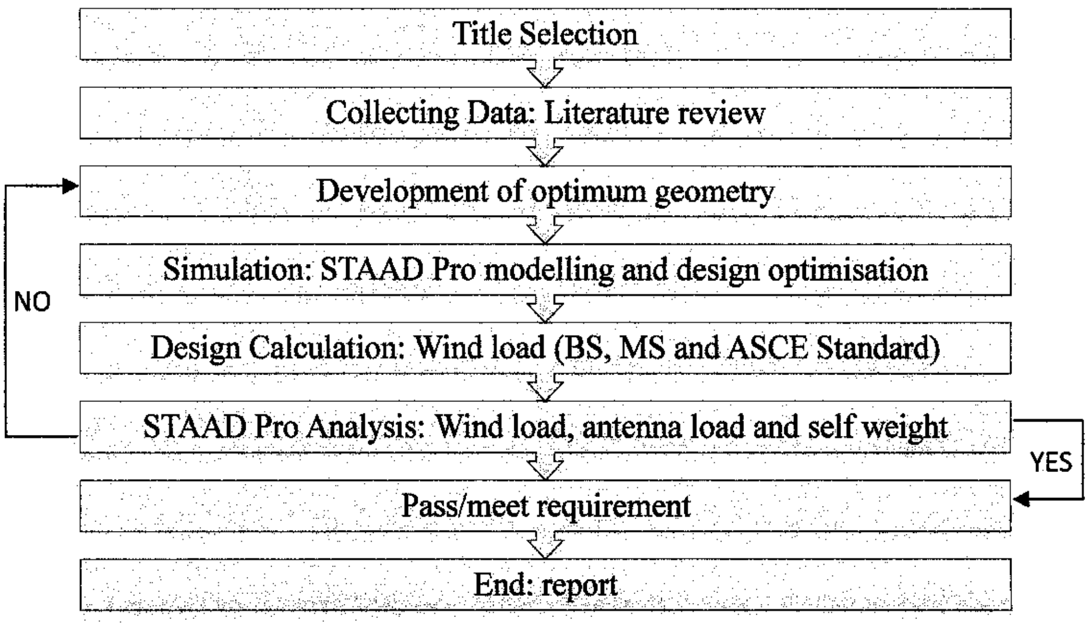

Figure 8. Summary of Project Flow.

From the figure above, it shows that the project will be done in several phases where it start with title selection and end with completing a report. The topic of "Design of Communication Tower and Its Performance" is chosen due the importance of communication tower as evident from the communication failures and power blackouts which are caused by several factors.

Collecting related literatures from the library or the internet which includes e-journal, paper works, thesis and etc helps a lot in understanding the real case of tower design and performance. All those relevant materials will be used as major reference and in addition to give improvement on the current findings by giving more facts and figures details or else to find new hypothesis regarding the topic.

In next phase, to study on development of optimum geometry, the tower is designed by making the straight part of the top tower's height constant, and to differentiate the slanting leg until it reach its most optimum base width. Basically, the bigger the base width is better as it can produce better foundation, but otherwise, it increases the total weight (thus, the cost is increased).

After tower geometry is chosen, the tower will be modeled into STAAD Pro software. The nodes are built according to their respective coordinate of x, y and z. Size of the angles is set to the respected member, where basically the size is decreasing from below to the top panel. After one model is finished, load case of self weight of the tower is created based on what material being used for the tower member. Modal calculation can be requested through STAAD Pro command file, and in the result analysis, it generates frequencies of several modes.

Next step is to calculate wind load acting on tower panel based on three different codes of BS 8100, ASCE 7-05 and MS 1553:2002. These three codes provide different ways of calculating the wind load, and therefore comparison of result of all codes will be analyzed thoroughly. Which codes give higher value of wind loads and vice versa, and this is what to be found out in this project. All the manual calculation is done in excel spreadsheet so that any modification on the design data can be applied without having to recalculate everything from start. Procedures of calculating the wind load for all three codes will be shown in Chapter 4, Result and Discussion.

There are two ways of inserting wind load on tower panel in STAAD Pro. The first method is to insert one by one Nodal Load where the calculated wind loads, Force, F (kN) is appointed at the specific node from top to bottom. Meanwhile the second method is to define wind; STAAD Pro defined wind action in Intensity, I (kN/mm^2), and thus the intensity will be automatically assigned to each panel area. This research used the second method since it is quicker and more accurate. The risk on putting up wrong load value is become much lesser since it did not require appointing wind load at each nodes of a tower panel. The command input in STAAD Pro for both methods is shown in Figure 9 and 10.

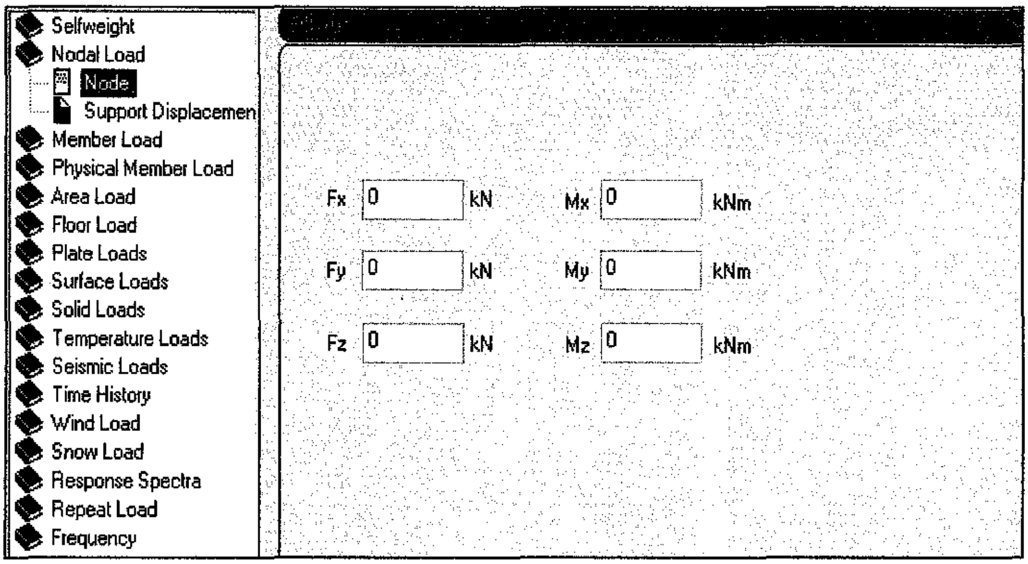

Figure 9. Command Window of Inserting Nodal Load in STAAD Pro.

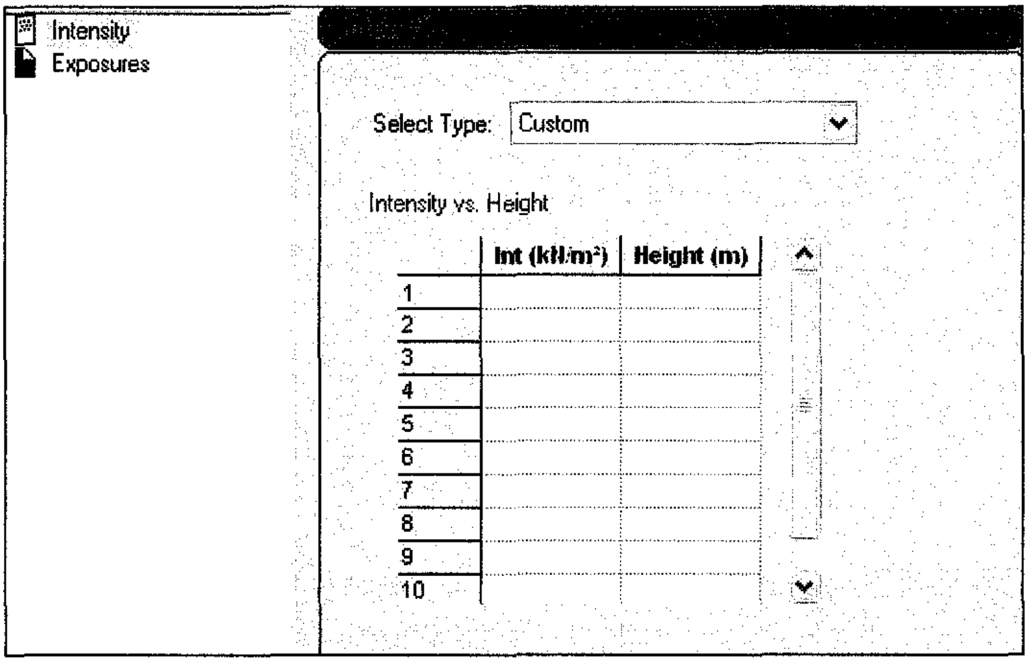

Figure 10. Command Window of Inserting Intensity of Wind in STAAD Pro.

Antennas that will be attached on the tower are TX and GSM type (refer Figure 11). The dimension and weight of the antenna are referred to Table 2. The position of the antenna had to be rearranged into new azimuths of tower with four edges. Clashing between two antennas can be avoided as long as the distance from centre of Antenna A to centre of Antenna B is greater than sum of radius of antenna A and antenna B.

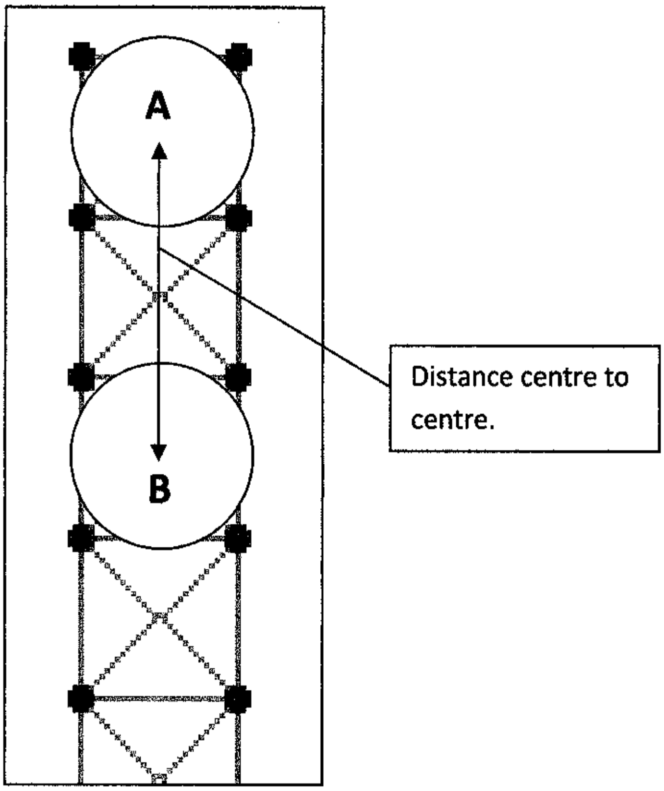

Figure 11. Distance between Two Antennas

STAAD Pro will run the analysis of the lattice tower with all three load cases of self weight, wind and antenna load. If the deflection is not critical and STAAD Pro has not figured out any member failure, so the design is considered pass. If not, the design shall be start over from phase 3, development of tower's geometry; and to continue until pass. Using software is actually giving extra advantages since the analysis can run faster as compared to the tedious way of doing iterative manual calculation. Lastly, a very detailed report is done to wrap up all the result.

Table 5. Gantt Chart/Timeline Final Year Project (FYP 1)

No	Details	FYP 1															
		1	2	3	4	5	6	Mid-Semester Break	7	8	9	10	11	12	13	14	15
1	Title selection: Design of Communication Towers and Its Performance																
2	Research on literatures related to the topic																
3	Submission of Extended Proposal																
4	Study and analyze all data compiled (literatures, codes of practices, textbooks, etc)																
5	Project defense & progress evaluation																
6	STAAD modeling (tower geometry, member properties)																
7	Design calculation (load)																
8	Submission of draft interim report																
9	Submission of interim report																

Table 6. Gantt Chart/Timeline Final Year Project (FYP 2)

No	Details	FYP 2															
		1	2	3	4	5	6	Mid-Semester Break	7	8	9	10	11	12	13	14	15
10	STAAD Pro analysis (load, angle size)																
11	Continue on design calculation																
12	Design analysis due to tower damages																
13	Preparation on report																
14	Submission of progress report																
15	Submission of draft final report																
16	Oral presentation																
17	Submission of final report																

CHAPTER 4

RESULT AND DISCUSSION

4.1 Design Stage of 45m Tall Square Foot Tower

Rather than to start with designing a standard communication tower from the very basic step, it would be better to analyze any one of existing communication tower first as this can help to know how the tower design was done. This will also served as cross check on the procedure. Figure 12 shows the tower that will be used as the design model, **45m tall square foot** self support tower.

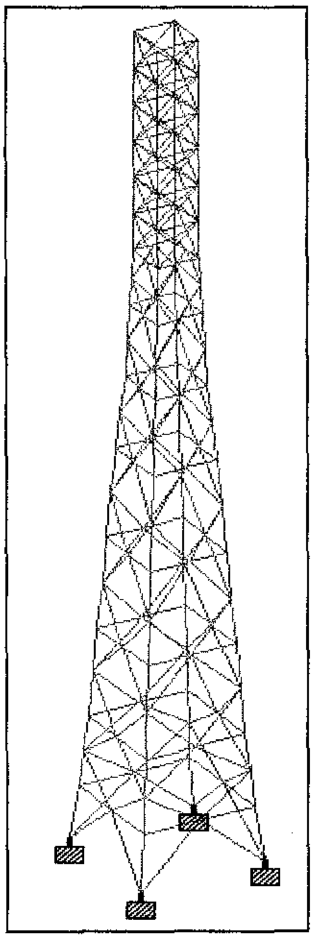

Figure 12. 45m Tall Square Foot Self Support Tower.

4.2 STAAD.Pro Simulation

Software features

Model: STAAD.ProV8i

Release: 20.07.04.12

Procedures in using STAAD.Pro for tower modeling

1. Entering job information
2. Build geometry: Node to Node
3. Define material: Steel
4. Set member properties : Angle Size
5. Set end support: Fixed
6. Set Load: Self Weight, Wind, Antenna
7. Perform analysis

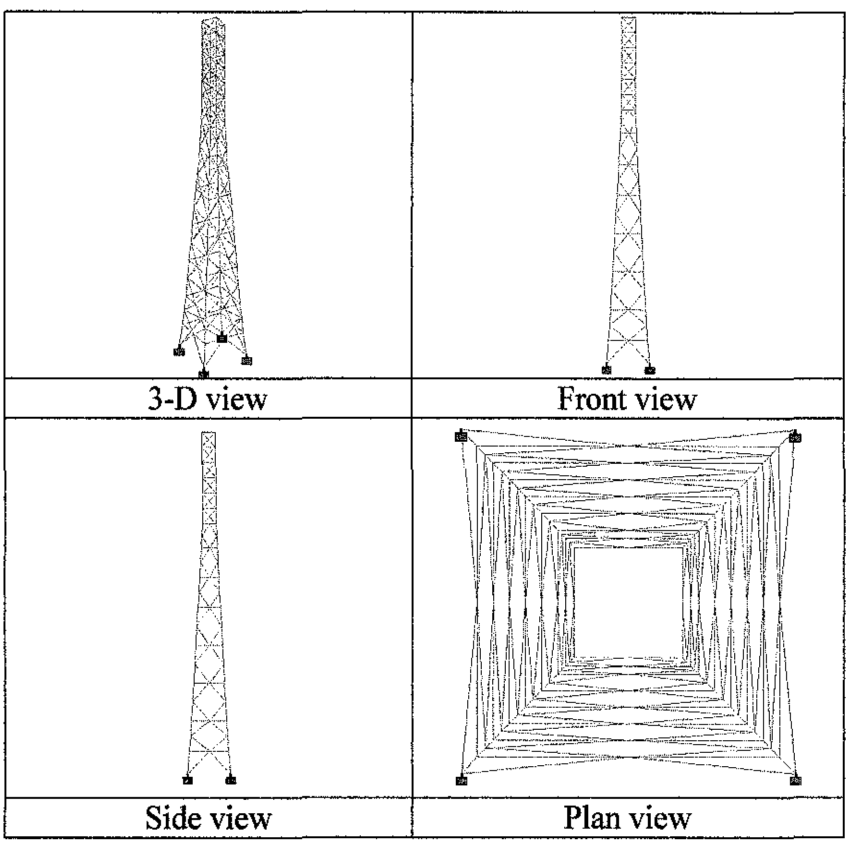

Figure 13. 3-D, Front, Side And Plan View of Self Support Tower.

4.3 Wind Loading Derivation

The detailed calculation of wind loads on the tower as per three different codes is given below:

4.3.1 Part 1: Based on British Standard (BS)

BS 8100-1:1986, Lattice towers and masts - Part 1: Code of practice for loading

Tower design parameters:

Height (H)	: 45m	
Base width (B)	: 6.125m	
Tower classification	: A	(clause 2.3.2 of the code)
Terrain category	: III	(table 3.1 of the code)
3 sec gust wind speed	: 33.3m/s	
1 hourly wind speed (V_B)	: 21.91m/s	
Partial safety factor, wind (γ_v)	: 1.2	(figure 2.1 of the code)
Partial safety factor, material (γ_m)	: 1.1	(figure 2.1 of the code)
Partial safety factor, dead load (γ_{dl})	: 1.05/0.9	(figure 2.1 of the code)
Wind direction factor (K_d)	: 1	(clause 3.1.3 of the code)
Terrain roughness (K_r)	: 1	(table 3.1 of the code)
Power law index variation (a)	: 0.65	(table 3.1 of the code)
Effective height (h_e)	: 0m	(table 3.1 of the code)

Natural frequency (f)

f = 19.665>1, so the lattice tower need dynamic analysis

Variation of wind speed with height (V_z)

1. Site reference wind speed, V_r

$$\bar{V}_r = \gamma_v K_d K_H \bar{V}_B$$

V_r = 1.2x1x1x21.91 = 26.29m/s

2. Variation of wind speed with height (V_z)

$$\overline{V}_z = \overline{V}_r \left(\frac{z - h_e}{10}\right)^{\alpha} \text{ for } z \geq 10 + h_e$$

$$\overline{V}_z = \frac{\overline{V}_r}{2}\left(1 + \frac{z}{10 + h_e}\right) \text{for } z < 10 + h_e$$

$10+h_e = 10+0 = 10m$

At z = 45m >10

$V_z = 26.29x(45\text{-}0)/10)^{0.65} = 33.69m/s$

At z = 3m <10

$V_z = 26.29/2x(1+3/10) = 17.09m/s$

Total wind resistance (R_T)

1. Projected area, A_S

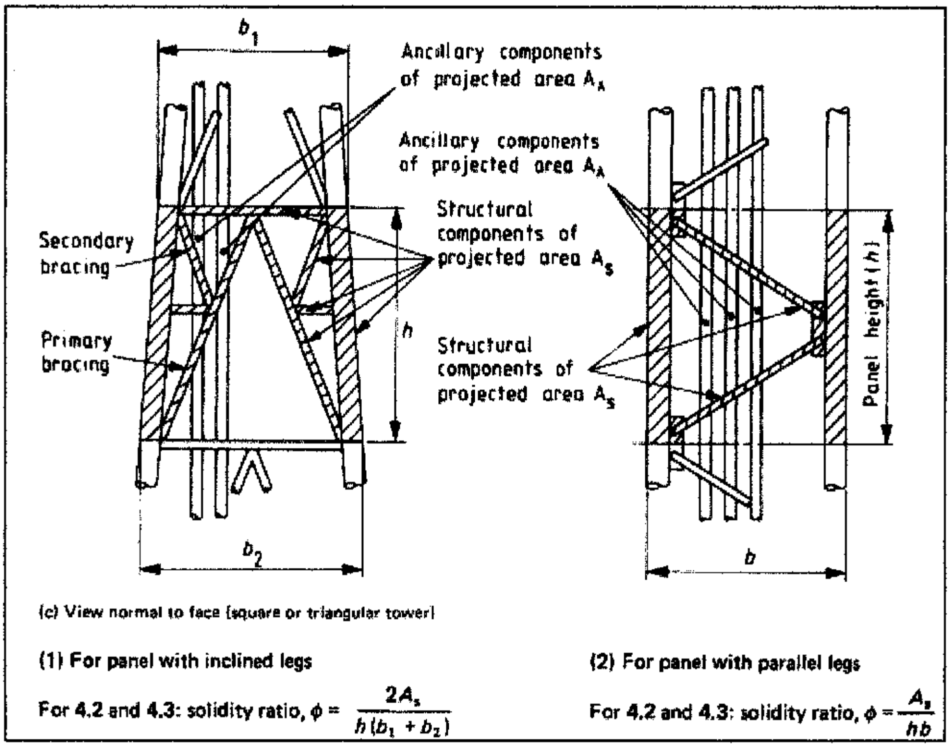

Figure 14. Projected Panel Area Used to Calculate Solidity Ratio, ø. Source: Figure 4.1 of The Code.

Table 7: Size of Angles Used For Tower Bracing System of Tower 45m

Size of Angle		
a	90x90x6	0.09
b	70x70x6	0.07
c	50x50x6	0.05
d	45x45x5	0.045
e	40x40x4	0.04
f	60x60x5	0.06
g	50x50x4	0.05
h	40x40x4	0.04

A_s (panel 3)

= sum of [no of similar bracing x (depth x length)

= 4(0.07x2.509)] + (0.05x4.358) + 4(0.05x3.418) + (0.06x4.946) = 1.9008m^2

Table 8. Calculation of A_s For All Panels.

Panel	Angle	No of Angle	Size (m)	Length (m)	As (m^2)
1	A	2	0.09	3.029	0.5452
	F	1	0.06	5.536	0.3322
	F	2	0.06	4.297	0.5156
					0.8774
2	A	4	0.09	2.011	0.724
	F	1	0.06	4.946	0.2968
	F	4	0.06	3.3	0.792
	F	1	0.06	5.536	0.3322
					2.1449
3	B	4	0.07	2.509	0.7025
	G	1	0.05	4.358	0.2179
	G	4	0.05	3.418	0.6836
	F	1	0.06	4.946	0.2968
					1.9008
4	B	4	0.07	2.509	0.7025
	G	1	0.05	3.768	0.1884
	G	4	0.05	3.224	0.6448
	G	1	0.05	4.358	0.2179
					1.7536
5	B	4	0.07	2.509	0.7025
	G	1	0.05	3.178	0.1589
	G	4	0.05	3.048	0.6096
	G	1	0.05	3.768	0.1884

					1.6594
6	c	4	0.05	2.011	0.4022
	h	1	0.04	2.59	0.1036
	h	4	0.04	2.47	0.3952
	g	1	0.05	3.178	0.1589
					1.0599
7	c	4	0.05	2.003	0.4006
	h	1	0.04	2.314	0.0926
	h	4	0.04	2.344	0.375
	h	1	0.04	2.59	0.1036
					0.9718
8	d	4	0.045	1.504	0.2707
	h	1	0.04	2	0.08
	h	4	0.04	1.846	0.2954
	h	1	0.04	2.314	0.0926
					0.7386
9 to 14	e	2	0.04	2	0.16
	h	2	0.04	2	0.16
	h	2	0.04	2.828	0.2262
					0.5462

2. Solidity ratio, ø

$$\phi = \frac{2A_s}{h(b_1 + b_2)}$$

ø (panel 3)

= [2x1.90078]/[5(4.946+4.358)] = 0.0817

3. Drag coefficient, C_N

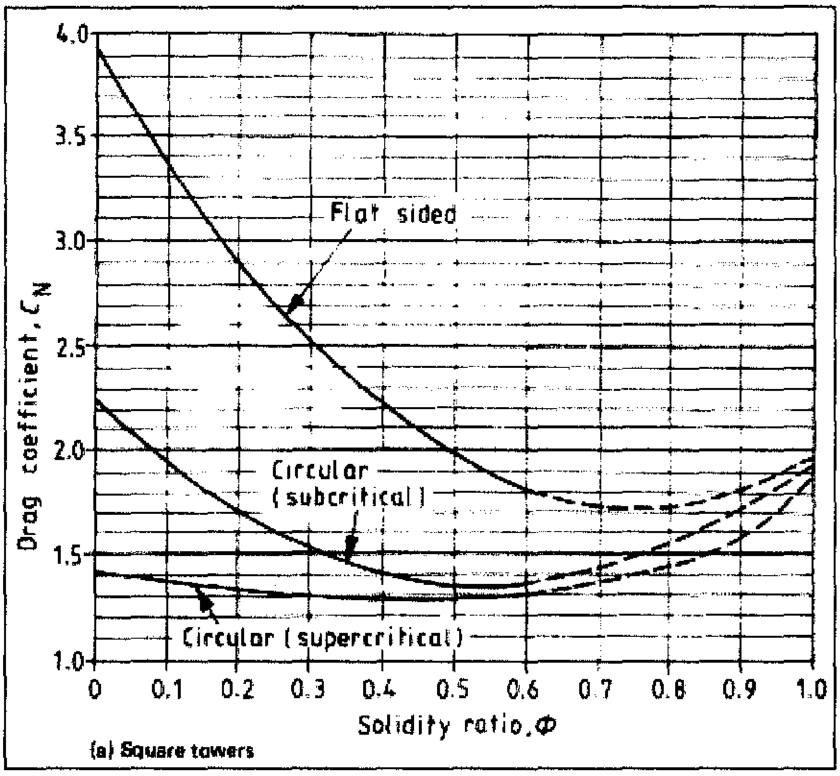

Figure 15. Overall Normal Drag Coefficients, C_N for Square Towers. Source: Figure 4.3 of The Code.

C_N (panel 3)

From the graph, assuming flat sided members, and since ø = 0.0817, so $C_N = 3.45$

4. Wind incidence factor, K_θ

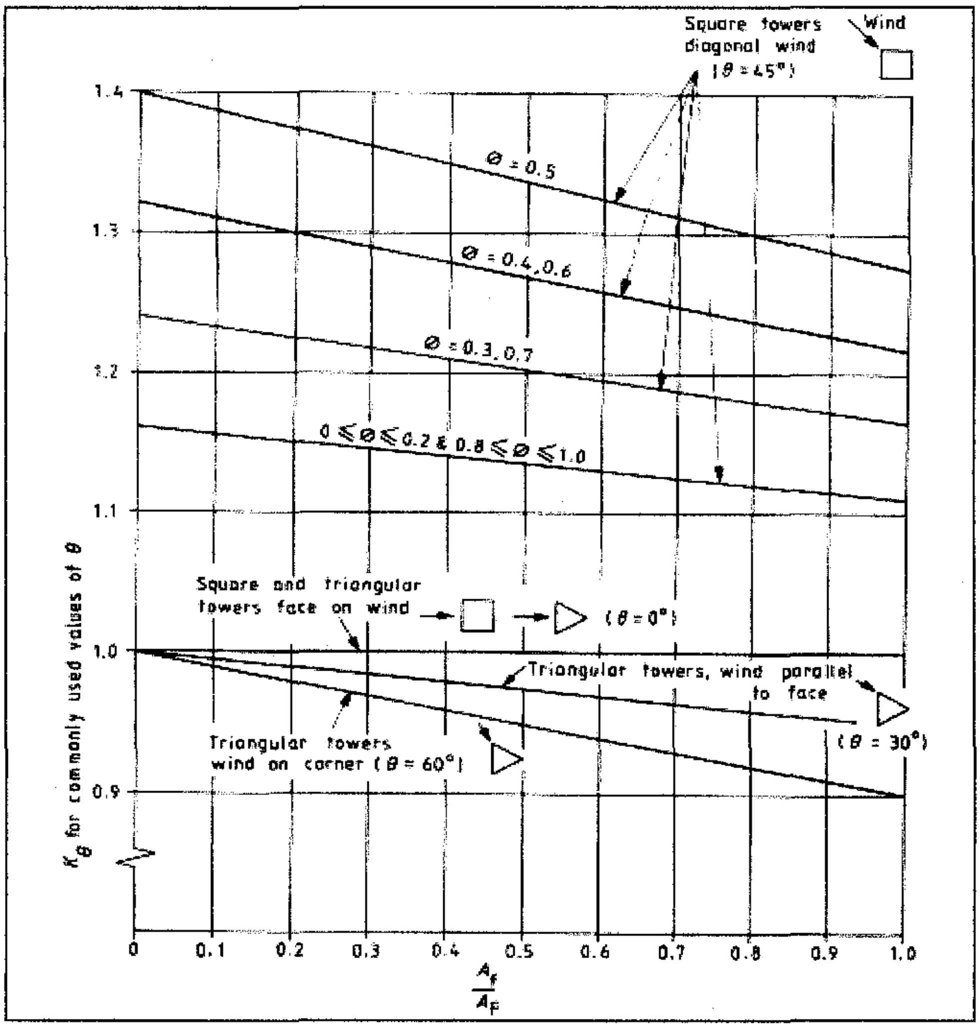

Figure 16. Wind Incidence Factor, K_θ. Source: Figure 4.2 of The Code.

K_θ (panel 3)

From the graph, take $\theta = 0$, so $K_\theta = 1$

Value for K_θ for all panels is 1

5. Total wind resistance (R_T)

$$R_T = K_\theta C_N A_s$$

R_T (panel 3)

= 1x3.45x1.90078= 9.13

Wind loading for symmetrical tower

1. Size factor, B

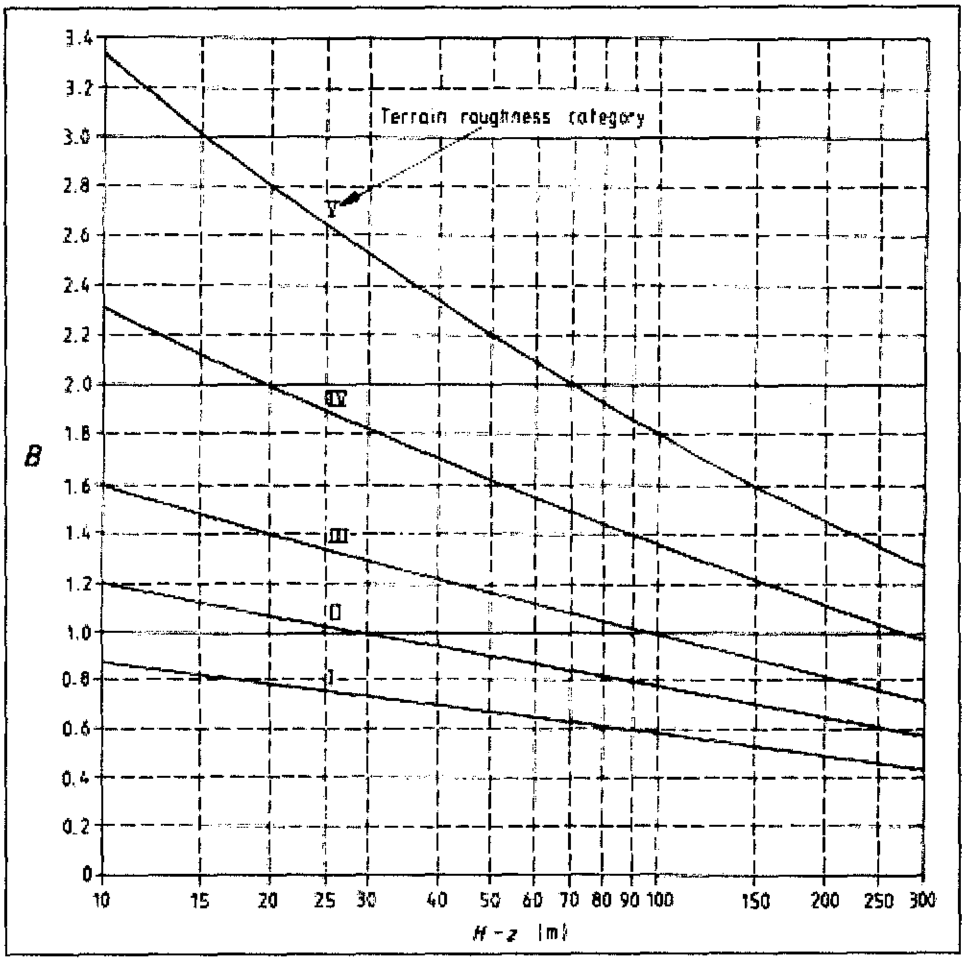

Figure 17. Size Factor, B. Source: Figure 5.1 of The Code.

B (panel 3)

H-z = 45-7 = 33m

From the graph, terrain roughness is category III, and since H-z = 33, so B = 1.27

2. Height factor, j

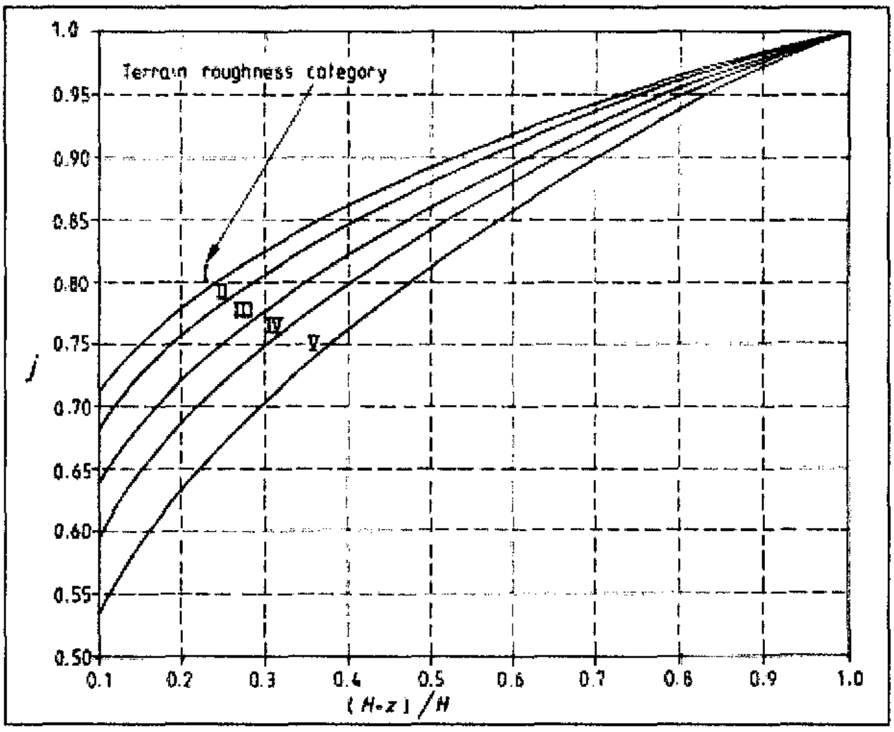

Figure 18. Height Factor, j. Source: Figure 5.2 of The Code.

j (panel 3)

(H-z)/H = (45-7)/45 = 0.733m

From the graph, terrain roughness is category III, and since (H-z)/H = 0.733, so j = 0.935

3. Basic gust response factor, G_B

$$G_B = Bj$$

G_B (panel 3)

= 1.27x0.733 = 1.1875

4. Gust Response Factor, G

$$G = G_B \left[1 + 0{,}2\left(\frac{z_m}{H}\right)^2\right]$$

G (panel 3)

= 1.1875x[1+0.2x(7/45)^2] = 1.2043

5. Wind loading, F (with no gust response factor)

$$\overline{F}_{TW} = \frac{\rho_a}{2}\overline{V}_z^2\ \Sigma R_w$$

Density or air, ρ_a = 1.22kg/m^3

F (panel 3)

= (1.22/2)x26.3^2x6.557 = 2,936.12N

6. Wind loading, F (with gust response factor)

$$F_{TW} = G\ \overline{F}_{TW}$$

F (panel 3)

= 1.2043x2,936.12 = 3,536.09N

Table 9. Computation of Wind Load Using BS 8100.

No Gust Response Factor										With Gust Response Factor							
Panel No	h (m)	z (m)	V_z (m/s)	b_1 (m)	b_2 (m)	A_s (m^2)	ø	C_N	P (N/m^2)	H-z (m)	B	(H-z)/H (m)	j	G_B	G	P (N/m^2)	F (N)
1	3	3	17.09	6.13	5.54	0.88	0.05	3.62	644.81	42.00	1.22	0.93	0.98	1.19	1.19	767.68	673.55
2	4	7	22.35	5.54	4.95	2.14	0.10	3.37	1026.51	38.00	1.24	0.84	0.97	1.20	1.20	1234.26	2647.34
3	5	12	27.09	4.95	4.36	1.90	0.08	3.45	1544.69	33.00	1.27	0.73	0.94	1.19	1.20	1860.33	3536.09
4	5	17	28.69	4.36	3.77	1.75	0.09	3.42	1717.78	28.00	1.30	0.62	0.90	1.17	1.20	2067.17	3625.03
5	5	22	29.94	3.77	3.18	1.66	0.10	3.37	1842.99	23.00	1.36	0.51	0.86	1.17	1.23	2263.85	3756.69
6	4	26	30.78	3.18	2.59	1.06	0.09	3.39	1959.00	19.00	1.40	0.42	0.84	1.17	1.25	2442.97	2589.30
7	4	30	31.51	2.59	2.31	0.97	0.10	3.36	2035.56	15.00	1.49	0.33	0.79	1.18	1.28	2609.03	2535.46
8	3	33	32.01	2.31	2.00	0.74	0.11	3.32	2075.59	12.00	1.54	0.27	0.76	1.17	1.30	2690.55	1987.35
9	2	35	32.33	2.00	2.00	0.55	0.14	3.15	2007.92	10.00	1.60	0.22	0.74	1.18	1.32	2647.01	1445.90
10	2	37	32.62	2.00	2.00	0.55	0.14	3.15	2045.08	10.00	1.60	0.22	0.74	1.18	1.34	2730.20	1491.34
11	2	39	32.91	2.00	2.00	0.55	0.14	3.15	2080.92	10.00	1.60	0.22	0.74	1.18	1.35	2814.78	1537.55
12	2	41	33.18	2.00	2.00	0.55	0.14	3.15	2115.55	10.00	1.60	0.22	0.74	1.18	1.37	2900.93	1584.61
13	2	43	33.44	2.00	2.00	0.55	0.14	3.15	2149.06	10.00	1.60	0.22	0.74	1.18	1.39	2988.82	1632.62
14	2	45	33.69	2.00	2.00	0.55	0.14	3.15	2181.55	10.00	1.60	0.22	0.74	1.18	1.41	3078.60	1681.65

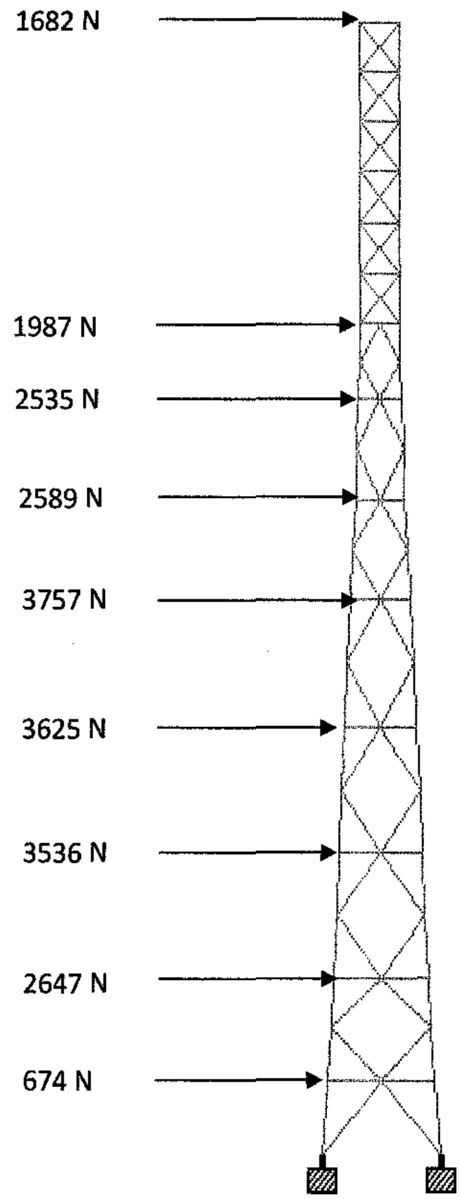

Figure 19. Wind Load on Tower Body (Design Code: BS8100).

4.3.2 Part 2: Based on American Standard (ASCE)

ASCE-7-05: Chapter 6 – Wind Loads

Tower design parameters:

Height (H)	: 45m	
Base width (B)	: 6.125m	
Tower classification	: III	(table 1.1 of the code)
Exposure	: B	(clause 6.5.7.1 of the code)
3 sec gust wind speed (V_B)	: 33.3m/s	
Wind directionality factor, K_d	: 0.85	(table 6-4 of the code)
Importance factor, I	: 1, Category II	(table 6-1 of the code)
Topographic factor, K_{zt}	: 1	(clause 6.5.7.1 of the code)
Damping ratio, β	: 5%	

Natural frequency (n_1)

n_1 = 19.665>1, so the lattice tower need dynamic analysis

Gust effect factor (Gf)

$$\bar{V}_z = \bar{b}\left(\frac{\bar{z}}{10}\right)^{\bar{\alpha}}$$

= 0.45x(27/10)^0.25

= 19.23m/s

$$L_z = l\left(\frac{\bar{z}}{10}\right)^{\bar{\epsilon}}$$

= 97.54x(27/10)^0.33

= 135.82

$$N_1 = \left(\frac{n_1 L_z}{\bar{V}_z}\right)$$

= (19.665x135.82)/19.23

= 138.92

$$R_n = \frac{7.47 N_1}{(1 + 10.3 N_1)^{5/3}}$$

= 0.01

$$n_{R_h} = 4.6 n_1 \frac{h}{\bar{V}_z}$$

= 211.73

$$R_h = \frac{1}{n} - \frac{1}{2n^2}\left(1 - e^{-2n}\right)$$

= 0.005

$n_{R_B} = 4.6 n_1 \frac{B}{\bar{V}_z}$

$= 28.82$

$R_B = \frac{1}{n} - \frac{1}{2n^2}(1 - e^{-2n})$

$= 0.03$

n_{R_L} 4.217 $= 15.4 n_1 \frac{L}{\bar{V}_z}$

$= 36.04$

$R_L = \frac{1}{n} - \frac{1}{2n^2}(1 - e^{-2n})$

$= 0.03$

1. Resonant response factor, R

With $\beta = 0.05$ (5% *damping*)

$$R = \sqrt{\frac{1}{\beta} R_n R_h R_B \,(0.53 + 0.47 R_L)}$$

$= 0.003$

2. Background response factor, Q

$$Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{B+h}{L_z}\right)^{0.63}}}$$

$= 0.86$

3. Intensity of Turbulences, I_z

$$I_z = C\left(\frac{10}{z}\right)^{1/6}$$

C = 0.3 (table 6.2), z (bar) = 27

I_z (bar) = 0.25

4. Gust Effect Factor, G_f

$$G_f = 0.925\left(\frac{1 + 1.71\, I_{\bar{z}}\sqrt{g^2_Q Q^2 + g^2_R R^2}}{1 + 1.7 g_{\bar{v}} I_{\bar{z}}}\right)$$

$G_f = 0.85$

Velocity pressure coefficient (K_z) (table 6.3 of the code)

$$K_z = 2.01\left(\frac{Z}{Z_g}\right)^{\alpha}$$

$Z_g = 365.76\ m$ $\alpha = 7.0$

Result of K_z will be shown in Table 10

Velocity pressure (q_z) (clause 6.5.10 of the code)

$q_z = 0.613 K_z K_{zt} K_d V^2\ I$

Result of q_z will be shown in Table 10

Force Coefficient, C_f (figure 6-23 of the code)

$4.0\,\epsilon^2 - 5.9\,\epsilon + 4.0$

Where ε is the solidity ratio, ε will be shown in Table 10

Determine wind load (F) (clause 6.5.15 of the code)

$F = q_Z G C_f A_f$

Result of P will be shown in Table 10

Table 10. Computation of Wind Load Using ASCE 7-05.

Panel No	H_t (m)	K_z (m)	q_z (N/m^2)	b_1 (m)	A (m^2)	A_f (m^2)	ε	C_f	P (N/m^2)	F (N)
1	3	0.57	379.42	6.13	17.49	0.88	0.05	3.71	1197.84	1050.961
2	7	0.65	432.07	5.54	20.96	2.14	0.10	3.44	1262.74	2708.425
3	12	0.76	504.01	4.95	23.26	1.90	0.08	3.54	1518.53	2886.394
4	17	0.84	556.75	4.36	20.32	1.75	0.09	3.52	1666.04	2921.597
5	22	0.90	599.31	3.77	17.37	1.66	0.10	3.47	1769.05	2935.605
6	26	0.94	628.61	3.18	11.54	1.06	0.09	3.49	1865.68	1977.429
7	30	0.98	654.84	2.59	9.81	0.97	0.10	3.45	1922.94	1868.712
8	33	1.01	672.92	2.31	6.47	0.74	0.11	3.38	1932.54	1427.448
9	35	1.03	684.33	2.00	4.00	0.55	0.14	3.27	1901.45	1038.649
10	37	1.04	695.28	2.00	4.00	0.55	0.14	3.27	1931.88	1055.271
11	39	1.06	705.82	2.00	4.00	0.55	0.14	3.27	1961.16	1071.264
12	41	1.08	715.97	2.00	4.00	0.55	0.14	3.27	1989.38	1086.68
13	43	1.09	725.78	2.00	4.00	0.55	0.14	3.27	2016.64	1101.569
14	45	1.10	735.27	2.00	4.00	0.55	0.14	3.27	2043.00	1115.971

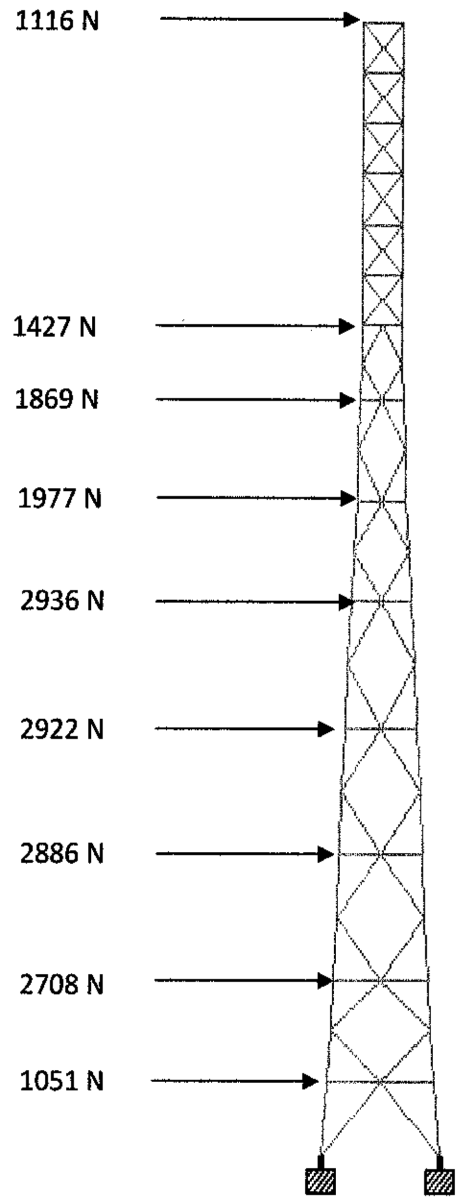

Figure 20. Wind Load on Tower Body (Design Code: ASCE 7-05).

4.3.3 Part 3: Based on Malaysian Standard (MS)

MS 1553:2002 – Code of Practice on Wind Loading For Building Structure

Tower design parameters:

Height (H)	: 45m	
Base width (B)	: 6.125m	
Tower classification	: IV	(table 3.2 of the code)
Exposure	: B	(clause 6.5.7.1 of the code)
3 sec gust wind speed	: 33.5m/s	(table 3.1 of the code)
1 hourly mean speed (V_s)	: 22.04m/s	
Wind directional multiplier, M_d	: 1	(clause 2.2 of the code)
Hill shape multiplier, M_h	: 1	(clause 4.4 of the code)
Shielding multiplier, M_s	: 1	(clause 4.3.1 of the code)
Density of air, ρ_{air}	: 1.225 kg/m^3	(clause 2.4.1 of the code)
Importance factor, I	: 1.15, Category IV	(table 3.2 of the code)
Dynamic response factor, C_{dyn}	: 1	(clause 6.1 of the code)

Natural frequency (f)

f = 19.665>1, so the lattice tower need dynamic analysis

Terrain/height multiplier ($M_{z,cat}$)

Values are to refer Table 4.1 of the code (Terrain Category 1). For intermediate values of height z and terrain category, use linear interpolation. Result of $M_{z,cat}$ will be shown in Table 11.

Site wind speed (V_{sit})

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

Result of V_{sit} will be shown in Table 11

Design wind speed (V_{des})

$$V_{des} = V_{sit} \times I$$

Importance factor, I = 1.15

Result of V_{des} will be shown in Table 11

Design wind pressure (P)

$$p = (0.5\, \rho_{air})\, [V_{des}]^2 C_{fig}\, C_{dyn} \;\; Pa$$

*Cfig = Cd (drag coefficient) value is to refer Table 11

Result of P will be shown in Table 11

Table 11. Computation of Wind Load Using MS 1553:2002

Panel No	h (m)	z (m)	$M_{z,cat}$	V_{sit} (m/s)	V_{des} (m/s)	b_1 (m)	A (m^2)	A_f (m^2)	ø	C_d	P (N/m^2)	F (N)
1	3	3	0.99	21.82	25.09	6.13	17.49	0.88	0.05	3.50	1349.72	1184.21
2	4	7	1.08	23.76	27.32	5.54	20.96	2.14	0.10	3.48	1592.97	3416.73
3	5	12	1.14	25.04	28.79	4.95	23.26	1.90	0.08	3.50	1777.17	3378.01
4	5	17	1.17	25.83	29.70	4.36	20.32	1.75	0.09	3.50	1891.59	3317.13
5	5	22	1.20	26.36	30.31	3.77	17.37	1.66	0.10	3.50	1969.86	3268.82
6	4	26	1.21	26.62	30.62	3.18	11.54	1.06	0.09	3.50	2009.58	2129.96
7	4	30	1.22	26.89	30.92	2.59	9.81	0.97	0.10	3.50	2049.71	1991.91
8	3	33	1.23	27.02	31.07	2.31	6.47	0.74	0.11	3.40	2011.55	1485.81
9	2	35	1.23	27.11	31.17	2.00	4.00	0.55	0.14	3.24	1930.94	1054.76
10	2	37	1.23	27.20	31.28	2.00	4.00	0.55	0.14	3.24	1943.52	1061.63
11	2	39	1.24	27.28	31.38	2.00	4.00	0.55	0.14	3.24	1956.14	1068.52
12	2	41	1.24	27.35	31.45	2.00	4.00	0.55	0.14	3.24	1965.63	1073.71
13	2	43	1.24	27.40	31.50	2.00	4.00	0.55	0.14	3.24	1971.97	1077.17
14	2	45	1.25	27.44	31.56	2.00	4.00	0.55	0.14	3.24	1978.32	1080.64

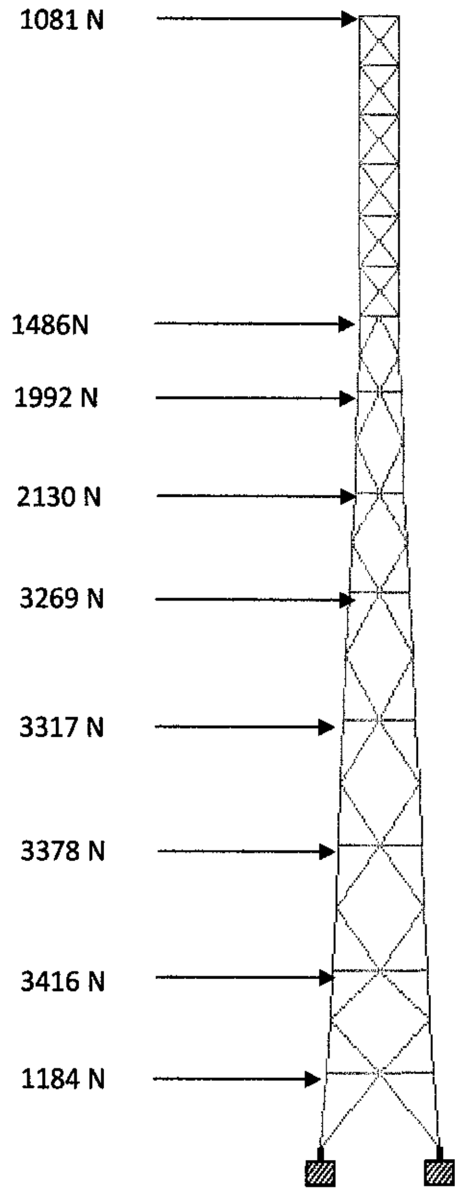

Figure 21. Wind Load on Tower Body (Design Code: MS 1553:2002).

4.4 Design Stage of 76m Tall Square Foot Tower

Design procedure of 76m tall square foot tower based on three codes (BS 8100, ASCE 7-05 and MS 1553:2002) can be referred to procedure in designing 46m tower (Section 4.1, page 20-39). Below is summary of changes in design parameter of the tower.

Tower design parameter

Height (H) : 76m

Base width (B) : 10m

Natural frequency (f)

f = 11.72>1, so the lattice tower need dynamic analysis

Size of angles used

Table 12: Size of Angles Used For Tower Bracing System of Tower 76m Tall

	Size of Angle	
a	120x120x8	0.12
b	100x100x8	0.1
c	90x90x6	0.09
d	80x80x6	0.08
e	70x70x6	0.07
f	50x50x6	0.05
g	45x45x5	0.045
h	80x80x6	0.08
i	70x70x6	0.07
j	60x60x5	0.06
k	45x45x5	0.045

4.4 Design Calculation Analysis

Table 13. Comparison of BS 8100, ASCE 7-05 and MS 1553:2002 of Wind Load Computation of Tower 45m

Height (m)	F (N)	F (N)	F (N)
	BS	ASCE	MS
3	674	1051	1184
7	2647	2708	3417
12	3536	2886	3378
17	3625	2922	3317
22	3757	2936	3269
26	2589	1977	2130
30	2535	1869	1992
33	1987	1427	1486
35	1446	1039	1055
37	1491	1055	1062
39	1538	1071	1069
41	1585	1087	1074
43	1633	1102	1077
45	1682	1116	1081

Table 14. Comparison of BS 8100, ASCE 7-05 and MS 1553:2002 of Wind Load Computation of Tower 76m

Height (m)	F (N)	F (N)	F (N)
	BS	ASCE	MS
4	2143	3168	3954
10	7375	6755	8221
16	7505	6690	7624
22	7820	6845	7502
28	7419	6313	6601
34	6665	5535	5543
40	5817	4775	4611
45	4977	4031	3828
50	4832	3888	3635
55	5066	3934	3658
58	3182	2441	2307
61	2945	2201	2061
64	2646	1952	1793
66	1790	1349	1205
68	1822	1360	1208
70	1855	1371	1211
72	1888	1382	1214
74	1922	1393	1217
76	1955	1404	1220

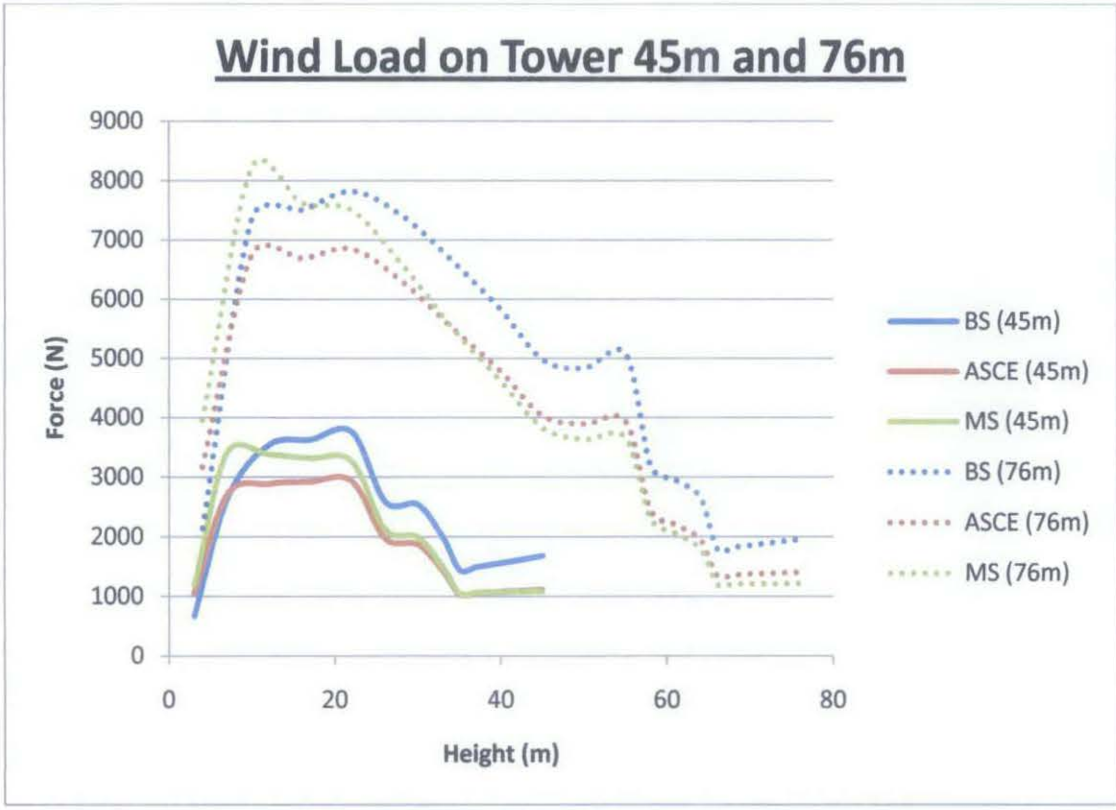

Figure 22. Graph Wind Load, F (N) vs Height, h (m)

From the graph above, it was clearly show graph lines of same pattern between all three codes. This is because BS, ASCE and MS have the same ways of calculating solidity ratio, ø where structural components of projected area, A_s or A_f, is divided with panel area, A. Therefore, the value of solidity ratio for both codes is similar at any level of tower panel. However the gap between the three graph lines is due to difference in several parameters:

a) Design wind speed (V_z, V_{des}) or design wind pressure (q_z)
   i. BS referred formula in clause 3.2.1 of the code. For tower 45m, V_z varied from 17.09-33.69m/s; and for tower 76m, V_z varied from 18.40-36.74m/s.
   ii. ASCE referred equation (6-15) of the code. For tower 45m, q_z is between 379.42-735.27 m/s^2; and for tower 76m, q_z varied from 379.42-854.04m/s^2

iii. MS referred Table 4.1 of the code. For tower 45m, V_{des} varies from 25.09-31.56 m/s; and for tower 76m, the values are between 25.85-32.21m/s.

b) Force or drag coefficient (C_N, C_f, C_d)

i. BS referred graph in Figure 4.3 of the code. For tower 45m tall, C_N varied from 3.15-3.62; and for tower 76m, C_N varied from 3.05-3.58.

ii. ASCE used formula of $4\varepsilon^2$-5.9ε +4, refer Figure 6-23 of the code. For tower 45m tall, C_f varied from 3.27-3.71; and for tower 76m, C_f varied from 3.19-3.67.

iii. MS interpolated the coefficient value from Table E6(a) of the code. For tower 45m tall, C_d varied from 3.24-3.5; and for tower 76m tall, C_d varied from 3.13-3.5.

c) Gust response factor (G, G_f, C_d)

i. In BS, for tower 45m, it varies with the panel height (between 1.19-1.41). For tower 76m, it varies from 1.07-1.27.

ii. In ASCE, for tower 45m, G_f is constant (0.85) all along the tower. For tower 76m, the value is 0.84.

iii. In MS, C_d is constant (1) all along both towers of 45m and 76m.

Summary of differences in these three parameters (design wind speed or pressure, force or drag coefficient and gust response factor) is shown in Table 15.

Table 15. Parameter Differences of All Cases

Parameter	Code/Tower					
	BS		ASCE		MS	
	45m	76m	45m	76m	45m	76m
Design Wind Speed(m/s) or *Pressure(m/s^2)*	17.09 - 33.69	18.40 - 36.74	*379.42 - 735.27*	*379.42 - 854.04*	25.09 – 31.56	25.85 – 32.21
Force or Drag Coefficient	3.15-3.62	3.05-3.58	3.27-3.71	3.19-3.67	3.24-3.5	3.13-3.5
Gust Response Factor	1.19-1.41	1.07-1.27	0.85	0.84	1	

*ASCE considers wind pressure in calculating wind load.

4.5 Position of Antennas

The communication tower shall be designed to withstand antenna(s) load. Table 16 and 17 show the position of antennas used on the tower body of 45m and 76m tower.

Table 16. Position of The Antennas on Tower Body of Tower 45m

Mounting From Tower Base (m)	Antenna Type	Quantity
43	GSM	4
39	TX/2.4m dia	2
35	GSM	4
33	TX/1.8m dia	2
30	TX/1.2m dia	2
	Total	14

Table 17. Position of The Antennas on Tower Body of Tower 76m

Mounting From Tower Base (m)	Antenna Type	Quantity
74	GSM	4
70	TX/2.4m dia	2
66	GSM	4
61	TX/1.8m dia	2
55	GSM	4
50	TX/1.2m dia	2
	Total	18

4.6 STAAD Pro Analysis (Tower Deflection)

This research consider wind load coming from one side of the tower panel. The wind load will push the tower towards the direction of the wind, thus restriction from opposite direction will create deflection. If the wind load come from the right side, so the tower body will deflect toward tower's right. Theoretically, the bigger wind load, the bigger deflection becomes. Figure 23 below shows the sample of tower deflection.

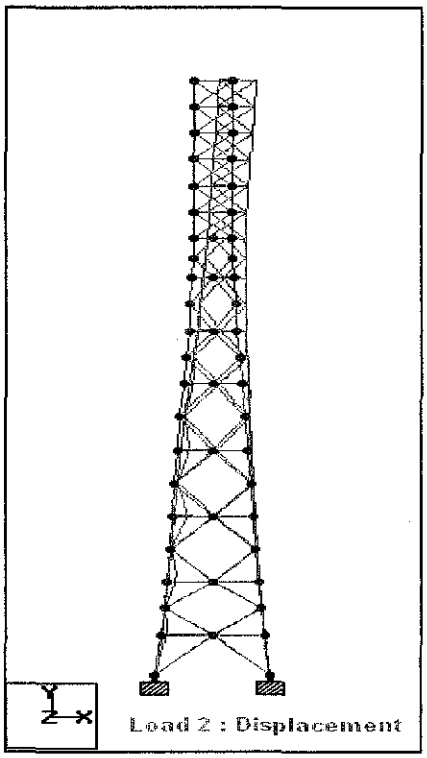

Figure 23. Tower Deflection Towards One Direction (Opposite of Wind Action)

Table 18. Comparison of BS 8100, ASCE 7-05 and MS 1553:2002 of Deflection of Tower 45m

	Code	BS	ASCE	MS
Node	Height Above Ground (mm)	Horizontal Displacement (mm)	Horizontal Displacement (mm)	Horizontal Displacement (mm)
16	0	0.00	0.00	0.00
18	3000	0.44	0.49	0.63
19	7000	13.99	10.33	10.91
20	12000	48.84	35.37	36.79
21	17000	103.15	74.04	36.79

22	22000	177.28	126.46	129.77
23	26000	252.89	179.66	183.67
24	30000	350.74	248.17	252.75
17	33000	435.36	307.23	312.12
26	35000	497.41	350.42	355.45
27	37000	563.03	396.05	401.16
28	39000	630.91	443.18	448.36
29	41000	699.85	491.03	496.23
30	43000	769.05	539.04	544.28
25	45000	838.16	587.00	592.26

Table 19. Comparison of BS 8100, ASCE 7-05 and MS 1553:2002 of Deflection of Tower 76m

	Code	BS	ASCE	MS
Node	Height Above Ground (mm)	Horizontal Displacement (mm)	Horizontal Displacement (mm)	Horizontal Displacement (mm)
21	0	0	0	0
40	4000	4.36	3.73	3.937
24	10000	30.02	24.17	23.815
25	16000	67.95	54.08	52.458
26	22000	120.64	95.24	91.351
27	28000	191.86	150.52	143.127
28	34000	281.36	219.48	207.199
29	40000	391.14	303.64	284.965
30	45000	495.72	383.48	358.447
31	50000	613.47	473.04	440.615
32	55000	744.50	572.32	531.402
33	58000	828.82	636.08	589.564
34	61000	920.21	705.00	652.268
22	64000	1019.57	779.77	720.102
35	66000	1091.20	833.53	768.76
36	68000	1165.61	889.32	819.182
37	70000	1241.81	946.40	870.737
38	72000	1318.94	1004.15	922.874
39	74000	1396.38	1062.13	975.209
23	76000	1473.80	1120.09	1027.528

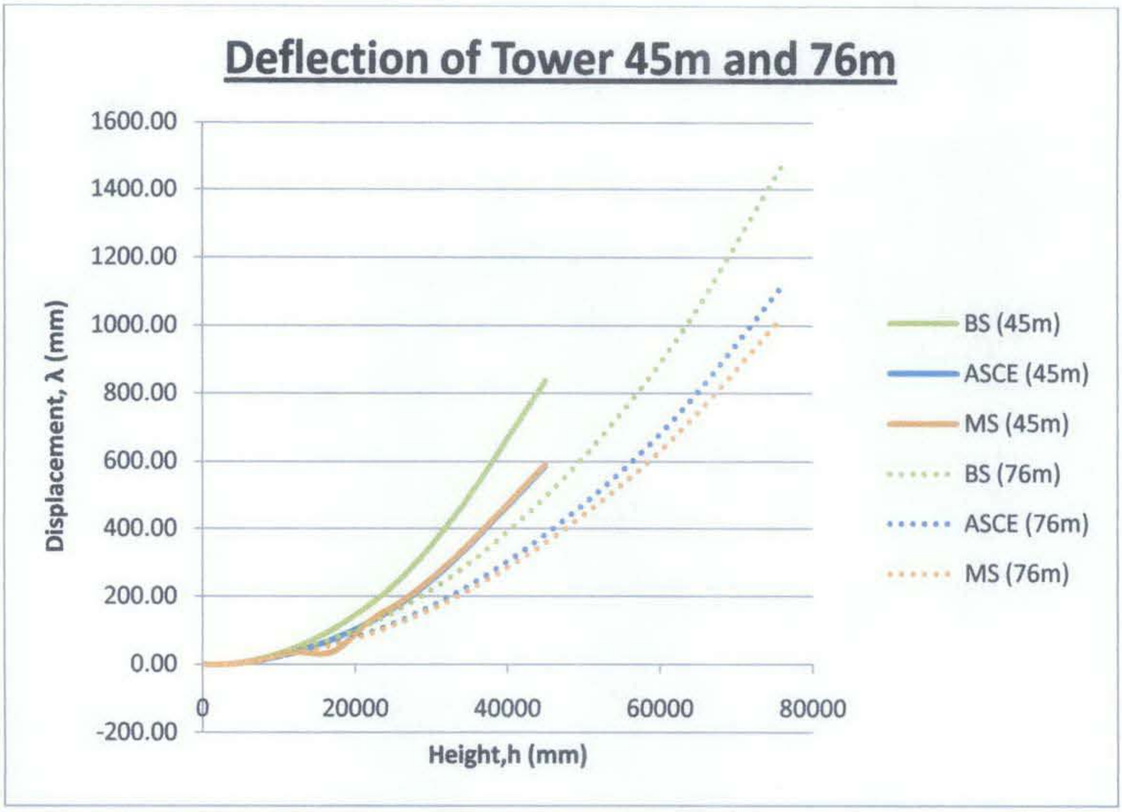

Figure 24. Graph Deflection,λ (mm) vs Height,h (mm)

From the graph, it shows that deflection is increasing as the height is increasing. Tower 76m has bigger deflection compared to tower 45m. Worst case condition for both towers is deflection by BS wind load that push from one side of the tower panel. This is because among all the three codes, BS computed highest value of wind load followed by ASCE, and MS.

CHAPTER 5

CONCLUSION

Base on the result comparison, it can be concluded that among three codes, BS computed highest value of wind load followed by ASCE, and MS. Thus, the deflection is more critical based on study case of BS wind load. Meanwhile, self weight and antennas does not affect much on tower deflection as the load action is not in x-direction but in y-direction, where it is pointing down towards the tower base. However both self weight and antenna load simultaneously produce total value of support reaction at the end supports.

Some recommendation can be in order to improve this research's findings, such as to check on design of communication tower with respect to seismic loading. Even though Malaysia is not categorized into the Ring of Fire region, but at several places like Japan and Indonesia, this seismic condition is consider crucial. Therefore, if the design also consider seismic, the tower will then be able to withstand most all of the external loads longer.

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[2] ASCE 7-05, American Society of Civil Engineers, *Minimum Design Loads for Buildings and Other Structures, Chapter 6 – WIND LOADS*

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[6] BS EN1993-3-1:2006, *Eurocode 3- Design of Steel Structures, Part 3-1: Tower, masts and chimneys – Tower and masts*

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[11] SR Satish Kumar and AR Santha Kumar, *Design of Steel Structures*, Indian Institute of Technology Madras

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APPENDICES

Job Information

	Engineer	Checked	Approved
Name:	HASMIRA		
Date:	17-Nov-11		

Structure Type	SPACE FRAME

Number of Nodes	120	Highest Node	120
Number of Elements	340	Highest Beam	352

Number of Basic Load Cases	3
Number of Combination Load Cases	0

Included in this printout are data for:

All	The Whole Structure

Included in this printout are results for load cases:

Type	L/C	Name
Primary	1	SELF WEIGHT
Primary	2	WIND LOAD (BS)
Primary	3	ANTENNA LOAD

Section Properties

Prop	Section	Area (cm^2)	I_{yy} (cm^4)	I_{zz} (cm^4)	J (cm^4)	Material
1	UA90X90X6 SD	21.200	294.766	165.174	2.549	STEEL
2	UA70X70X6 SD	16.400	139.366	75.613	1.973	STEEL
3	UA50X50X6 SD	11.600	51.325	26.252	1.397	STEEL
4	UA45X45X5 SD	8.820	31.257	16.148	0.729	STEEL
5	UA40X40X4 SD	6.400	17.642	9.216	0.333	STEEL
6	UA60X60X5 SD	11.820	73.367	39.816	0.979	STEEL
7	UA50X50X4 SD	8.000	34.155	18.522	0.418	STEEL
8	UA40X40X4 SD	6.400	17.642	9.216	0.333	STEEL

Materials

Mat	Name	E (kN/mm^2)	ν	Density (kg/m^3)	α (1/°K)
1	STEEL	205.000	0.300	7.83E+3	12E -6
2	STAINLESSSTEEL	197.930	0.300	7.83E+3	18E -6
3	ALUMINUM	68.948	0.330	2.71E+3	23E -6
4	CONCRETE	21.718	0.170	2.4E+3	10E -6

Basic Load Cases

Number	Name
1	SELF WEIGHT
2	WIND LOAD (BS)
3	ANTENNA LOAD

Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	10	2:WIND LOAD	**838.182**	34.832	1.088	838.906	0.000	-0.000	-0.035
Min X	115	2:WIND LOAD	**-6.890**	-0.860	0.005	6.943	0.000	-0.000	-0.000
Max Y	10	2:WIND LOAD	838.182	**34.832**	1.088	838.906	0.000	-0.000	-0.035
Min Y	25	2:WIND LOAD	838.161	**-34.201**	-1.075	838.859	-0.000	-0.000	-0.035
Max Z	98	2:WIND LOAD	48.934	3.108	**46.470**	67.555	0.000	0.010	-0.009
Min Z	46	2:WIND LOAD	48.837	3.108	**-46.470**	67.485	-0.000	-0.010	-0.009
Max rX	101	2:WIND LOAD	14.104	1.547	29.802	33.008	**0.007**	0.005	-0.004
Min rX	49	2:WIND LOAD	14.084	1.547	-29.803	32.999	**-0.007**	-0.005	-0.004
Max rY	5	2:WIND LOAD	48.970	17.998	-0.059	52.173	0.007	**0.069**	-0.004
Min rY	57	2:WIND LOAD	49.067	18.042	-0.129	52.279	-0.007	**-0.069**	-0.005
Max rZ	25	1:SELF WEIGI	0.000	-0.855	-0.000	0.855	0.000	-0.000	**0.000**
Min rZ	105	2:WIND LOAD	447.566	28.259	-0.457	448.458	0.000	0.000	**-0.035**
Max Rst	10	2:WIND LOAD	838.182	34.832	1.088	**838.906**	0.000	-0.000	-0.035

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	14	10	2:WIND LOAD	**838.182**	34.832	1.088	838.906
Min X	320	115	2:WIND LOAD	**-6.890**	-0.860	0.005	6.943
Max Y	14	10	2:WIND LOAD	838.182	**34.832**	1.088	838.906
Min Y	28	25	2:WIND LOAD	838.161	**-34.203**	-1.075	838.859
Max Z	137	98	2:WIND LOAD	48.934	3.108	**46.470**	67.555
Min Z	31	46	2:WIND LOAD	48.837	3.108	**-46.470**	67.485
Max Rst	14	10	2:WIND LOAD	838.182	34.832	1.088	**838.906**

Beam End Force Summary

The signs of the forces at end B of each beam have been reversed. For example: this means that the Min Fx entry gives the largest tension value for an beam.

				Axial	Shear		Torsion	Bending	
	Beam	Node	L/C	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	121	68	2:WIND LOAD	**725.687**	0.786	-0.211	-0.004	0.267	0.828
Min Fx	107	53	2:WIND LOAD	**-723.874**	-0.825	-0.298	0.015	0.357	-0.864
Max Fy	108	55	2:WIND LOAD	-721.371	**1.629**	1.741	0.006	-0.537	1.484
Min Fy	180	102	2:WIND LOAD	-682.247	**-1.663**	-1.247	0.008	2.069	-1.998
Max Fz	241	6	2:WIND LOAD	2.617	0.141	**5.968**	-0.001	-3.584	0.107
Min Fz	258	110	2:WIND LOAD	2.608	-0.140	**-5.959**	0.001	7.660	-0.158
Max Mx	107	53	2:WIND LOAD	-723.874	-0.825	-0.298	**0.015**	0.357	-0.864
Min Mx	1	1	2:WIND LOAD	-721.672	-0.823	0.300	**-0.015**	-0.360	-0.861
Max My	253	109	2:WIND LOAD	2.603	-0.208	-5.556	-0.000	**8.187**	-0.343
Min My	242	5	2:WIND LOAD	2.604	0.208	5.558	0.000	**-3.923**	0.111
Max Mz	122	104	2:WIND LOAD	723.048	-1.650	1.012	-0.001	1.696	**1.799**
Min Mz	180	102	2:WIND LOAD	-682.247	-1.663	-1.247	0.008	2.069	**-1.998**

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (mm)	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	121	2:WIND LOAD	0.000	**725.687**	0.786	-0.211	-0.004	0.267	0.828
Min Fx	107	2:WIND LOAD	0.000	**-723.874**	-0.825	-0.298	0.015	0.357	-0.864
Max Fy	108	2:WIND LOAD	0.000	-721.371	**1.629**	1.741	0.006	-0.537	1.484
Min Fy	180	2:WIND LOAD	0.000	-682.247	**-1.663**	-1.247	0.008	2.069	-1.998
Max Fz	241	2:WIND LOAD	0.000	2.617	0.141	**5.968**	-0.001	-3.584	0.107
Min Fz	258	2:WIND LOAD	0.000	2.608	-0.140	**-5.959**	0.001	7.660	-0.158
Max Mx	107	2:WIND LOAD	0.000	-723.874	-0.825	-0.298	**0.015**	0.357	-0.864
Min Mx	1	2:WIND LOAD	0.000	-721.672	-0.823	0.300	**-0.015**	-0.360	-0.861
Max My	253	2:WIND LOAD	0.000	2.603	-0.208	-5.556	-0.000	**8.187**	-0.343
Min My	242	2:WIND LOAD	0.000	2.604	0.208	5.558	0.000	**-3.923**	0.111
Max Mz	122	2:WIND LOAD	2.01E+3	723.048	-1.650	1.012	-0.001	1.696	**1.799**
Min Mz	180	2:WIND LOAD	0.000	-682.247	-1.663	-1.247	0.008	2.069	**-1.998**

Reaction Summary

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
Max FX	53	1:SELF WEIGI	**1.688**	14.468	-1.690	0.141	0.000	0.141
Min FX	1	2:WIND LOAD	**-94.053**	-738.450	-75.755	1.404	-2.578	1.487
Max FY	68	2:WIND LOAD	-87.386	**740.644**	-76.990	0.405	-0.603	-0.691
Min FY	53	2:WIND LOAD	-94.026	**-740.644**	76.219	-1.403	2.577	1.482
Max FZ	16	2:WIND LOAD	-87.413	738.450	**76.525**	-0.406	0.602	-0.686
Min FZ	68	2:WIND LOAD	-87.386	740.644	**-76.990**	0.405	-0.603	-0.691
Max MX	1	2:WIND LOAD	-94.053	-738.450	-75.755	**1.404**	-2.578	1.487
Min MX	53	2:WIND LOAD	-94.026	-740.644	76.219	**-1.403**	2.577	1.482
Max MY	53	2:WIND LOAD	-94.026	-740.644	76.219	-1.403	**2.577**	1.482
Min MY	1	2:WIND LOAD	-94.053	-738.450	-75.755	1.404	**-2.578**	1.487
Max MZ	1	2:WIND LOAD	-94.053	-738.450	-75.755	1.404	-2.578	**1.487**
Min MZ	68	2:WIND LOAD	-87.386	740.644	-76.990	0.405	-0.603	**-0.691**

Failed Members

There is no data of this type.

Job Information

	Engineer	Checked	Approved
Name:	HASMIRA		
Date:	17-Nov-11		

Structure Type	SPACE FRAME

Number of Nodes	120	Highest Node	120
Number of Elements	340	Highest Beam	352

Number of Basic Load Cases	3
Number of Combination Load Cases	0

Included in this printout are data for:

All	The Whole Structure

Included in this printout are results for load cases:

Type	L/C	Name
Primary	1	SELF WEIGHT
Primary	2	WIND LOAD (ASCE)
Primary	3	ANTENNA LOAD

Section Properties

Prop	Section	Area (cm^2)	I_{yy} (cm^4)	I_{zz} (cm^4)	J (cm^4)	Material
1	UA90X90X6 SD	21.200	294.766	165.174	2.549	STEEL
2	UA70X70X6 SD	16.400	139.366	75.613	1.973	STEEL
3	UA50X50X6 SD	11.600	51.325	26.252	1.397	STEEL
4	UA45X45X5 SD	8.820	31.257	16.148	0.729	STEEL
5	UA40X40X4 SD	6.400	17.642	9.216	0.333	STEEL
6	UA60X60X5 SD	11.820	73.367	39.816	0.979	STEEL
7	UA50X50X4 SD	8.000	34.155	18.522	0.418	STEEL
8	UA40X40X4 SD	6.400	17.642	9.216	0.333	STEEL

Materials

Mat	Name	E (kN/mm^2)	ν	Density (kg/m^3)	α (1/°K)
1	STEEL	205.000	0.300	7.83E+3	12E -6
2	STAINLESSSTEEL	197.930	0.300	7.83E+3	18E -6
3	ALUMINUM	68.948	0.330	2.71E+3	23E -6
4	CONCRETE	21.718	0.170	2.4E+3	10E -6

Basic Load Cases

Number	Name
1	SELF WEIGHT
2	WIND LOAD (ASCE)
3	ANTENNA LOAD

Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	10	2:WIND LOAD	**587.011**	24.198	0.736	587.510	0.000	-0.000	-0.024
Min X	115	2:WIND LOAD	**-7.351**	-0.850	0.003	7.400	0.000	-0.000	0.000
Max Y	10	2:WIND LOAD	587.011	**24.198**	0.736	587.510	0.000	-0.000	-0.024
Min Y	25	2:WIND LOAD	586.997	**-23.706**	-0.728	587.476	-0.000	-0.000	-0.024
Max Z	98	2:WIND LOAD	35.440	2.557	**38.224**	52.188	-0.000	0.009	-0.006
Min Z	46	2:WIND LOAD	35.368	2.557	**-38.224**	52.139	0.000	-0.009	-0.006
Max rX	5	2:WIND LOAD	35.475	12.811	-0.038	37.717	**0.005**	0.056	-0.003
Min rX	57	2:WIND LOAD	35.547	12.842	-0.090	37.796	**-0.005**	-0.056	-0.003
Max rY	5	2:WIND LOAD	35.475	12.811	-0.038	37.717	0.005	**0.056**	-0.003
Min rY	57	2:WIND LOAD	35.547	12.842	-0.090	37.796	-0.005	**-0.056**	-0.003
Max rZ	3	2:WIND LOAD	0.553	3.610	-0.109	3.654	0.005	0.026	**0.001**
Min rZ	105	2:WIND LOAD	316.020	19.778	-0.323	316.638	0.000	0.000	**-0.024**
Max Rst	10	2:WIND LOAD	587.011	24.198	0.736	**587.510**	0.000	-0.000	-0.024

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	14	10	2:WIND LOAD	**587.011**	24.197	0.736	587.510
Min X	320	115	2:WIND LOAD	**-7.351**	-0.850	0.003	7.400
Max Y	14	10	2:WIND LOAD	587.011	**24.197**	0.736	587.510
Min Y	28	25	2:WIND LOAD	586.998	**-23.707**	-0.728	587.476
Max Z	137	98	2:WIND LOAD	35.440	2.557	**38.224**	52.188
Min Z	31	46	2:WIND LOAD	35.368	2.557	**-38.224**	52.139
Max Rst	14	10	2:WIND LOAD	587.011	24.197	0.736	**587.510**

Beam End Force Summary

The signs of the forces at end B of each beam have been reversed. For example: this means that the Min Fx entry gives the largest tension value for an beam.

	Beam	Node	L/C	Axial	Shear		Torsion	Bending	
				Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	121	68	2:WIND LOAD	**521.286**	0.561	-0.171	-0.004	0.226	0.582
Min Fx	107	53	2:WIND LOAD	**-520.852**	-0.638	-0.209	0.017	0.269	-0.655
Max Fy	108	55	2:WIND LOAD	-519.136	**1.310**	1.233	0.003	-0.346	1.111
Min Fy	122	70	2:WIND LOAD	519.393	**-1.195**	0.718	-0.001	-0.260	-1.088
Max Fz	241	6	2:WIND LOAD	1.932	0.110	**4.730**	-0.001	-2.834	0.084
Min Fz	258	110	2:WIND LOAD	1.926	-0.109	**-4.723**	0.001	6.077	-0.123
Max Mx	107	53	2:WIND LOAD	-520.852	-0.638	-0.209	**0.017**	0.269	-0.655
Min Mx	1	1	2:WIND LOAD	-519.301	-0.636	0.210	**-0.017**	-0.271	-0.653
Max My	243	108	2:WIND LOAD	-4.073	0.121	4.353	0.006	**7.375**	-0.135
Min My	136	56	2:WIND LOAD	-0.058	0.056	0.904	-0.002	**-3.402**	0.148
Max Mz	122	104	2:WIND LOAD	519.393	-1.195	0.718	-0.001	1.184	**1.314**
Min Mz	108	102	2:WIND LOAD	-519.136	1.310	1.233	0.003	2.133	**-1.523**

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A.

	Beam	L/C	d	Axial	Shear		Torsion	Bending	
			(mm)	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	121	2:WIND LOAD	0.000	**521.286**	0.561	-0.171	-0.004	0.226	0.582
Min Fx	107	2:WIND LOAD	0.000	**-520.852**	-0.638	-0.209	0.017	0.269	-0.655
Max Fy	108	2:WIND LOAD	0.000	-519.136	**1.310**	1.233	0.003	-0.346	1.111
Min Fy	122	2:WIND LOAD	0.000	519.393	**-1.195**	0.718	-0.001	-0.260	-1.088
Max Fz	241	2:WIND LOAD	0.000	1.932	0.110	**4.730**	-0.001	-2.834	0.084
Min Fz	258	2:WIND LOAD	0.000	1.926	-0.109	**-4.723**	0.001	6.077	-0.123
Max Mx	107	2:WIND LOAD	0.000	-520.852	-0.638	-0.209	**0.017**	0.269	-0.655
Min Mx	1	2:WIND LOAD	0.000	-519.301	-0.636	0.210	**-0.017**	-0.271	-0.653
Max My	243	2:WIND LOAD	2.47E+3	-4.073	0.121	4.353	0.006	**7.375**	-0.135
Min My	136	2:WIND LOAD	0.000	-0.058	0.056	0.904	-0.002	**-3.402**	0.148
Max Mz	122	2:WIND LOAD	2.01E+3	519.393	-1.195	0.718	-0.001	1.184	**1.314**
Min Mz	108	2:WIND LOAD	2.01E+3	-519.136	1.310	1.233	0.003	2.133	**-1.523**

Reaction Summary

	Node	L/C	Horizontal FX (kN)	Vertical FY (kN)	Horizontal FZ (kN)	Moment MX (kNm)	MY (kNm)	MZ (kNm)
Max FX	53	1:SELF WEIGI	**1.688**	14.468	-1.690	0.141	0.000	0.141
Min FX	53	2:WIND LOAD	**-75.442**	-537.394	55.369	-1.266	3.107	2.033
Max FY	68	2:WIND LOAD	-68.325	**537.394**	-55.788	0.169	-0.637	-0.523
Min FY	53	2:WIND LOAD	-75.442	**-537.394**	55.369	-1.266	3.107	2.033
Max FZ	16	2:WIND LOAD	-68.324	535.854	**55.485**	-0.169	0.637	-0.520
Min FZ	68	2:WIND LOAD	-68.325	537.394	**-55.788**	0.169	-0.637	-0.523
Max MX	1	2:WIND LOAD	-75.441	-535.854	-55.066	**1.267**	-3.108	2.036
Min MX	53	2:WIND LOAD	-75.442	-537.394	55.369	**-1.266**	3.107	2.033
Max MY	53	2:WIND LOAD	-75.442	-537.394	55.369	-1.266	**3.107**	2.033
Min MY	1	2:WIND LOAD	-75.441	-535.854	-55.066	1.267	**-3.108**	2.036
Max MZ	1	2:WIND LOAD	-75.441	-535.854	-55.066	1.267	-3.108	**2.036**
Min MZ	68	2:WIND LOAD	-68.325	537.394	-55.788	0.169	-0.637	**-0.523**

Failed Members

There is no data of this type.

Job Information

	Engineer	Checked	Approved
Name:	HASMIRA		
Date:	17-Nov-11		

Structure Type	SPACE FRAME

Number of Nodes	120	Highest Node	120
Number of Elements	340	Highest Beam	352

Number of Basic Load Cases	3
Number of Combination Load Cases	0

Included in this printout are data for:

All	The Whole Structure

Included in this printout are results for load cases:

Type	L/C	Name
Primary	1	SELF WEIGHT
Primary	2	WIND LOAD (MS)
Primary	3	ANTENNA LOAD

Section Properties

Prop	Section	Area (cm^2)	I_{yy} (cm^4)	I_{zz} (cm^4)	J (cm^4)	Material
1	UA90X90X6 SD	21.200	294.766	165.174	2.549	STEEL
2	UA70X70X6 SD	16.400	139.366	75.613	1.973	STEEL
3	UA50X50X6 SD	11.600	51.325	26.252	1.397	STEEL
4	UA45X45X5 SD	8.820	31.257	16.148	0.729	STEEL
5	UA40X40X4 SD	6.400	17.642	9.216	0.333	STEEL
6	UA60X60X5 SD	11.820	73.367	39.816	0.979	STEEL
7	UA50X50X4 SD	8.000	34.155	18.522	0.418	STEEL
8	UA40X40X4 SD	6.400	17.642	9.216	0.333	STEEL

Materials

Mat	Name	E (kN/mm^2)	v	Density (kg/m^3)	α (1/°K)
1	STEEL	205.000	0.300	7.83E+3	12E -6
2	STAINLESSSTEEL	197.930	0.300	7.83E+3	18E -6
3	ALUMINUM	68.948	0.330	2.71E+3	23E -6
4	CONCRETE	21.718	0.170	2.4E+3	10E -6

Basic Load Cases

Number	Name
1	SELF WEIGHT
2	WIND LOAD (MS)
3	ANTENNA LOAD

Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	10	2:WIND LOAD	**592.272**	24.238	0.721	592.768	0.000	-0.000	-0.024
Min X	115	2:WIND LOAD	**-8.779**	-0.994	0.003	8.835	0.000	-0.000	0.000
Max Y	10	2:WIND LOAD	592.272	**24.238**	0.721	592.768	0.000	-0.000	-0.024
Min Y	25	2:WIND LOAD	592.259	**-23.696**	-0.714	592.733	-0.000	-0.000	-0.024
Max Z	98	2:WIND LOAD	36.863	2.943	**44.191**	57.623	-0.000	0.010	-0.007
Min Z	46	2:WIND LOAD	36.789	2.944	**-44.191**	57.575	0.000	-0.010	-0.007
Max rX	101	2:WIND LOAD	10.989	1.765	32.925	34.755	**0.006**	0.006	-0.003
Min rX	49	2:WIND LOAD	10.973	1.765	-32.925	34.750	**-0.006**	-0.006	-0.003
Max rY	5	2:WIND LOAD	36.911	13.123	-0.035	39.175	0.006	**0.065**	-0.003
Min rY	57	2:WIND LOAD	36.986	13.154	-0.091	39.256	-0.006	**-0.065**	-0.003
Max rZ	3	2:WIND LOAD	0.706	3.721	-0.110	3.789	0.005	0.031	**0.001**
Min rZ	105	2:WIND LOAD	321.218	19.843	-0.325	321.830	0.000	0.000	**-0.025**
Max Rst	10	2:WIND LOAD	592.272	24.238	0.721	**592.768**	0.000	-0.000	-0.024

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	14	10	2:WIND LOAD	**592.272**	24.237	0.721	592.768
Min X	320	115	2:WIND LOAD	**-8.779**	-0.994	0.003	8.835
Max Y	14	10	2:WIND LOAD	592.272	**24.237**	0.721	592.768
Min Y	28	25	2:WIND LOAD	592.259	**-23.695**	-0.714	592.733
Max Z	137	98	2:WIND LOAD	36.863	2.943	**44.191**	57.623
Min Z	31	46	2:WIND LOAD	36.788	2.943	**-44.191**	57.575
Max Rst	14	10	2:WIND LOAD	592.272	24.237	0.721	**592.768**

Beam End Force Summary

The signs of the forces at end B of each beam have been reversed. For example: this means that the Min Fx entry gives the largest tension value for an beam.

				Axial	Shear		Torsion	Bending	
	Beam	Node	L/C	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	121	68	2:WIND LOAD	**538.779**	0.574	-0.187	-0.005	0.255	0.589
Min Fx	107	53	2:WIND LOAD	**-538.687**	-0.667	-0.230	0.021	0.305	-0.678
Max Fy	108	55	2:WIND LOAD	-536.939	**1.373**	1.339	0.004	-0.373	1.151
Min Fy	122	70	2:WIND LOAD	536.822	**-1.234**	0.726	-0.001	-0.273	-1.121
Max Fz	241	6	2:WIND LOAD	2.043	0.126	**5.315**	-0.001	-3.178	0.094
Min Fz	258	110	2:WIND LOAD	2.037	-0.125	**-5.308**	0.001	6.834	-0.144
Max Mx	107	53	2:WIND LOAD	-538.687	-0.667	-0.230	**0.021**	0.305	-0.678
Min Mx	1	1	2:WIND LOAD	-537.131	-0.666	0.231	**-0.021**	-0.307	-0.676
Max My	243	108	2:WIND LOAD	-3.976	0.146	5.221	0.007	**8.841**	-0.176
Min My	136	56	2:WIND LOAD	1.177	0.062	1.085	-0.002	**-4.082**	0.170
Max Mz	122	104	2:WIND LOAD	536.822	-1.234	0.726	-0.001	1.187	**1.361**
Min Mz	108	102	2:WIND LOAD	-536.939	1.373	1.339	0.004	2.320	**-1.609**

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (mm)	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	121	2:WIND LOAD	0.000	**538.779**	0.574	-0.187	-0.005	0.255	0.589
Min Fx	107	2:WIND LOAD	0.000	**-538.687**	-0.667	-0.230	0.021	0.305	-0.678
Max Fy	108	2:WIND LOAD	0.000	-536.939	**1.373**	1.339	0.004	-0.373	1.151
Min Fy	122	2:WIND LOAD	0.000	536.822	**-1.234**	0.726	-0.001	-0.273	-1.121
Max Fz	241	2:WIND LOAD	0.000	2.043	0.126	**5.315**	-0.001	-3.178	0.094
Min Fz	258	2:WIND LOAD	0.000	2.037	-0.125	**-5.308**	0.001	6.834	-0.144
Max Mx	107	2:WIND LOAD	0.000	-538.687	-0.667	-0.230	**0.021**	0.305	-0.678
Min Mx	1	2:WIND LOAD	0.000	-537.131	-0.666	0.231	**-0.021**	-0.307	-0.676
Max My	243	2:WIND LOAD	2.47E+3	-3.976	0.146	5.221	0.007	**8.841**	-0.176
Min My	136	2:WIND LOAD	0.000	1.177	0.062	1.085	-0.002	**-4.082**	0.170
Max Mz	122	2:WIND LOAD	2.01E+3	536.822	-1.234	0.726	-0.001	1.187	**1.361**
Min Mz	108	2:WIND LOAD	2.01E+3	-536.939	1.373	1.339	0.004	2.320	**-1.609**

Reaction Summary

	Node	L/C	Horizontal FX (kN)	Vertical FY (kN)	Horizontal FZ (kN)	Moment MX (kNm)	MY (kNm)	MZ (kNm)
Max FX	53	1:SELF WEIGI	**1.688**	14.468	-1.690	0.141	0.000	0.141
Min FX	53	2:WIND LOAD	**-82.124**	-559.123	57.549	-1.425	3.698	2.489
Max FY	68	2:WIND LOAD	-74.421	**559.123**	-58.010	0.122	-0.749	-0.546
Min FY	53	2:WIND LOAD	-82.124	**-559.123**	57.549	-1.425	3.698	2.489
Max FZ	16	2:WIND LOAD	-74.409	557.581	**57.720**	-0.123	0.748	-0.543
Min FZ	68	2:WIND LOAD	-74.421	559.123	**-58.010**	0.122	-0.749	-0.546
Max MX	1	2:WIND LOAD	-82.112	-557.581	-57.259	**1.425**	-3.698	2.492
Min MX	53	2:WIND LOAD	-82.124	-559.123	57.549	**-1.425**	3.698	2.489
Max MY	53	2:WIND LOAD	-82.124	-559.123	57.549	-1.425	**3.698**	2.489
Min MY	1	2:WIND LOAD	-82.112	-557.581	-57.259	1.425	**-3.698**	2.492
Max MZ	1	2:WIND LOAD	-82.112	-557.581	-57.259	1.425	-3.698	**2.492**
Min MZ	68	2:WIND LOAD	-74.421	559.123	-58.010	0.122	-0.749	**-0.546**

Failed Members

There is no data of this type.

Job Information

	Engineer	Checked	Approved
Name:	HASMIRA		
Date:	13-Nov-11		

Structure Type	SPACE FRAME

Number of Nodes	180	Highest Node	180
Number of Elements	500	Highest Beam	500

Number of Basic Load Cases	3
Number of Combination Load Cases	0

Included in this printout are data for:

All	The Whole Structure

Included in this printout are results for load cases:

Type	L/C	Name
Primary	1	SELF WEIGHT
Primary	2	WIND LOAD (BS)
Primary	3	ANTENNA

Section Properties

Prop	Section	Area (cm^2)	I_{yy} (cm^4)	I_{zz} (cm^4)	J (cm^4)	Material
1	UA120X120X8 SD	37.600	930.639	522.030	8.055	STEEL
2	UA100X100X8 SD	31.200	540.226	296.345	6.690	STEEL
3	UA90X90X6 SD	21.200	294.766	165.174	2.549	STEEL
4	UA80X80X6 SD	18.800	207.446	114.618	2.261	STEEL
5	UA70X70X6 SD	16.400	139.366	75.613	1.973	STEEL
6	UA50X50X6 SD	11.600	51.325	26.252	1.397	STEEL
7	UA45X45X5 SD	8.820	31.257	16.148	0.729	STEEL
8	UA80X80X6 SD	18.800	207.446	114.618	2.261	STEEL
9	UA70X70X6 SD	16.400	139.366	75.613	1.973	STEEL
10	UA60X60X5 SD	11.820	73.367	39.816	0.979	STEEL
11	UA45X45X5 SD	8.820	31.257	16.148	0.729	STEEL

Materials

Mat	Name	E (kN/mm^2)	ν	Density (kg/m^3)	α (1/°K)
1	STEEL	205.000	0.300	7.83E+3	12E -6
2	STAINLESSSTEEL	197.930	0.300	7.83E+3	18E -6
3	ALUMINUM	68.948	0.330	2.71E+3	23E -6
4	CONCRETE	21.718	0.170	2.4E+3	10E -6

Basic Load Cases

Number	Name
1	SELF WEIGHT
2	WIND LOAD (BS)
3	ANTENNA

Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	80	2:WIND LOAD	**1.48E+3**	39.406	-0.662	1.48E+3	-0.000	0.001	-0.039
Min X	179	2:WIND LOAD	**-38.699**	-28.219	-0.032	47.895	0.000	0.000	0.003
Max Y	141	2:WIND LOAD	556.987	**57.577**	1.354	559.956	-0.007	-0.112	-0.015
Min Y	173	2:WIND LOAD	444.861	**-62.799**	-0.135	449.272	0.000	0.000	-0.023
Max Z	128	2:WIND LOAD	192.061	14.661	**204.596**	281.001	-0.007	0.028	-0.014
Min Z	51	2:WIND LOAD	191.858	14.660	**-204.596**	280.863	0.007	-0.028	-0.014
Max rX	125	2:WIND LOAD	120.766	6.997	186.672	222.440	**0.018**	0.022	-0.010
Min rX	48	2:WIND LOAD	120.631	6.997	-186.672	222.367	**-0.018**	-0.022	-0.010
Max rY	7	2:WIND LOAD	192.187	45.862	0.152	197.584	0.016	**0.178**	-0.003
Min rY	84	2:WIND LOAD	192.391	45.875	0.037	197.784	-0.016	**-0.178**	-0.003
Max rZ	163	2:WIND LOAD	826.246	-3.601	0.095	826.254	-0.000	0.000	**0.006**
Min rZ	162	2:WIND LOAD	744.464	39.330	0.113	745.502	-0.000	0.000	**-0.063**
Max Rst	80	2:WIND LOAD	1.48E+3	39.406	-0.662	**1.48E+3**	-0.000	0.001	-0.039

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	174	80	2:WIND LOAD	**1.48E+3**	39.408	-0.662	1.48E+3
Min X	408	179	2:WIND LOAD	**-38.699**	-28.219	-0.032	47.895
Max Y	165	141	2:WIND LOAD	556.987	**57.578**	1.354	559.956
Min Y	414	173	2:WIND LOAD	444.861	**-62.799**	-0.135	449.272
Max Z	199	128	2:WIND LOAD	192.061	14.660	**204.596**	281.002
Min Z	43	51	2:WIND LOAD	191.858	14.660	**-204.596**	280.863
Max Rst	174	80	2:WIND LOAD	1.48E+3	39.408	-0.662	**1.48E+3**

Beam End Force Summary

The signs of the forces at end B of each beam have been reversed. For example: this means that the Min Fx entry gives the largest tension value for an beam.

				Axial	Shear		Torsion	Bending	
	Beam	Node	L/C	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	20	21	2:WIND LOAD	**1.58E+3**	0.981	0.774	0.023	-1.786	0.977
Min Fx	1	1	2:WIND LOAD	**-1.59E+3**	-1.069	0.895	-0.089	-1.965	-1.078
Max Fy	175	97	2:WIND LOAD	-1.58E+3	**2.082**	2.969	0.039	-1.502	3.059
Min Fy	194	117	2:WIND LOAD	1.58E+3	**-2.116**	1.474	-0.014	-1.112	-3.041
Max Fz	316	6	2:WIND LOAD	5.211	0.255	**12.794**	0.023	-15.922	0.450
Min Fz	381	164	2:WIND LOAD	5.210	-0.256	**-12.794**	-0.023	35.254	-0.572
Max Mx	157	78	2:WIND LOAD	-1.59E+3	-1.069	-0.900	**0.089**	1.979	-1.079
Min Mx	1	1	2:WIND LOAD	-1.59E+3	-1.069	0.895	**-0.089**	-1.965	-1.078
Max My	316	164	2:WIND LOAD	5.211	0.255	12.794	0.023	**35.254**	-0.572
Min My	394	165	2:WIND LOAD	-18.118	0.425	-5.761	-0.017	**-20.326**	-1.310
Max Mz	194	121	2:WIND LOAD	1.58E+3	-2.116	1.474	-0.014	3.315	**3.312**
Min Mz	209	119	2:WIND LOAD	-1.37E+3	-1.797	-1.638	0.038	3.538	**-3.978**

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (mm)	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	20	2:WIND LOAD	0.000	**1.58E+3**	0.981	0.774	0.023	-1.786	0.977
Min Fx	1	2:WIND LOAD	0.000	**-1.59E+3**	-1.069	0.895	-0.089	-1.965	-1.078
Max Fy	175	2:WIND LOAD	0.000	-1.58E+3	**2.082**	2.969	0.039	-1.502	3.059
Min Fy	194	2:WIND LOAD	0.000	1.58E+3	**-2.116**	1.474	-0.014	-1.112	-3.041
Max Fz	316	2:WIND LOAD	0.000	5.211	0.255	**12.794**	0.023	-15.922	0.450
Min Fz	381	2:WIND LOAD	0.000	5.210	-0.256	**-12.794**	-0.023	35.254	-0.572
Max Mx	157	2:WIND LOAD	0.000	-1.59E+3	-1.069	-0.900	**0.089**	1.979	-1.079
Min Mx	1	2:WIND LOAD	0.000	-1.59E+3	-1.069	0.895	**-0.089**	-1.965	-1.078
Max My	316	2:WIND LOAD	4E+3	5.211	0.255	12.794	0.023	**35.254**	-0.572
Min My	394	2:WIND LOAD	5.41E+3	-18.118	0.425	-5.761	-0.017	**-20.326**	-1.310
Max Mz	194	2:WIND LOAD	3E+3	1.58E+3	-2.116	1.474	-0.014	3.315	**3.312**
Min Mz	209	2:WIND LOAD	0.000	-1.37E+3	-1.797	-1.638	0.038	3.538	**-3.978**

Reaction Summary

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
Max FX	1	1:SELF WEIGH	**2.653**	43.005	2.653	-0.442	0.000	0.442
Min FX	98	2:WIND LOAD	**-244.117**	1.73E+3	-77.495	0.432	-2.921	-0.263
Max FY	21	2:WIND LOAD	-243.306	**1.73E+3**	78.411	-0.420	2.923	-0.274
Min FY	1	2:WIND LOAD	-240.086	**-1.73E+3**	-87.174	4.626	-15.287	10.070
Max FZ	78	2:WIND LOAD	-240.896	-1.73E+3	**86.258**	-4.638	15.289	10.081
Min FZ	1	2:WIND LOAD	-240.086	-1.73E+3	**-87.174**	4.626	-15.287	10.070
Max MX	1	2:WIND LOAD	-240.086	-1.73E+3	-87.174	**4.626**	-15.287	10.070
Min MX	78	2:WIND LOAD	-240.896	-1.73E+3	86.258	**-4.638**	15.289	10.081
Max MY	78	2:WIND LOAD	-240.896	-1.73E+3	86.258	-4.638	**15.289**	10.081
Min MY	1	2:WIND LOAD	-240.086	-1.73E+3	-87.174	4.626	**-15.287**	10.070
Max MZ	78	2:WIND LOAD	-240.896	-1.73E+3	86.258	-4.638	15.289	**10.081**
Min MZ	21	1:SELF WEIGH	-2.653	43.005	2.653	-0.442	-0.000	**-0.442**

Failed Members

There is no data of this type.

Job Information

	Engineer	Checked	Approved
Name:	HASMIRA		
Date:	13-Nov-11		

Structure Type	SPACE FRAME

Number of Nodes	180	Highest Node	180
Number of Elements	500	Highest Beam	500

Number of Basic Load Cases	3
Number of Combination Load Cases	0

Included in this printout are data for:

All	The Whole Structure

Included in this printout are results for load cases:

Type	L/C	Name
Primary	1	SELF WEIGHT
Primary	2	WIND LOAD (ASCE)
Primary	3	ANTENNA

Section Properties

Prop	Section	Area (cm^2)	I_{yy} (cm^4)	I_{zz} (cm^4)	J (cm^4)	Material
1	UA120X120X8 SD	37.600	930.639	522.030	8.055	STEEL
2	UA100X100X8 SD	31.200	540.226	296.345	6.690	STEEL
3	UA90X90X6 SD	21.200	294.766	165.174	2.549	STEEL
4	UA80X80X6 SD	18.800	207.446	114.618	2.261	STEEL
5	UA70X70X6 SD	16.400	139.366	75.613	1.973	STEEL
6	UA50X50X6 SD	11.600	51.325	26.252	1.397	STEEL
7	UA45X45X5 SD	8.820	31.257	16.148	0.729	STEEL
8	UA80X80X6 SD	18.800	207.446	114.618	2.261	STEEL
9	UA70X70X6 SD	16.400	139.366	75.613	1.973	STEEL
10	UA60X60X5 SD	11.820	73.367	39.816	0.979	STEEL
11	UA45X45X5 SD	8.820	31.257	16.148	0.729	STEEL

Materials

Mat	Name	E (kN/mm^2)	ν	Density (kg/m^3)	α (1/°K)
1	STEEL	205.000	0.300	7.83E+3	12E -6
2	STAINLESSSTEEL	197.930	0.300	7.83E+3	18E -6
3	ALUMINUM	68.948	0.330	2.71E+3	23E -6
4	CONCRETE	21.718	0.170	2.4E+3	10E -6

Basic Load Cases

Number	Name
1	SELF WEIGHT
2	WIND LOAD (ASCE)
3	ANTENNA

Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	80	2:WIND LOAD	**1.12E+3**	29.546	-0.475	1.12E+3	-0.000	0.000	-0.029
Min X	179	2:WIND LOAD	**-39.627**	-22.349	-0.023	45.495	0.000	0.000	0.003
Max Y	141	2:WIND LOAD	430.359	**43.881**	2.037	432.595	-0.006	-0.090	-0.011
Min Y	173	2:WIND LOAD	342.276	**-47.906**	-0.096	345.612	0.000	0.000	-0.018
Max Z	128	2:WIND LOAD	150.663	12.652	**172.644**	229.489	-0.006	0.024	-0.011
Min Z	51	2:WIND LOAD	150.511	12.652	**-172.644**	229.390	0.006	-0.024	-0.011
Max rX	125	2:WIND LOAD	95.337	5.803	161.111	187.296	**0.015**	0.019	-0.008
Min rX	48	2:WIND LOAD	95.237	5.803	-161.111	187.244	**-0.015**	-0.019	-0.008
Max rY	7	2:WIND LOAD	150.787	35.393	0.115	154.885	0.014	**0.150**	-0.001
Min rY	84	2:WIND LOAD	150.939	35.403	0.022	155.035	-0.014	**-0.150**	-0.001
Max rZ	163	2:WIND LOAD	684.410	-7.025	0.069	684.446	-0.000	0.000	**0.007**
Min rZ	164	2:WIND LOAD	543.807	18.574	0.051	544.124	-0.000	0.000	**-0.052**
Max Rst	80	2:WIND LOAD	1.12E+3	29.546	-0.475	**1.12E+3**	-0.000	0.000	-0.029

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	174	80	2:WIND LOAD	**1.12E+3**	29.549	-0.475	1.12E+3
Min X	408	179	2:WIND LOAD	**-39.627**	-22.349	-0.023	45.495
Max Y	165	141	2:WIND LOAD	430.359	**43.879**	2.037	432.595
Min Y	414	173	2:WIND LOAD	342.276	**-47.904**	-0.096	345.612
Max Z	199	128	2:WIND LOAD	150.663	12.653	**172.644**	229.489
Min Z	43	51	2:WIND LOAD	150.511	12.650	**-172.644**	229.390
Max Rst	174	80	2:WIND LOAD	1.12E+3	29.549	-0.475	**1.12E+3**

Beam End Force Summary

The signs of the forces at end B of each beam have been reversed. For example: this means that the Min Fx entry gives the largest tension value for an beam.

				Axial	Shear		Torsion	Bending	
	Beam	Node	L/C	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	176	98	2:WIND LOAD	**1.24E+3**	0.755	-0.652	-0.023	1.516	0.718
Min Fx	157	78	2:WIND LOAD	**-1.25E+3**	-0.895	-0.695	0.095	1.596	-0.887
Max Fy	175	97	2:WIND LOAD	-1.24E+3	**1.849**	2.266	0.028	-1.072	2.533
Min Fy	194	117	2:WIND LOAD	1.24E+3	**-1.667**	1.148	-0.013	-0.916	-2.378
Max Fz	316	6	2:WIND LOAD	4.308	0.215	**11.032**	0.019	-13.723	0.385
Min Fz	381	164	2:WIND LOAD	4.308	-0.215	**-11.032**	-0.019	30.404	-0.476
Max Mx	157	78	2:WIND LOAD	-1.25E+3	-0.895	-0.695	**0.095**	1.596	-0.887
Min Mx	1	1	2:WIND LOAD	-1.25E+3	-0.895	0.692	**-0.095**	-1.585	-0.887
Max My	316	164	2:WIND LOAD	4.308	0.215	11.032	0.019	**30.404**	-0.475
Min My	394	165	2:WIND LOAD	-16.155	0.385	-5.056	-0.015	**-17.958**	-1.189
Max Mz	157	97	2:WIND LOAD	-1.25E+3	-0.895	-0.695	0.095	-1.189	**2.700**
Min Mz	19	42	2:WIND LOAD	-1.24E+3	1.849	-2.265	-0.028	-5.732	**-3.018**

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (mm)	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	176	2:WIND LOAD	0.000	**1.24E+3**	0.755	-0.652	-0.023	1.516	0.718
Min Fx	157	2:WIND LOAD	0.000	**-1.25E+3**	-0.895	-0.695	0.095	1.596	-0.887
Max Fy	175	2:WIND LOAD	0.000	-1.24E+3	**1.849**	2.266	0.028	-1.072	2.533
Min Fy	194	2:WIND LOAD	0.000	1.24E+3	**-1.667**	1.148	-0.013	-0.916	-2.378
Max Fz	316	2:WIND LOAD	0.000	4.308	0.215	**11.032**	0.019	-13.723	0.385
Min Fz	381	2:WIND LOAD	0.000	4.308	-0.215	**-11.032**	-0.019	30.404	-0.476
Max Mx	157	2:WIND LOAD	0.000	-1.25E+3	-0.895	-0.695	**0.095**	1.596	-0.887
Min Mx	1	2:WIND LOAD	0.000	-1.25E+3	-0.895	0.692	**-0.095**	-1.585	-0.887
Max My	316	2:WIND LOAD	4E+3	4.308	0.215	11.032	0.019	**30.404**	-0.475
Min My	394	2:WIND LOAD	5.41E+3	-16.155	0.385	-5.056	-0.015	**-17.958**	-1.189
Max Mz	157	2:WIND LOAD	4.01E+3	-1.25E+3	-0.895	-0.695	0.095	-1.189	**2.700**
Min Mz	19	2:WIND LOAD	3E+3	-1.24E+3	1.849	-2.265	-0.028	-5.732	**-3.018**

Reaction Summary

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
Max FX	1	1:SELF WEIGH	**2.653**	43.005	2.653	-0.442	0.000	0.442
Min FX	78	2:WIND LOAD	**-205.327**	-1.36E+3	69.308	-4.324	16.499	10.824
Max FY	21	2:WIND LOAD	-203.617	**1.36E+3**	61.649	0.006	2.987	-0.276
Min FY	1	2:WIND LOAD	-204.730	**-1.36E+3**	-69.981	4.316	-16.498	10.816
Max FZ	78	2:WIND LOAD	-205.327	-1.36E+3	**69.308**	-4.324	16.499	10.824
Min FZ	1	2:WIND LOAD	-204.730	-1.36E+3	**-69.981**	4.316	-16.498	10.816
Max MX	1	2:WIND LOAD	-204.730	-1.36E+3	-69.981	**4.316**	-16.498	10.816
Min MX	78	2:WIND LOAD	-205.327	-1.36E+3	69.308	**-4.324**	16.499	10.824
Max MY	78	2:WIND LOAD	-205.327	-1.36E+3	69.308	-4.324	**16.499**	10.824
Min MY	1	2:WIND LOAD	-204.730	-1.36E+3	-69.981	4.316	**-16.498**	10.816
Max MZ	78	2:WIND LOAD	-205.327	-1.36E+3	69.308	-4.324	16.499	**10.824**
Min MZ	21	1:SELF WEIGH	-2.653	43.005	2.653	-0.442	-0.000	**-0.442**

Failed Members

There is no data of this type.

Job Information

	Engineer	Checked	Approved
Name:	HASMIRA		
Date:	13-Nov-11		

Structure Type	SPACE FRAME

Number of Nodes	180	Highest Node	180
Number of Elements	500	Highest Beam	500

Number of Basic Load Cases	3
Number of Combination Load Cases	0

Included in this printout are data for:

All	The Whole Structure

Included in this printout are results for load cases:

Type	L/C	Name
Primary	1	SELF WEIGHT
Primary	2	WIND LOAD (MS)
Primary	3	ANTENNA

Section Properties

Prop	Section	Area (cm^2)	I_{yy} (cm^4)	I_{zz} (cm^4)	J (cm^4)	Material
1	UA120X120X8 SD	37.600	930.639	522.030	8.055	STEEL
2	UA100X100X8 SD	31.200	540.226	296.345	6.690	STEEL
3	UA90X90X6 SD	21.200	294.766	165.174	2.549	STEEL
4	UA80X80X6 SD	18.800	207.446	114.618	2.261	STEEL
5	UA70X70X6 SD	16.400	139.366	75.613	1.973	STEEL
6	UA50X50X6 SD	11.600	51.325	26.252	1.397	STEEL
7	UA45X45X5 SD	8.820	31.257	16.148	0.729	STEEL
8	UA80X80X6 SD	18.800	207.446	114.618	2.261	STEEL
9	UA70X70X6 SD	16.400	139.366	75.613	1.973	STEEL
10	UA60X60X5 SD	11.820	73.367	39.816	0.979	STEEL
11	UA45X45X5 SD	8.820	31.257	16.148	0.729	STEEL

Materials

Mat	Name	E (kN/mm^2)	ν	Density (kg/m^3)	α (1/°K)
1	STEEL	205.000	0.300	7.83E+3	12E -6
2	STAINLESSSTEEL	197.930	0.300	7.83E+3	18E -6
3	ALUMINUM	68.948	0.330	2.71E+3	23E -6
4	CONCRETE	21.718	0.170	2.4E+3	10E -6

Basic Load Cases

Number	Name
1	SELF WEIGHT
2	WIND LOAD (MS)
3	ANTENNA

Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	80	2:WIND LOAD	**1.03E+3**	26.727	-0.413	1.03E+3	-0.000	0.000	-0.026
Min X	179	2:WIND LOAD	**-50.428**	-21.562	-0.020	54.845	0.000	0.000	0.003
Max Y	141	2:WIND LOAD	401.789	**40.381**	3.258	403.826	-0.005	-0.084	-0.010
Min Y	173	2:WIND LOAD	319.358	**-43.928**	-0.083	322.365	0.000	0.000	-0.016
Max Z	128	2:WIND LOAD	143.258	13.394	**177.805**	228.729	-0.008	0.025	-0.010
Min Z	51	2:WIND LOAD	143.123	13.393	**-177.805**	228.645	0.008	-0.025	-0.010
Max rX	120	2:WIND LOAD	4.150	3.494	92.014	92.174	**0.018**	0.011	-0.001
Min rX	43	2:WIND LOAD	4.135	3.494	-92.014	92.173	**-0.018**	-0.011	-0.001
Max rY	7	2:WIND LOAD	143.405	32.977	0.105	147.148	0.015	**0.154**	-0.000
Min rY	84	2:WIND LOAD	143.539	32.986	0.015	147.281	-0.015	**-0.154**	-0.000
Max rZ	163	2:WIND LOAD	690.722	-11.689	0.060	690.821	-0.000	0.000	**0.009**
Min rZ	164	2:WIND LOAD	571.569	16.782	0.044	571.816	-0.000	0.000	**-0.053**
Max Rst	80	2:WIND LOAD	1.03E+3	26.727	-0.413	**1.03E+3**	-0.000	0.000	-0.026

Beam End Displacement Summary

Displacements shown in italic indicate the presence of an offset

	Beam	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max X	174	80	2:WIND LOAD	**1.03E+3**	26.727	-0.413	1.03E+3
Min X	408	179	2:WIND LOAD	**-50.429**	-21.562	-0.020	54.845
Max Y	165	141	2:WIND LOAD	401.789	**40.382**	3.258	403.826
Min Y	414	173	2:WIND LOAD	319.358	**-43.929**	-0.083	322.365
Max Z	199	128	2:WIND LOAD	143.258	13.395	**177.805**	228.729
Min Z	43	51	2:WIND LOAD	143.123	13.395	**-177.805**	228.645
Max Rst	174	80	2:WIND LOAD	1.03E+3	26.727	-0.413	**1.03E+3**

Beam End Force Summary

The signs of the forces at end B of each beam have been reversed. For example: this means that the Min Fx entry gives the largest tension value for an beam.

				Axial	Shear		Torsion	Bending	
	Beam	Node	L/C	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	176	98	2:WIND LOAD	**1.18E+3**	0.695	-0.667	-0.028	1.569	0.615
Min Fx	157	78	2:WIND LOAD	**-1.19E+3**	-0.881	-0.688	0.115	1.625	-0.841
Max Fy	175	97	2:WIND LOAD	-1.19E+3	**1.863**	2.266	0.030	-1.009	2.473
Min Fy	194	117	2:WIND LOAD	1.18E+3	**-1.577**	1.062	-0.015	-0.915	-2.240
Max Fz	316	6	2:WIND LOAD	4.389	0.224	**11.803**	0.020	-14.673	0.409
Min Fz	381	164	2:WIND LOAD	4.388	-0.225	**-11.803**	-0.020	32.540	-0.489
Max Mx	157	78	2:WIND LOAD	-1.19E+3	-0.881	-0.688	**0.115**	1.625	-0.841
Min Mx	1	1	2:WIND LOAD	-1.19E+3	-0.881	0.685	**-0.115**	-1.616	-0.841
Max My	314	166	2:WIND LOAD	31.559	0.124	10.333	0.013	**33.095**	-0.251
Min My	388	167	2:WIND LOAD	-24.124	-0.386	5.250	-0.008	**-21.243**	-1.194
Max Mz	157	97	2:WIND LOAD	-1.19E+3	-0.881	-0.688	0.115	-1.132	**2.691**
Min Mz	19	42	2:WIND LOAD	-1.19E+3	1.863	-2.266	-0.030	-5.796	**-3.120**

Beam Force Detail Summary

Sign convention as diagrams:- positive above line, negative below line except Fx where positive is compression. Distance d is given from beam end A.

				Axial	Shear		Torsion	Bending	
	Beam	L/C	d (mm)	Fx (kN)	Fy (kN)	Fz (kN)	Mx (kNm)	My (kNm)	Mz (kNm)
Max Fx	176	2:WIND LOAD	0.000	**1.18E+3**	0.695	-0.667	-0.028	1.569	0.615
Min Fx	157	2:WIND LOAD	0.000	**-1.19E+3**	-0.881	-0.688	0.115	1.625	-0.841
Max Fy	175	2:WIND LOAD	0.000	-1.19E+3	**1.863**	2.266	0.030	-1.009	2.473
Min Fy	194	2:WIND LOAD	0.000	1.18E+3	**-1.577**	1.062	-0.015	-0.915	-2.240
Max Fz	316	2:WIND LOAD	0.000	4.389	0.224	**11.803**	0.020	-14.673	0.409
Min Fz	381	2:WIND LOAD	0.000	4.388	-0.225	**-11.803**	-0.020	32.540	-0.489
Max Mx	157	2:WIND LOAD	0.000	-1.19E+3	-0.881	-0.688	**0.115**	1.625	-0.841
Min Mx	1	2:WIND LOAD	0.000	-1.19E+3	-0.881	0.685	**-0.115**	-1.616	-0.841
Max My	314	2:WIND LOAD	4.67E+3	31.559	0.124	10.333	0.013	**33.095**	-0.251
Min My	388	2:WIND LOAD	0.000	-24.124	-0.386	5.250	-0.008	**-21.243**	-1.194
Max Mz	157	2:WIND LOAD	4.01E+3	-1.19E+3	-0.881	-0.688	0.115	-1.132	**2.691**
Min Mz	19	2:WIND LOAD	3E+3	-1.19E+3	1.863	-2.266	-0.030	-5.796	**-3.120**

Reaction Summary

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
Max FX	1	1:SELF WEIGI	**2.653**	43.005	2.653	-0.442	0.000	0.442
Min FX	78	2:WIND LOAD	**-212.198**	-1.31E+3	68.225	-4.856	20.161	13.216
Max FY	21	2:WIND LOAD	-210.413	**1.31E+3**	58.868	0.362	3.598	-0.317
Min FY	1	2:WIND LOAD	-211.672	**-1.31E+3**	-68.817	4.848	-20.160	13.209
Max FZ	78	2:WIND LOAD	-212.198	-1.31E+3	**68.225**	-4.856	20.161	13.216
Min FZ	1	2:WIND LOAD	-211.672	-1.31E+3	**-68.817**	4.848	-20.160	13.209
Max MX	1	2:WIND LOAD	-211.672	-1.31E+3	-68.817	**4.848**	-20.160	13.209
Min MX	78	2:WIND LOAD	-212.198	-1.31E+3	68.225	**-4.856**	20.161	13.216
Max MY	78	2:WIND LOAD	-212.198	-1.31E+3	68.225	-4.856	**20.161**	13.216
Min MY	1	2:WIND LOAD	-211.672	-1.31E+3	-68.817	4.848	**-20.160**	13.209
Max MZ	78	2:WIND LOAD	-212.198	-1.31E+3	68.225	-4.856	20.161	**13.216**
Min MZ	21	1:SELF WEIGI	-2.653	43.005	2.653	-0.442	-0.000	**-0.442**

Failed Members

There is no data of this type.