RE-CONDUCTORING OF TRANSMISSION LINES TO INCREASE CAPACITY

Ramjee Kuberalingam

(119135A)

Degree of Master of Science

Department of Electrical Engineering

University of Moratuwa
Sri Lanka

July 2016

RE-CONDUCTORING OF TRANSMISSION LINES TO INCREASE CAPACITY

A thesis submitted to the

Department of Electrical Engineering, University of Moratuwa
in partial fulfillment of the requirements for the

Degree of Master of Science

Ramjee Kuberalingam

Supervised by:

Prof. H. Y. Ranjith Perera

Department of Electrical Engineering

University of Moratuwa, Sri Lanka

DECLARATION

The work submitted in this thesis is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

Ramjee K

(Candidate)

April 4, 2016

I endorse the declaration by the candidate.

Prof. H. Y. Ranjith Perera

(Supervisor)

Acknowledgement

Many thanks are due first to my supervisor, Prof. H. Y. Ranjith Perera, for his great insights, perspectives and guidance throughout the entire duration of the study.

Author extends his sincere gratitude Prof. N. Wickramarachchi, Head of the Department of Electrical Engineering, for providing him the Research Assistantship and excellent assistance during the study period.

Sincere thanks are also due to the officers in Post Graduate Office of the Faculty of Engineering, University of Moratuwa for helping in various ways to clarify the things related to academic works in time with excellent cooperation and guidance. Thanks are also due to the staff of the Department of Electrical Engineering for the support extended during the study period. Also, I wish to gratefully acknowledge the assistance extended by Mr. Anuruddha Tilakaratne, Project Manager, Ceylon Electricity Board.

I would also like to acknowledge with much appreciation to Mr R.C.V. Kumara, Civil Engineer, Ceylon Electricity Board, Mr. S.M.D Senerath., Senior Design Engineer, LTL Projects and Mr GR Kodikara, Electrical Engineer, Ceylon Electricity Board who gave assistance in PLS Tower software the valuable advices and friendly help for this research to end up with efficient result.

Many thanks are also due to many individuals, friends and colleagues who have not been mentioned here by name in making this educational process as success. Lastly, I would like to express my heartiest gratitude and love to my parents, my daughter and wife, who took a lot of burden and patience, helping me to complete this work in difficult circumstances.

Abstract

Electric power consumption, is increasing rapidly, showing growth faster growth in the last few decades. To meet the increase in demand of electricity the expansion of transmission networks is needed all over the country. In Sri Lanka most of the electric lines are saturated, they are reaching critical values of capacity and sag. Therefore, building new lines is necessary to provide the ever increasing consumption. The difficulty to find line route and environmental issues limited the construction of new overhead lines. Therefore, there is an urgent need to find out some alternatives that increases the power transfer capacity of the existing lines. This circumstance is forcing the use of the existing lines, which represents a cheaper solution compared underground transmission for countries like Sri Lanka.

This research study is focused on finding facts to replace the conductor by a high current capacity one. In this study, a suitable alternative method is proposed for existing transmission lines comprising zebra conductors. In order to evaluate the potential benefits of re conducting of a transmission network a holistic computational methodology is used. This allows sag, capacity and tension calculations to be carried out for each section of selected transmission line.

Further, PLS -Tower and PLS – CADD software is used to analyze usage of various high current rating conductors in the market with the new technologies. Tower loads due to wind, weight of the conductor etc.. are calculated and loaded to the existing towers to check the strength.

The proposed technique can be used to analyze the tower strength to replace high current capacity conductors. The same can also be used as a powerful method at planning stage at the new transmission line projects.

TABLE OF CONTENTS

List of Figures

List of Tables

List of Abbreviations

BS – British Standards for Design and Construction

CEB - Ceylon Electricity Board

ISO – International Organization for Standardization

OPGW – Optical Fibre Ground wire

PLS – Power Line System software

TDL - Tower Double circuit Line

TD1 - (Tower Double circuit –Deviation angle 0°- 10°)

TD3 - (Tower Double circuit –Deviation angle 10°- 30°)

TD6 - (Tower Double circuit –Deviation angle 30°- 60°)

TDT - (Tower Double circuit Terminal)

WS– Wind span

For Earth wire (OPGW)

- Ne –Numbers
- De (mm) - Diameter
- We (kN/m) - Weight
- Te (kN) – Tension
- Pe (kN/m^2) – Wind pressure

List of Appendices

1. INTRODUCTION

1.1 Background

Power Transmission from Generating Station to Substations (Grid) is the fundamental objects of the Power System. This function is accomplished by overhead transmission lines that connect the power plants into the distribution networks in Sri Lanka.

The growing demands on the dynamic capacity of transmission system and utilities in Sri Lanka are looking costly. The construction of new transmission line essential to cater reliable supply of electricity and meet the growing demand in each provinces in the country. The construction of new transmission line require additional land, environmental issues, project implementation period also relatively high. The cost of new transmission line construction includes cost of towers, conductor, insulators, hardware and the cost of land covered by the tower foundation. Also environmental clearance from the government, stating that there are no objections on environmental issues in the particular transmission line project needs to be submitted to the funding agency when looking for funds.

Therefore we need to come across the solution how the existing lines can be utilized more efficiently. In this regard, several alternative way to increase the power transfer capacity of an existing Transmission line, such as , convert it from AC to DC transmission system, Consider the Voltage upgrading mechanism, replace the conductor by a high current capacity one without modifying the existing towers, line accessories etc… Hence, AC to DC conversion system need total modification in the Grid substation and suitable for long transmission line system and other hand the Voltage upgrading mechanism also require the modification in the Grid Substation as well as Transmission Line that imply more cost and time. Therefore, Re-conductoring of Transmission Line by substituting a high current carrying conductor is the relatively best option for countries like Sri Lanka while considering the electromechanical properties of the particular transmission line.

1.2 Objectives

The construction of new transmission lines to transfer more power from the Generating Station to Substations (Grid) need large extent of land, substance amount of steel and foundation cost, consume more time for construction works and etc.., which cause to the high cost to the supply providers. In addition to the high cost a number of indirect impediments are encountered in implementing of the projects with the current design of towers such as objection by land owners and environmentalists where the transmission lines running through urban areas. Therefore, it becomes essential to increase current carrying capacity of the existing transmission line with the optimum cost in this study. In this case I used low loss conductor to substitute the existing one.

1.3 Case Study

This case studies have been carried out by modeling the existing 132kV transmission lines currently in operation in 132kV Vavuniya to Kilinochchi transmission line (Zebra conductor with the nominal current rating of 760 A @ 75° C) and 132kV Anuradhapura to Vavuniya transmission line (Lynx conductor with the nominal current rating of 450 A @ 75° C). This achieved by using computer software's PLS-Tower and PLS-CADD.

Five different spans form each transmission lines are selected for this study. The existing tower architecture and profile survey were used to configure the additional load of the larger current rating conductors for the safety of the towers and the electrical clearances. The details are given in the Appendix A and B.

1.4 Methodology

Earlier the design of transmission line was made as per design philosophy based on deterministic concept of Loadings and strengths with specified factors of safety for the different operating conditions. Now the design of transmission line is made as per design philosophy based on probabilistic concept of Loadings and strengths with specified factors of safety for the different operating conditions. Further the design must consider the optimum utilization of the transmission towers because those are constituting about 30-40 percent of the cost of transmission line.

This case study is based on data obtained by reviewing the existing tower literature on different design of transmission towers and comparing the cost of manufacture and other social and practical implication of existing design with the proposed design. In this study the proposed large current rating conductors manufacturing data used to analyze the tower by using the computer software called PLS-Tower and profile design of selected spans has been achieved by the software called PLS-CADD.

2.0 DESIGN ASPECTS OF A 132kV TRANSMISSION LINE

2.1 Applicable Standards

Following standards are used in this study.

- ANSI/ASCE 10-97 –Design of Latticed steel transmission structures
- ISO 898–1 –Mechanical properties of fasteners. Part 1-Bolts, screws and studs.
- ISO 630 – Structural Steels – plates, wide flats, bars, sections and profiles
- ISO 1459 – Metallic coatings – Protection against corrosion by Hot Dip Galvanizing.
- ISO 7411 – Hexagon Bolts for high strength structural bolting with large width across flats.
- ISO 657– 5 – Hot rolled structural steel sections equal and unequal leg angles.

Basically Transmission Line Design comprise the followings.

1. Sag-Tension calculation
2. Tower Design
3. Wind Span Vs Angle of Deviation
4. Creep Calculation
5. Profile Design

2.2 132kV Tower Design

Tower design is one of the most important factors for reliable operation and lifetime of a transmission line. The tower of various shapes is being used with increasing environmental concern and the public becoming more and more conscious of the detrimental effects of transmission line towers on the environment and land use. In Ceylon Electricity Board (CEB) transmission system there are three types of towers.

a) Suspension Tower
b) Tension Tower
c) Transposition Tower

2.2.1 Suspension Tower

These towers are used on the lines for straight run or for small angle of deviation up to 2° or 5°. Conductor on suspension towers may be supported by means of I-string in CEB transmission System. In double circuit transmission lines this types of towers are called TDL towers.

2.2.2 Tension Tower

Tension towers also known as angle towers are used at locations where the angle of deviation exceeds that permissible on suspension towers and/or where the towers are subject to uplift loads. These towers are further classified as

Up to 10^o angle deviation TD1

10^o - 30^o angle deviation TD3

30^o- 60^o angle deviation TD6

Terminal tower (more than 60^o of angle of deviation) TDT

Those towers are used according to the angle of deviation of line. One of the classes of angle towers depending on the site conditions is also designated as Section Tower. The section tower is introduced in the line after certain distance to avoid cascade failure or series failure of towers.

2.2.3 Transposition Tower

Transposition towers are used to transpose the phase conductors in three sections in such a way that each phase by rotation occupies each of the three phase positions in a circuit.

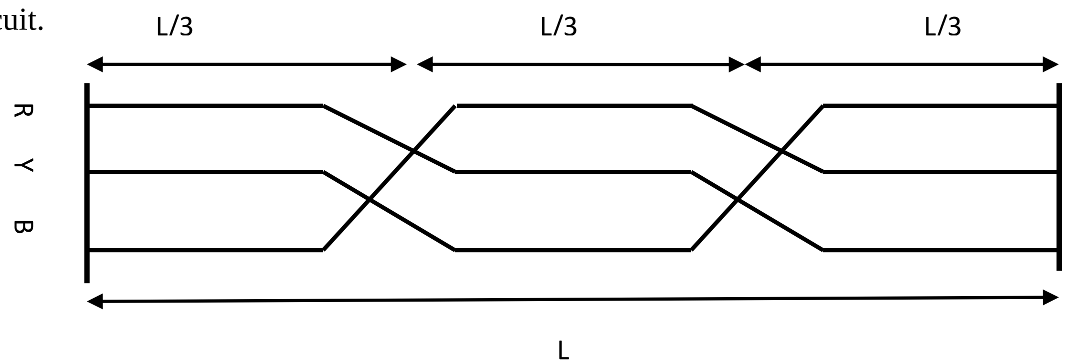


Figure 2.2.3: Transposition

2.2.4 Tower Extensions (Leg or Body Extensions)

Body extension is used to increase the height of tower (3m, 6m, 9m, and 12m) with a view to obtaining the required minimum ground clearance over road crossing, river crossings, power line crossings, ground obstacles etc. For body extensions having greater heights more than 25m, the suitability of the standard tower is checked by reducing the span length and angle of deviation. Leg extensions are used either with anyone leg or any pair of legs at locations where footings of the towers are at different levels. Leg extensions are generally used in hilly regions to reduce benching or cutting. Leg extensions of –2m, -1m, +1m, +2m, and +3m also used where necessary.

2.2.5 Tower structure

Tower structure is fixed from the requirement of minimum ground clearance, terrain type, right of way limitation, electrical clearances etc. Tower structure is defined in terms of the following parameters.

Tower Height

- Minimum ground clearance
- Maximum sag of conductor
- Length of suspension insulator string assembly
- Vertical spacing between power conductors
- Location of ground wire
- Angle of shield
- Minimum mid span clearance

Cross Arm Spread

- Length of insulator string assembly
- Length of the insulator
- Tension string
- Jumper Suspension string
- Swing angle
- Conductor jumper

- Phase to phase horizontal spacing
- Bundle Conductor configuration

2.2.6 Insulator Swing Angle

At the heavy wind condition suspension insulators swing with certain angle. If we consider a double circuit line one circuit swings away from the tower and one is towards the tower. Then the line clearance gets reduced. Therefore, it is important to consider swing angle during the design. The factors effects to swing angle is length of the insulator set, Wind force, weight span, wind span, conductor type, Insulator type, etc.

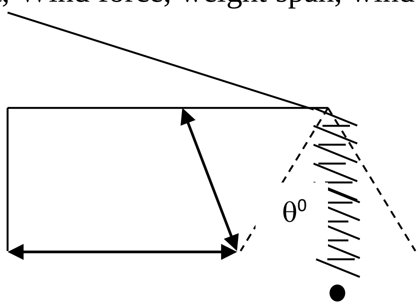


Figure 2.2.6 : Insulator Swing Angle

2.2.7 Arching Horn Gap

This is very important in connection with lightning protection. This mainly depends on air breaking voltage and the pollution level of the area. Normal air breaking voltage is 21kV/cm at the clear air. For 132kV transmission line the Arching Horn Gap is calculated for the impulse voltage of 800kV.

2.2.8 Overhead Earth and Shielding Angle

Double earth wire configuration towers are erected in areas of high lightning activity, or with supporting structures with wide horizontal spacing configurations, two earth wires were provided to permit a lower shielding angle and superior protection. The tower height reduce by the use of double earth configurations. Shielding angle of the double earth configuration is almost 0 degree. In this case more critical in the mid span clearance of the conductors.

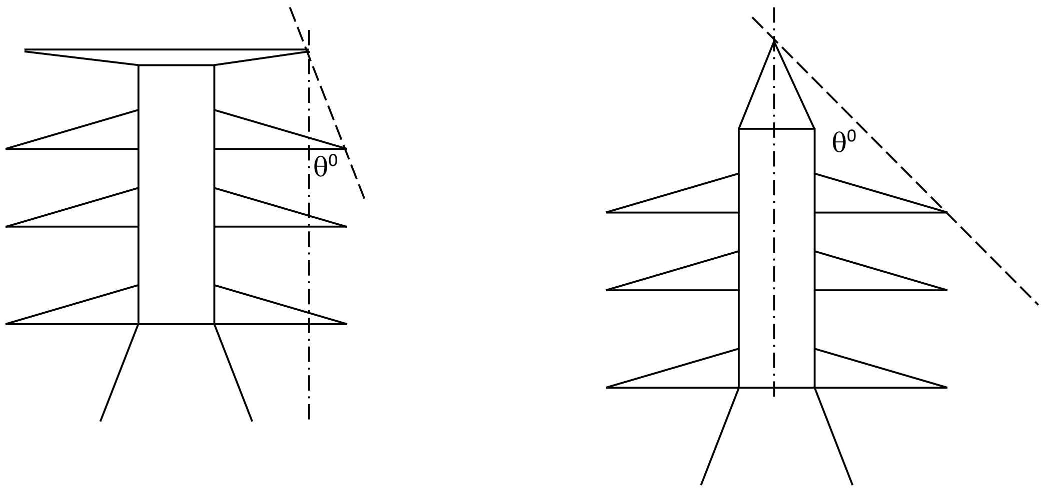


Figure 2.2.8 : Overhead Earth and Shielding Angle

The design of a transmission line tower is distinctly classified into Mechanical design and Electrical design. Electrical clearance between live parts to metal parts is to be considered while designing the tower. For checking the clearance, swing angle of insulator (for suspension towers) and swing angle of jumper (for tension towers) is required, Sample electrical clearance diagram for suspension tower, tension tower and swing angle calculation as per the CEB Technical Specifications are attached as Appendix-C.

2.2.9 Basic Span

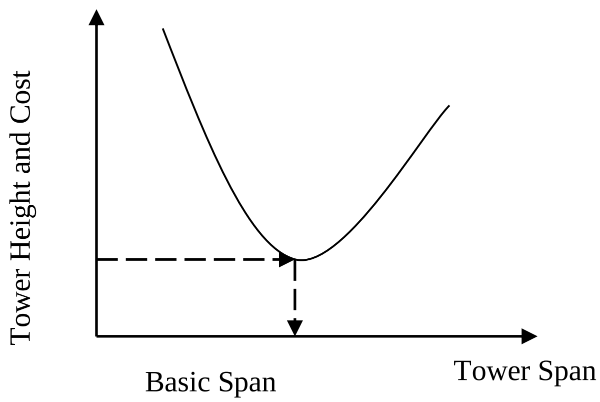


Figure 2.2.9 : Basic Span

Basic span for a 132kV Transmission line is 300m.

2.2.10 Equivalent Span or Ruling span

Equivalent span calculates for a particular section. It considersall the spans in a section. This varies from section to section.

$$\text{Eq. Span} = \sqrt{\frac{l_1^3 + l_2^3 + l_3^3}{l_1 + l_2 + l_3}}$$

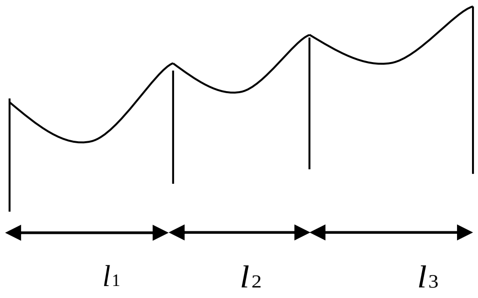


Figure 2.2.10: Equivalent Span or Ruling span

2.2.11 Wind Span

Wind span for a particular tower is half of a sum of adjacent spans. The wind force act on the tower due to conductor section represents by multiplying wind span by wind force act on the unit length of the conductor.

$$\text{Wind Span} = \frac{l_1 + l_2}{2}$$

2.2.12 Weight Span

The weight span is the equivalent length of the weight of conductor supported at any one tower at minimum temperature in still air. At suspension positions the minimum weight of conductor, inclusive of weights where used.

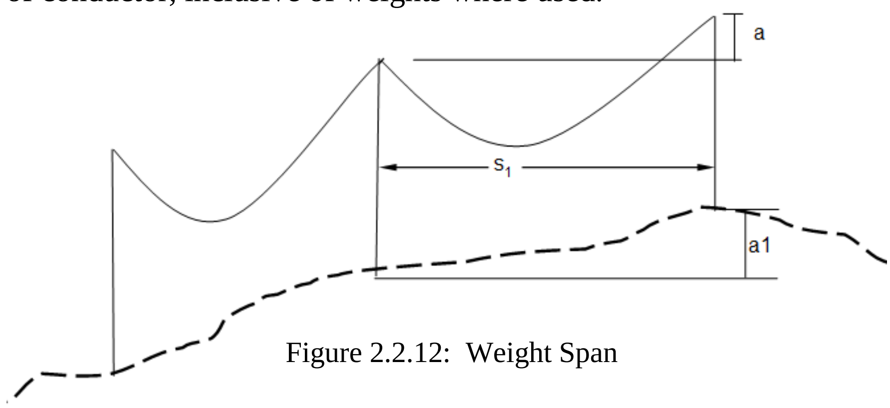


Figure 2.2.12: Weight Span

$$Weight\ Span = \frac{S_1}{2} + \left(\frac{T_1}{w}\right)\left(\frac{h}{S_1}\right)$$

Where T_1 Tension of conductor at required temperature

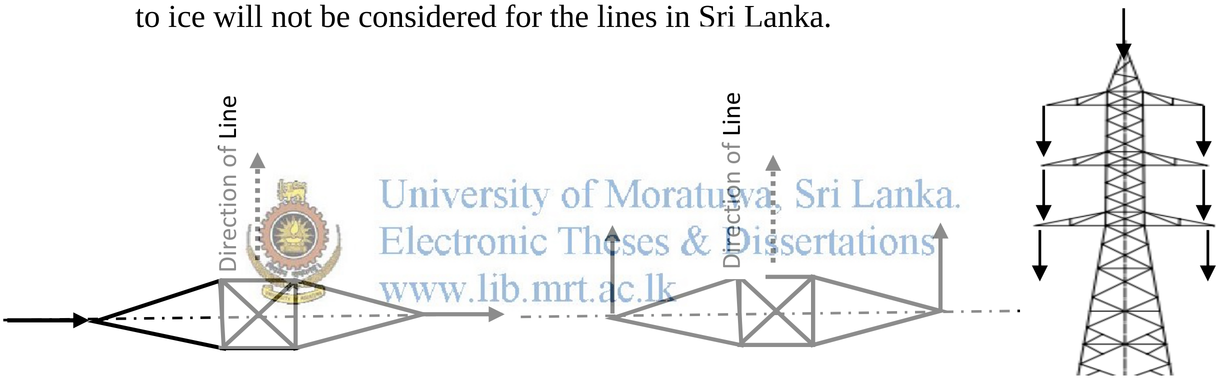
w unit weight of the conductor

S_1 Span

h_1 Level deference between towers

2.3 Loading on Tower (Suspension Tower - TDL)

The following parameters were used to calculate the force acting on a transmission tower as per the CEB technical specifications and the conductor, Earthwire and insulator manufacturers specifications are attached as Appendix-D. Transmission Conductor and Tower are usually subject to the following external forces. Forces due to ice will not be considered for the lines in Sri Lanka.



Transverse Load Longitudinal Load Vertical Load

Figure 2.3: Loading on Tower (Suspension Tower - TDL)

2.3.1 Transverse Load

The following factors produce the Transverse Load on a Tower.

- Component of mechanical tension of conductor , ground wire OPGW and insulator string
- Wind load on tower structure, conductor, ground wire / OPGW

2.3.2 Longitudinal Load

Unbalanced Horizontal loads in longitudinal direction due to mechanical tension of conductor and/or ground wire during Broken wire condition.

In the case of supports with suspension strings may be reduced value of maximum working tension of the conductor in broken wire condition as specified in CEB specification and this value is taken as a 30% reduction in maximum conductor tension.

For the ground wire broken condition, maximum working tension shall be considered for the purpose of design of a tower.

When there is a possibility of the tower being used with a longer span by reducing the angle of line deviation, the tower member needs to be checked for maximum longitudinal and transverse components arising out of the reduced angle of deviation.

2.3.3 Vertical Load

Loads due to weight of each conductor, ground wires based on appropriate weight span weight of insulator strings and hardware fittings.

A provision of 150 kg is made for the weight of a lineman with tools in addition to the vertical loads due to insulators and fittings and dead weight of the structure.

- Dead load of conductor = Unit weight of Conductor (kN/m) × Weight Span (W1+W2)
- Dead load of Tower (Self Weight of Tower)

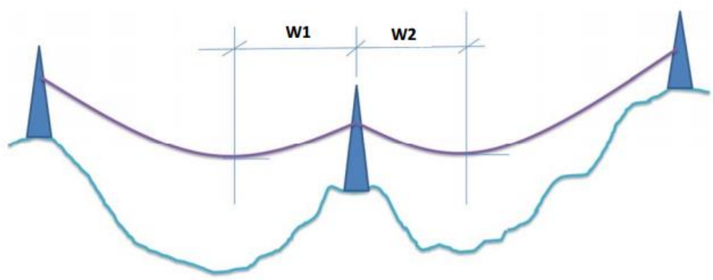


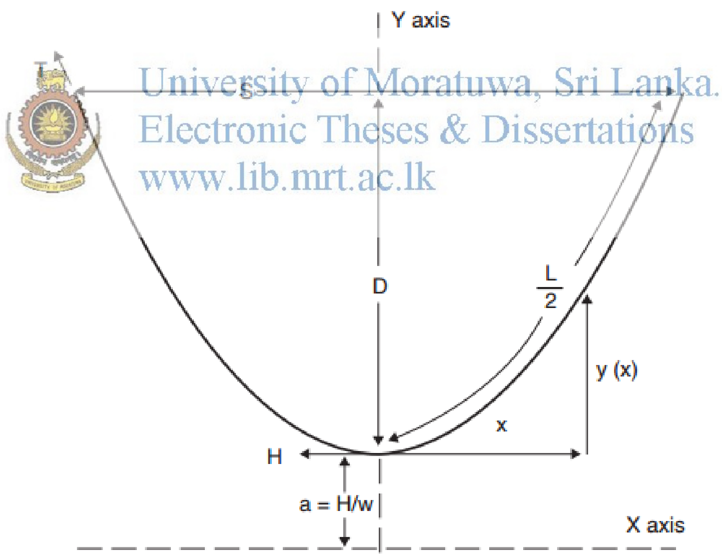
Figure 2.3.3: Vertical Load on a tower

Table 2.3.3: Weight Span of a 132kV Transmission tower according to CEB Specification

Basic Span (m)		300	
Wind Span (m)			
All Towers	Normal Working Condition	360	
	Broken wire condition	270	
Weight Span (m)		Maximum	Minimum
Suspension towers	Normal Working Condition	600	150
	Broken wire condition	450	112.5

2.4 Sag Tension Calculation

$$y(x) = \frac{H}{w}\cosh\left(\left(\frac{w}{H}x\right) - 1\right) = \frac{w(x^2)}{2H}$$



The catenary curve for level spans.

Figure 2.4 Catenary Curve for level spans

Sag Tension Calculation is carried out for both existing conductor (ACSR Zebra - 54/7/3.18) and the proposed conductor Low loss conductors.

Table 2.4.1: Properties of the Conductors and Earthwire

Properties of the Earthwire

Earthwire	**GSW**
Earthwire Size	7/3.25
Overall Diameter of the earthwire (D)	9.8 mm
Area of earthwire (for all strands) (A)	58.07 mm²
Weight of the earthwire (w)	0.46 kg/m
Ultimate breaking strength	58.1 kN
Coefficient of linear expansion	0.0000115 per ^{o} C
Modulus of elasticity (E)	193 kN/mm²

Table 2.4.2 : Properties of the Conductors

Conductor	**Existing (ACSR-ZEBRA)**	**Low Loss ACSR**
Conductor Size	54/7/3.18	-
Overall Diameter of the conductor (D)	28.62 mm	28.62 mm
Area of conductor (for all strands) (A)	484.00 mm²	590.5 mm²
Weight of the conductor with grease (W)	1.6307 kg/m	1.814 kg/m
Ultimate breaking strength	130.32 kN	140.9 kN
Coefficient of linear expansion	0.0000193 per ^{o} C	0.00002 per ^{o} C
Modulus of elasticity (E)	69.00 kN/mm²	71.00 kN/mm²

Span (L) 300m	Existing ACSR Zebra	Proposed Low Loss Conductor
Temperature		
Minimum (T min)	15°C	15°C
Everyday (T)	32°C	32°C
Maximum (T max)	75°C	90°C
Wind Pressure (P)	970 N/m²	970 N/m²
Minimum factor of safety for Conductors and Earthwires based on Ultimate Strength		
At Maximum working tension	2.5	2.5
Everyday Temperature, still air	4.5	4.5

As per the technical specification the proposed low loss conductor can be operated up to 90°C.

The detailed sag tension calculation for the both existing Zebra conductors and proposed conductors are given in the Appendix – C.

2.5 Tower Structure Design

1. Technical requirement of the Transmission Line

I.	Voltage	132kV
II.	Circuit	Double Circuit
III.	Peak	One
IV.	Phase Conductor	Low Loss ACSR and ACSR Zebra
V.	Earthwire	OPGW (D=13.25mm)

2. Wind Pressure — 970N/m² on Conductor and OPGW; 1170 N/m² on Insulator

1640 N/m^2 on Tower Body (1.5 times the projected area of the members of one face of the tower)

3. Span

	Normal Span	300m
	Wind Span	360m for Normal Condition (NC)
		270m for Broken wire Condition (BWC)
	Max. Weight Span	600m (NC) and 450m (BWC)
	Min. Weight Span	150m (NC) and 112.5m (BWC)

4. Conductor Temperature

	Min. Temp	15^{o}C
	Everyday Temp	32^{o}C
	Max. Temp	75^{o}C

5. Conductor Height (Ground Clearance)

   Min height of the phase conductor = 6.7m + 0.3m (Survey error) + Max Sag of the conductor

6. Electrical Clearance

0^o - 10^o	1650mm
10^o - 40^o	1550mm

7. Safety Factors

Tower	Normal Condition	2.0
	Broken wire Condition	1.25
Conductor	Max Working Tension	2.5
	Everyday Temp	4.5

Note: Following Load Calculations are carried out as per the Transmission Line Structures By SS Murthy and AR Santhakumar

Normal Conduction (Min.Temp- Full Wind)

		Normal Conduction	
		Max Wt	**Min Wt**
For Earth Wire(OPGW)			
Transverse Loads			
Win Load on Earthwire	Ne*De*Swnnc*Pe*Sin(90)^2*F1	472	472
Due to Deviation	Ne*Te*Sin(θ2/2)^2*F1	0	0
	Total	**472**	**472**
Vertical Loads			
Weight of Earthwire	Ne*We*Swtnc*F1	271	68
	Total	**271**	**68**
Longitudinal Loads		0	0
For Conductor (ACSR/ZEBRA)			
Transverse Loads			
Wind Load on Conductor	Nc*Dc*Swnnc*Pc*Sin(90)^2*F1	1020	1020
Win Load on Insulator	0.5*Ni*Di*Pi*F1	31	31
Due to Deviation	Nc*Tc*Sin(θ2/2)^2*F1	0	0
	Total	**1051**	**1051**
Vertical Loads			
Weight of Conductor	Nc*Wc*Swtnc*F1	979	245
Weight of Insulator	Ni*Wi*F1	70	70
	Total	**1049**	**315**
Longitudinal Loads		0	0

Broken Wire Conduction (Min.Temp- Full Wind)

		Broken Wire Conduction	
		Max Wt	**Min Wt**
For Earth Wire(OPGW)			
Transverse Loads			
Win Load on Earthwire	Ne*De*Swnbwc*Pe*Sin(90)^2*F2	354	354
Due to Deviation	Ne*Te*Sin(θ2/2)^2*F2	0	0
	Total	**354**	**354**
Vertical Loads			
Weight of Earthwire	Ne*We*Swnbwc*F2	203	51
	Total	**203**	**51**
Longitudinal Loads			
	Ne*Te*Cos(θ1/2)F2	2193	2193
	Total	**2193**	**2193**
For Conductor (ACSR/ZEBRA)			
Transverse Loads			
Win Load on Conductor	Nc*Dc*Swnbwc*Pc*Sin(90)^2*F2	765	765
Win Load on Insulator	0.5*Ni*Di*Pi*F2	31	31
Due to Deviation	Nc*Tc*Sin(θ2/2)^2*F2	0	0
	Total	**796**	**796**
Vertical Loads			
Weight of Conductor	Nc*Wc*Swtbwc*F2	734	183
Weight of Insulator	Ni*Wi*F2	70	70
	Total	**804**	**253**
Longitudinal Loads			
	0.7*Nc*Tc*Cos(θ1/2)F2	3677	3677
	Total	**3677**	**3677**

Swnnc	Standard Wind Span in Normal Conduction
Swtnc	Standard Weight in Normal Conduction
Swnbwc	Standard Wind Span in Broken Wire Conduction

2.6 Electrical Clearance Diagram of 132kV Transmission Tower

The Electrical Clearance Diagram of 132kV Transmission Tower is given in the Appendix – D.

2.7 Wind Load on Tower

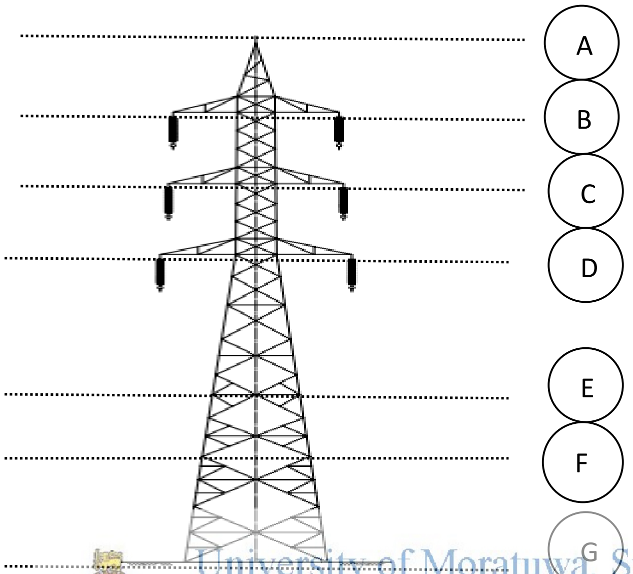


Figure 2.7: Wind Load on Tower

Note: Wind pressure on tower = 1640 N/m^2 = 167kg

Table 2.7: Wind load on a TDL single peak tower

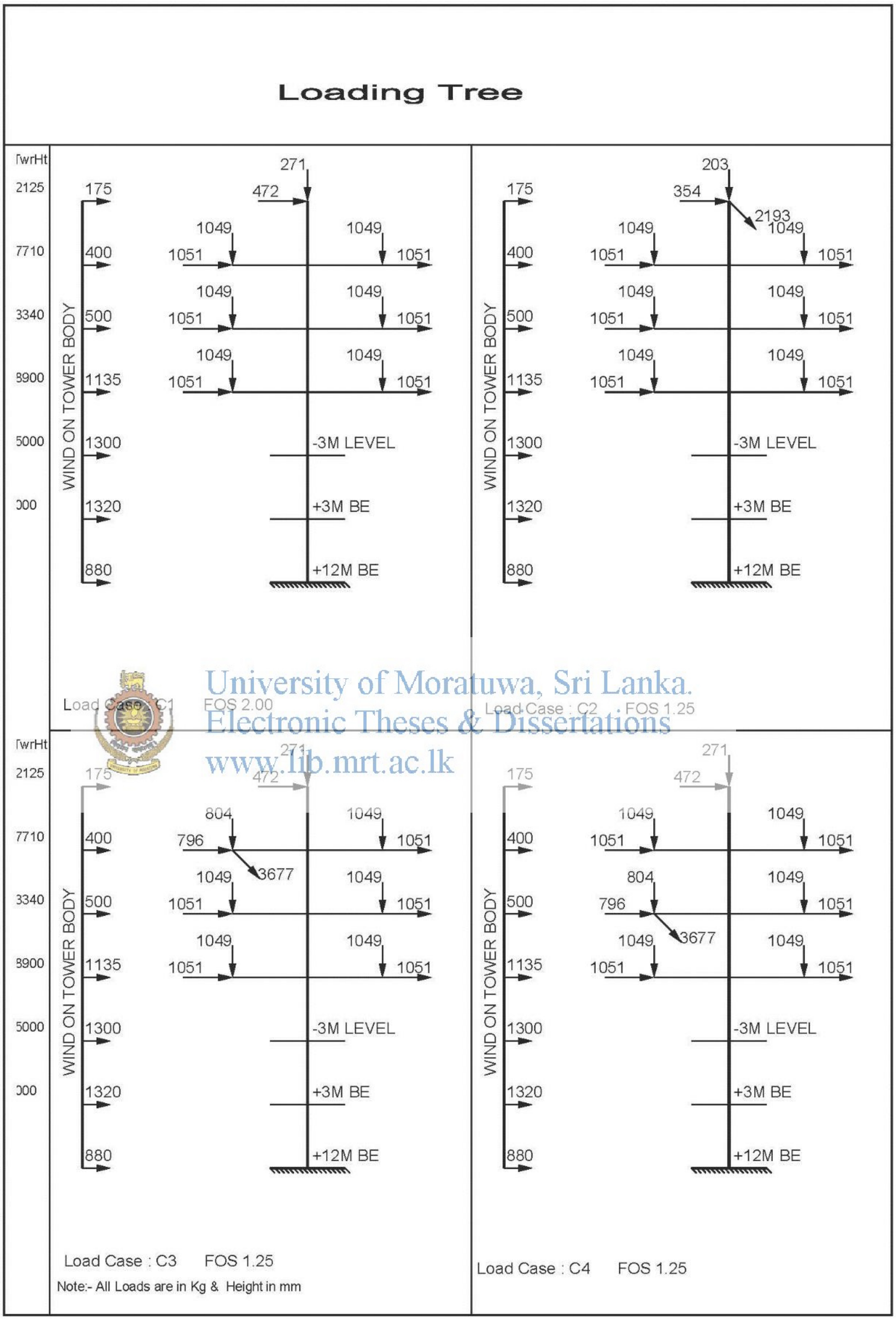
Description	Net Area (m^2)	Wind Pressure (kg/m^3)	Coefficient as per the Specification	Actual Wind (kg)	Distribution (kg)	Applied (kg)
A- B	1.353	167	1.5	339	170	175
					170+221	400
B- C	1.766	167	1.5	443		
					221+267	500
C- D	2.130	167	1.5	534		
					267+842	1135
D- E	6.712	167	1.5	1684		
					842+430	1300
E- F	3.434	167	1.5	861		
					430+861	1320
F- G	6.870	167	1.5	1723		
					862	880

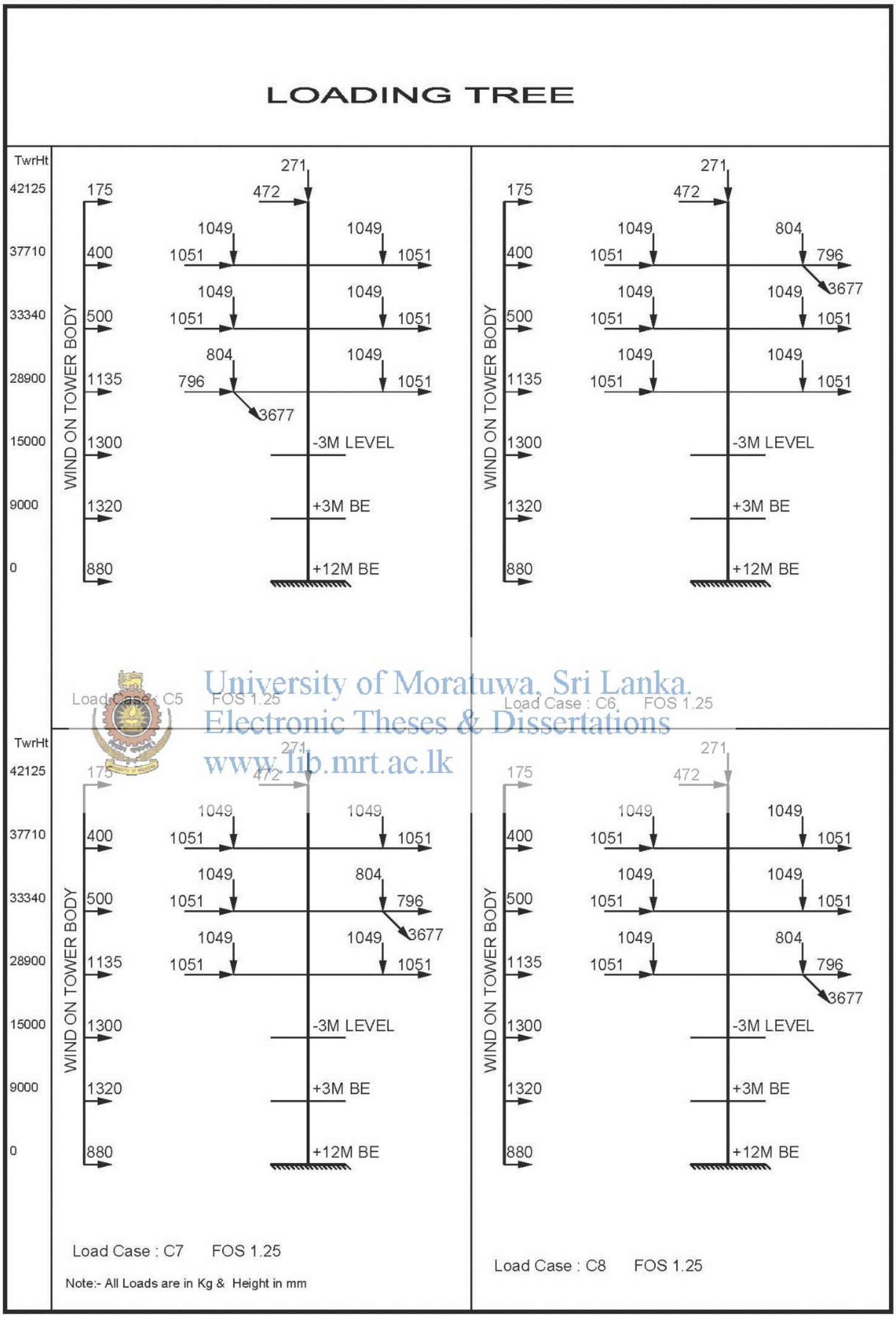
Applied Load is calculated 2% higher than the actual distribution load (Additional safety factor to cover Name, Joint plate areas). Net area of the tower is calculated from the members used and the detail drawing with the member dimensions are attached as Appendix – E.

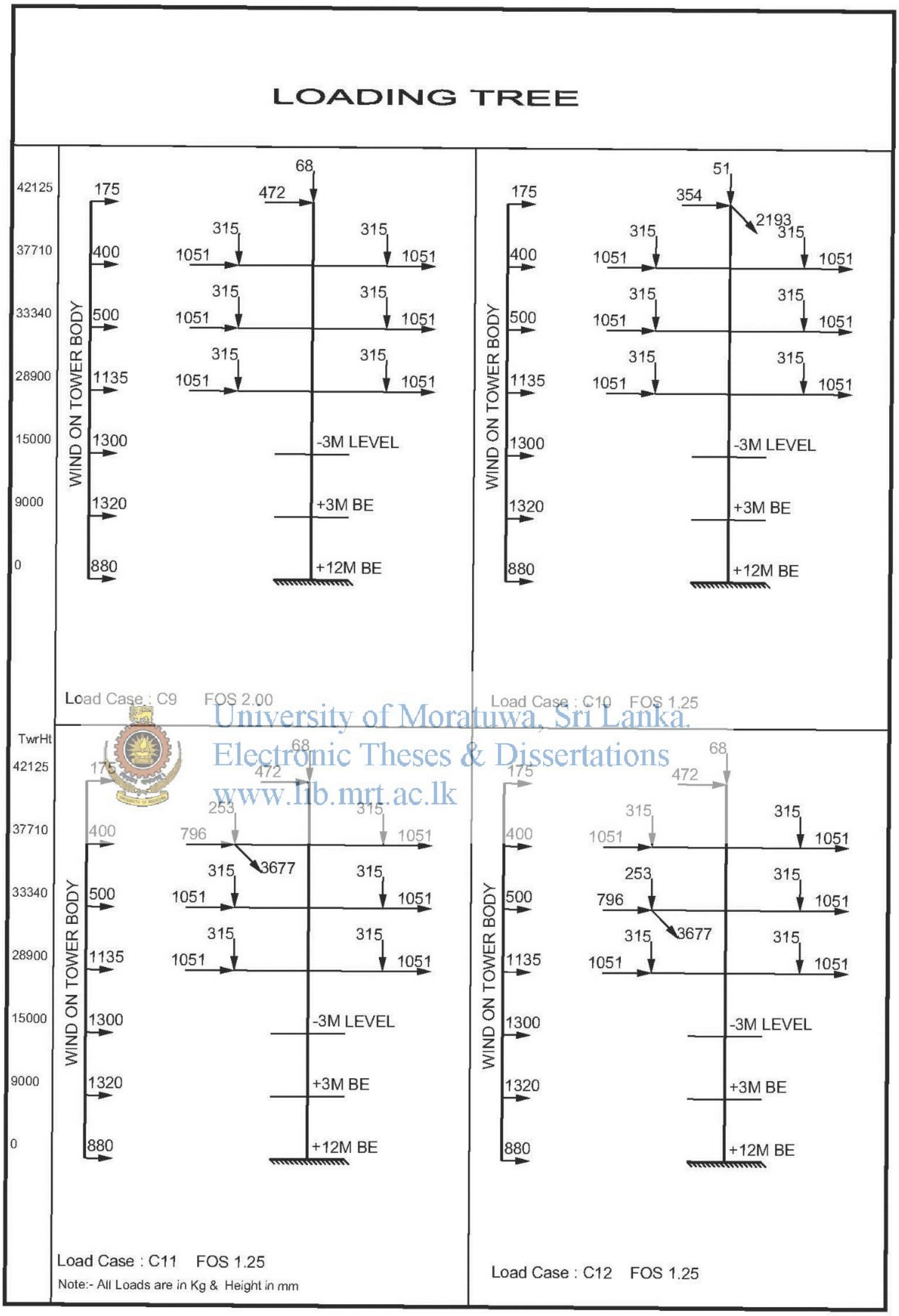
As per the load calculated above the loading trees were draw for the Normal and Broken wire Conditions. Total 18 different cases have been analyzed the detailed analyzed are as follows.

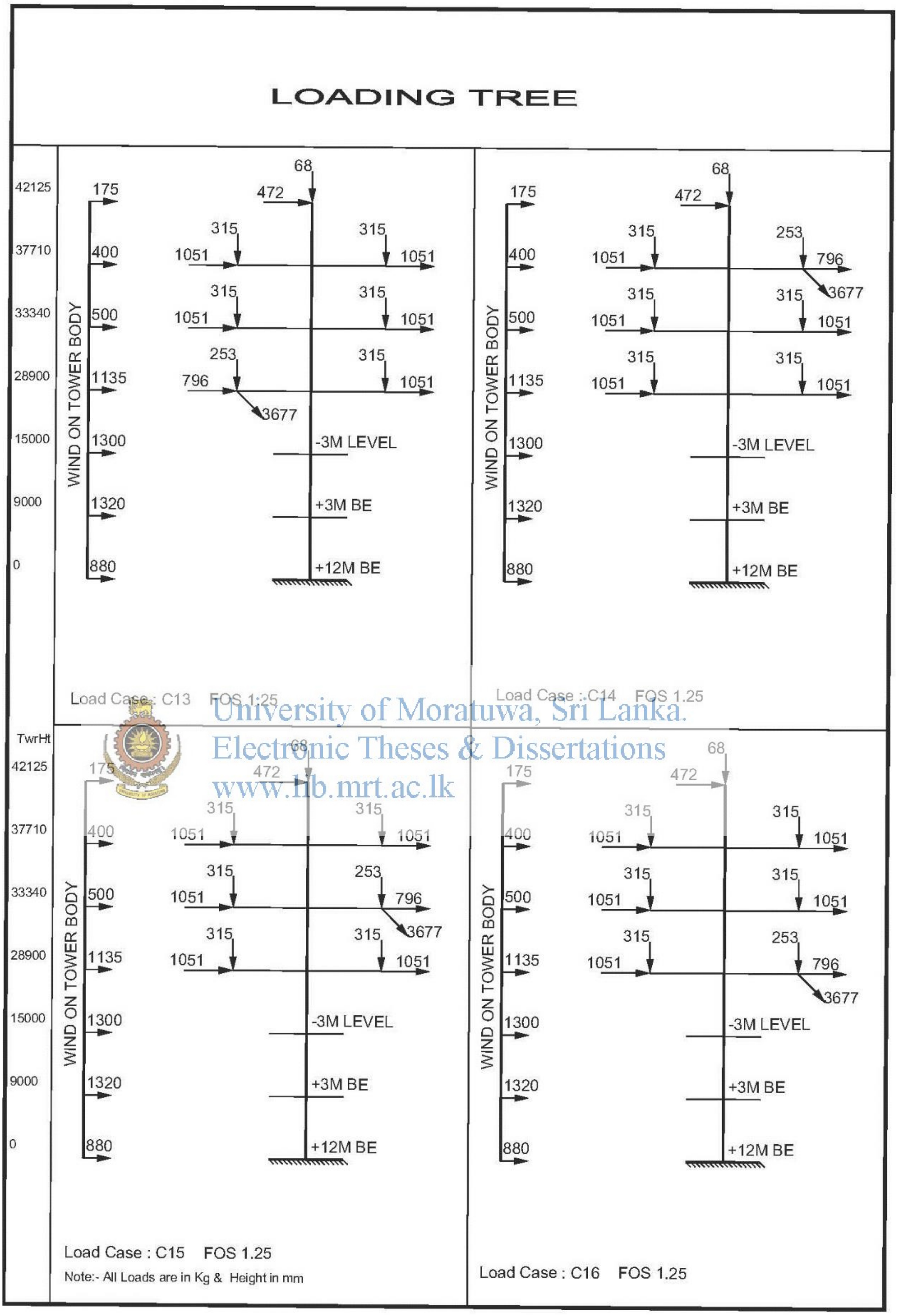
In order to ensure the additional safety Drag coefficient is not considered
(or taken as 1).

2.8 Load Showing on Tree Diagram for Each Case

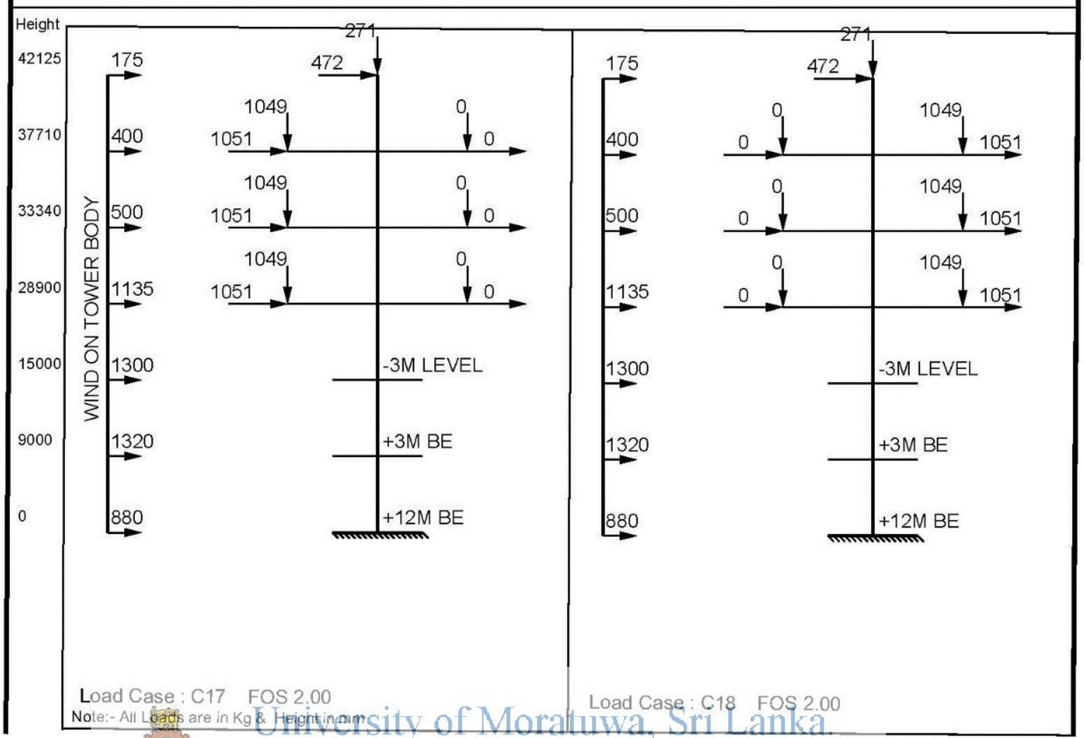



LOADING TREE
TwrHt
42125
37710
33340
28900
15000
9000
0
WIND ON TOWER BODY
175
400
500
1135
1300
1320
880
271
472
1049
1051
804
796
3677
-3M LEVEL
+3M BE
+12M BE
Load Case : C5 FOS 1.25
Load Case : C6 FOS 1.25
Load Case : C7 FOS 1.25
Note:- All Loads are in Kg & Height in mm
Load Case : C8 FOS 1.25


LOADING TREE
WIND ON TOWER BODY
TwrHt
42125
37710
33340
28900
15000
9000
0
175
400
500
1135
1300
1320
880
-3M LEVEL
+3M BE
+12M BE
Load Case : C9 FOS 2.00
Load Case : C10 FOS 1.25
Load Case : C11 FOS 1.25
Load Case : C12 FOS 1.25
Note:- All Loads are in Kg & Height in mm


LOADING TREE
TwrHt
42125
37710
33340
28900
15000
9000
0
WIND ON TOWER BODY
175
400
500
1135
1300
1320
880
68
472
315
1051
253
796
3677
-3M LEVEL
+3M BE
+12M BE
Load Case : C13 FOS 1.25
Load Case : C14 FOS 1.25
Load Case : C15 FOS 1.25
Note:- All Loads are in Kg & Height in mm
Load Case : C16 FOS 1.25

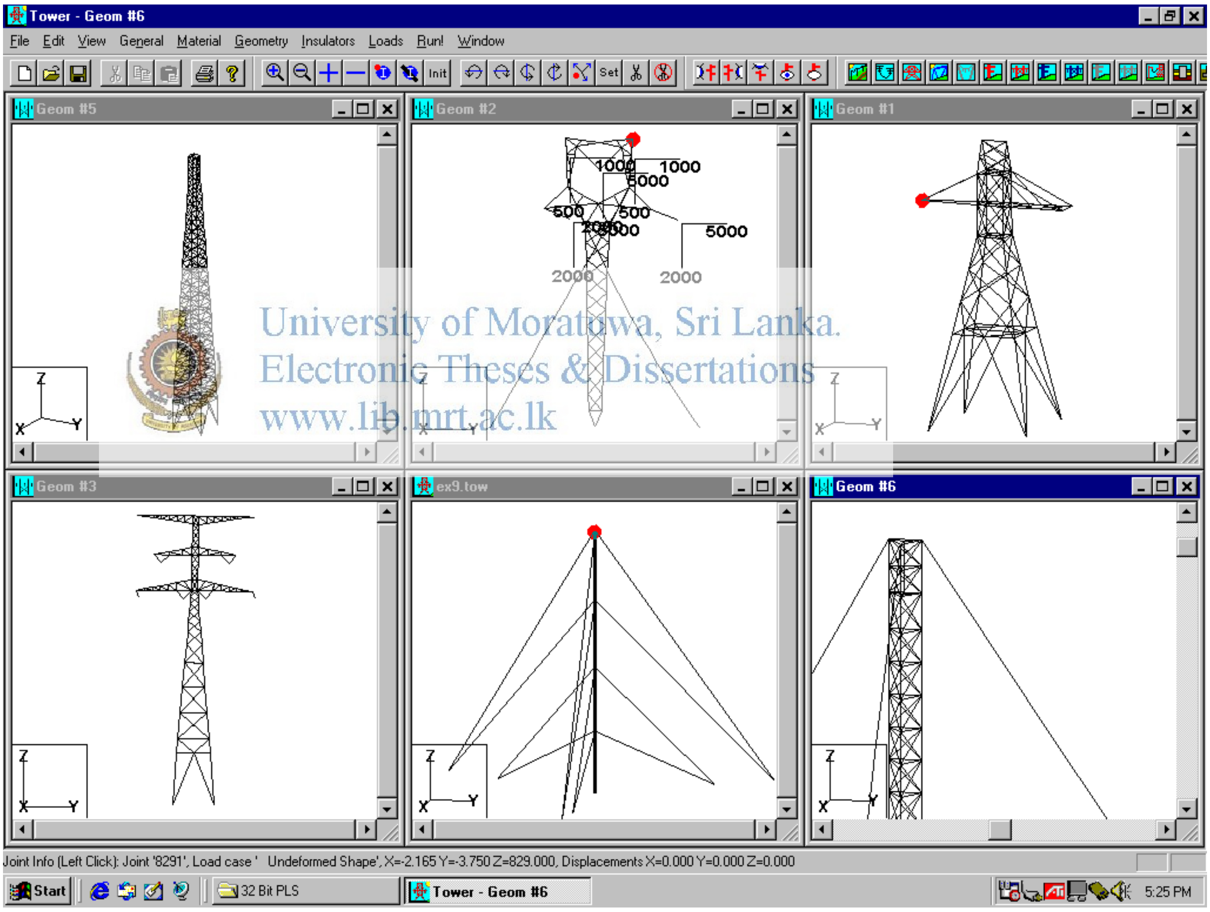
LOADING TREE



3.0 SOFTWARE USED FOR STRUCTURAL ANALYSIS AND MODELING

PLS-TOWER is the modeling MS-WINDOWS based software developed by Power Line Systems for the analysis and design of transmission structures. All these programs have many features in common. It is now used by hundreds of organizations in over eighty countries and is probably the most widely used tower program in the world.

PLS-TOWER deals with the analysis and design of steel latticed towers.



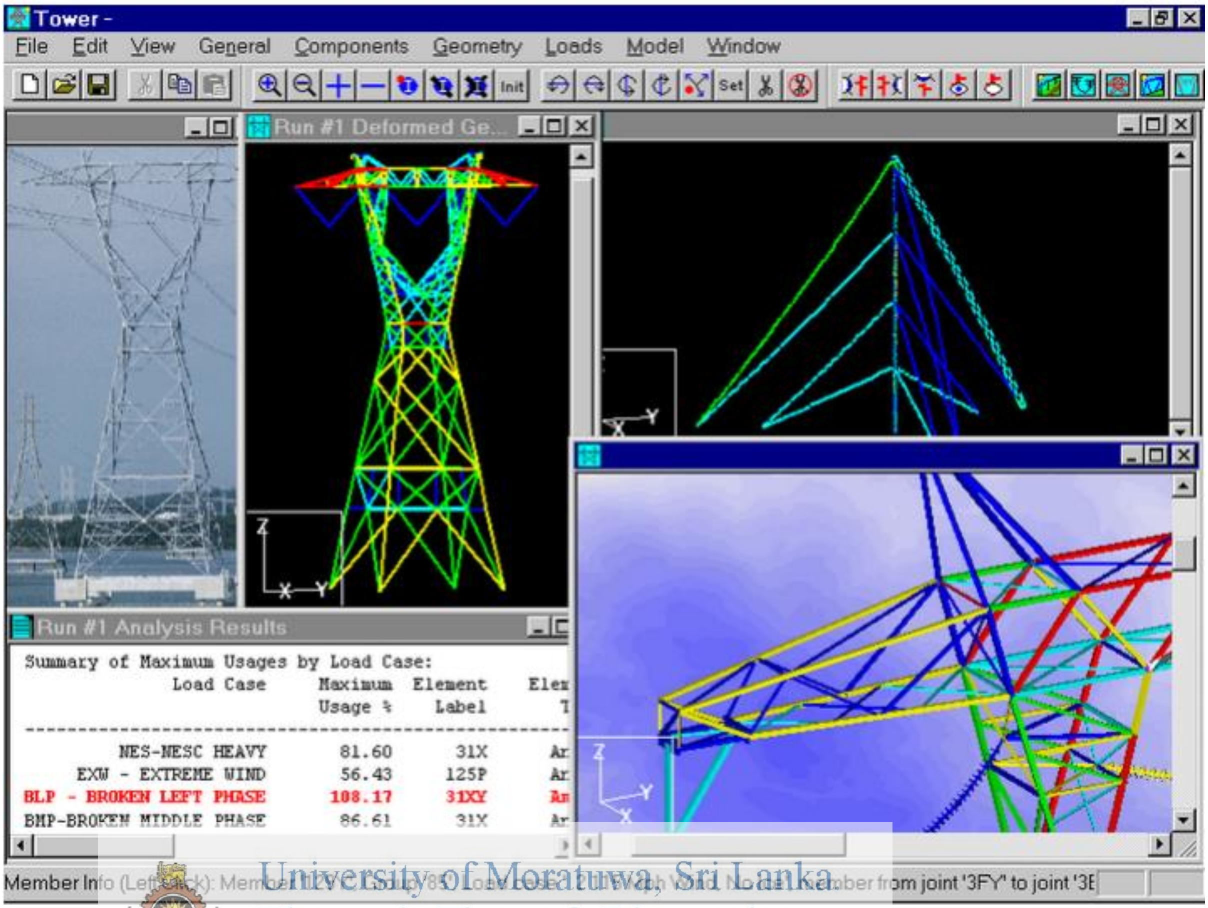


Figure: 3.0 shows typical transmission towers configurations which can be modeled with PLS-TOWER.

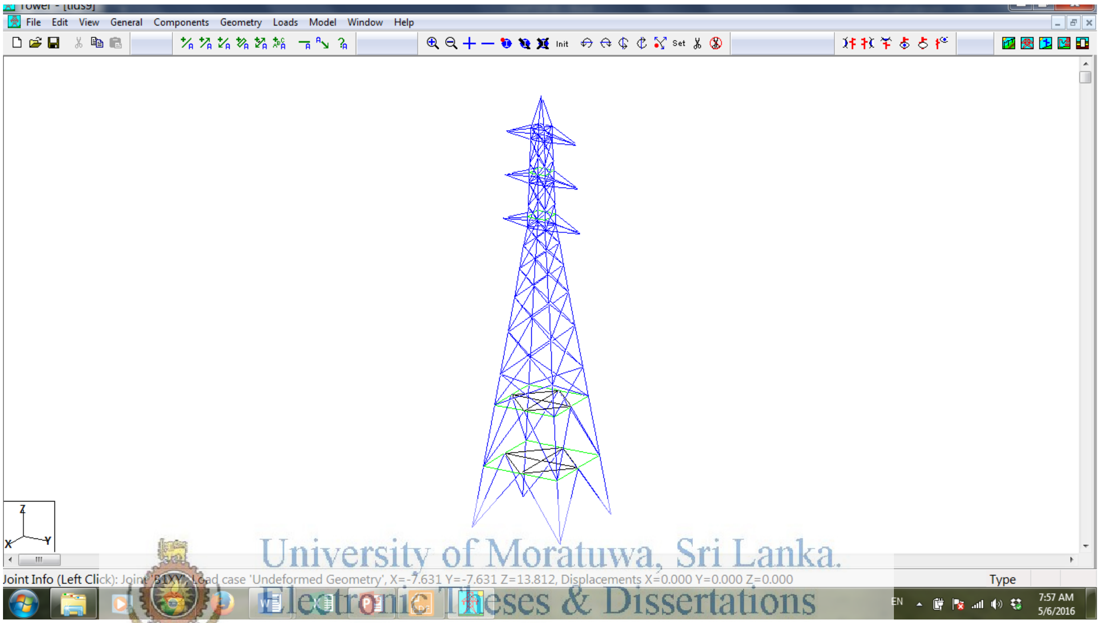
3.1 Design Criteria

The design of tower based on varying conductor size under different atmospheric conditions, environmental impacts and possible abnormal conditions arising from accidental and natural failures was computed using PLS – TOWER software was obtained. The PLS – TOWER software is more user friendly for Transmission Tower designing compared with other software. The relevant usages of land and Steel materials were calculated and tabled with cost based on market values.

3.2 Modeling and Analysis in PLS – Tower (for TDL tower)

1. Step by step instruction and method for modeling and analysis of PLS – Tower are shown in Appendix F.

2. Analysis Results as shown in Appendix G for a TDL+9 tower.



Similarly, all types of towers (TD1, TD3, TD6 and TDT) were used in the 73km of Vavuniya Kilinochchi transmission Project analyzed for the new conductors (Low Loss conductor) and the result for each tower analysis have been tabulated in the Appendix H. According to my result minor changes to be done in the tower members to replace the low loss conductor.

3.3 Wind Span Vs Angle of Deviation

Angle of deviation is important for profile design which is used to determine the type of tower to be used for a particular span and the optimum design will depend on the Wind Span Vs Angle of Deviation of the tower.

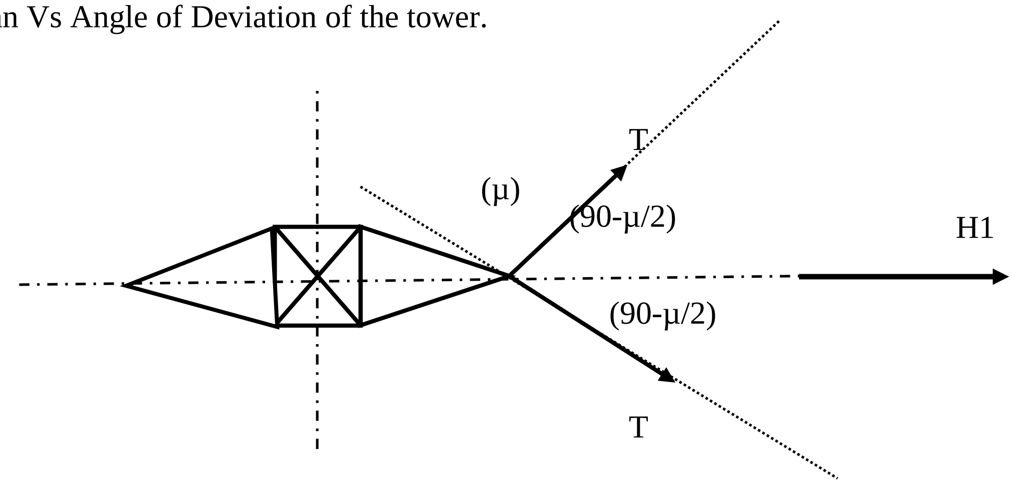


Figure 3.3: Wind Span Vs Angle of Deviation

The transverse load imposed on a tower by one conductor

$$H1 = 2T\sin\left(\frac{\mu}{2}\right) + LW_c$$

Where T Tension of the conductor

L Wind Span

W_c Wind Load per unit length

μ Line Angle

For General Condition

Normal Wind Span $L_n = 360m$

Line Angle μ_n

by resolving the forces

$$2T\sin\left(\frac{\mu_n}{2}\right) + L_n W_c = 2T\sin\left(\frac{\mu}{2}\right) + LW_c$$

Wind load on conductor per meter run $W_c = 970 \times 28.62 \times 10^{-3} = 27.76Nm$

Wind load on earth wire per meter run $W_e = 970 \times 9.8 \times 10^{-3} = 9.5$ Nm

Maximum allowable working tension of the conductor T_c = 51,000 N

(As per the Sag Tension Calculation)

Maximum allowable working tension of the earth wire Te = 18,762N

(As per the Sag Tension Calculation)

i. Suspension Towers

For Conductor

$$27.7614 \times L + 2 \times 51000 \times \sin(\mu/2) = 27.7614 \times 360 + 2 \times 51{,}000 \times \sin(0)$$

$$27.7614\,L = 9994.1 - 102{,}000 \sin(\mu/2)$$

For Earthwire

$$9.5 \times L + 2 \times 18{,}762 \times \sin(\mu/2) = 9.506 \times 360 + 2 \times 18{,}762 \times \sin(0)$$

$$9.5\,L = 3{,}422.16 - 37{,}524 \sin(\mu/2)$$

Table 3.3.1: Angle of Deviation of TDL tower

Angle of Deviation (Degree)	Wind Span (m)	
	Conductor	Earthwire
0	***360.0***	***360.0***
1	327.9	325.6
2	295.9	291.1
3	263.8	256.7
4	231.8	222.2
5	199.7	187.8
6	167.7	153.4
7	135.7	119.0
8	103.7	84.6
9	71.7	50.3
10	39.8	16.0

ii. Angle Tower (TD1)

For Conductor

$$27.7614 \times L + 2 \times 51{,}000 \times \sin(\mu/2) = 27.7614 \times 360 + 2 \times 51{,}000 \times \sin(5)$$

$$27.7614\, L = 18{,}883.1 - 102{,}000 \sin(\mu/2)$$

For Earthwire

$$9.5 \times L + 2 \times 18{,}762 \times \sin(\mu/2) = 9.506 \times 360 + 2 \times 18{,}762 \times \sin(5)$$

$$9.5\, L = 6{,}692.59 - 37{,}524 \sin(\mu/2)$$

Table 3.3.2: Angle of Deviation of TD1 tower

Angle of Deviation (degree)	**Wind Span (m)**	
	Conductor	**Earthwire**
0	680.2	704.0
1	648.2	669.6
2	616.1	635.1
3	584.0	600.7
4	552.0	566.3
5	520.0	531.9
6	487.9	497.4
7	455.9	463.1
8	423.9	428.7
9	392.0	394.3
10	***360.0***	***360.0***
11	328.1	325.7
12	296.2	291.4
13	264.3	257.2
14	232.5	223.0
15	200.6	188.8

Similarly Angle of Deviation for the other towers such as TD3, TD6 and TDT were calculated and the values are shown in the Appendix I.

3.4 Creep Calculation (Temperature Shift Calculation)

Creep in a conductor is defined as permanent set in the conductor. It is a continuous process and takes place throughout its life. The rate of creep is higher initially but decreases with time. Creep compensation is provided for by over tensioning of the conductor in the form of temperature correction.

Creeps strain leads to increase in length and in turn the sag of an overhead line conductor with passage of time. The effect of intermittent high temperature operation of transmission lines accelerates creep strain.

For this calculation the assessment method in [9] was used.

$$e = K\frac{(Tx100)^B}{T_{ult}}\ O^{\emptyset}t^{y} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq (4)}$$

e	=	Creep strain mm/km
T	=	Tension in conductor at 32 °C (kg)
T_{ult}	=	Ultimate Tensile Strength of Conductor (kg)
K	=	Creep Constant
B, Ø, y	=	Creep Indices
O	=	Conductor Temperature °C
t	=	Duration in Hrs.

Where,

From Table 2

K	=	1.4
B	=	1.3
Ø	=	0
y	=	0.16

Conversion of Tension to temperature differences is calculated from the equation of sag calculations.

$$\frac{W^2\,ES^2}{24T_2^2} - \frac{T_2}{A} = \frac{W^2\,ES^2}{24T_1^2} - \frac{T_1}{A} + \alpha Et \text{ ....Eq (8)}$$

W	=	Unit weight of conductor (kg/m)
S	=	Span Length (m)
E	=	Young's Modulus of conductor (kg/cm²)
T_1	=	Final Tension of Conductor (kg)
T_2	=	Initial Tension of Conductor (kg)
A	=	Cross sectional Area of Conductor (cm²)
α	=	Co-efficient of Linear Expansion of Conductor (per °C)
t	=	Temperature Difference (°C)

Where

$$t = \frac{\frac{W^2EAS^2}{24}\left(\frac{1}{T_2^2} - \frac{1}{T_1^2}\right) - (T_2 - T_1)}{\alpha EA}$$

Table 3.4.1: Creep Calculation

Span (m)	**T1 Tension at 32 °C (kg) (at UTS/2.5)**	**T(ult) Ultimate Tension(kg)**	**T1 *100/T(ult) (%)**
200	2950.89		22.21
300	2948.87	13288.94	22.19
400	2803.77		21.10
500	2731.11		20.55

As the result of the calculation above table indicates that the percentage of everyday tension - (T1) to ultimate tension-T(ult) does not vary with the length of equivalent span. The percentage of creep can be calculated from the Equation (4) of *Transmission*

Line Structures by S. Murthy and AR Santhakumar [7] and values are tabulated as follows.

Table 3.4.2: Creep Calculation

Span(m)	**$\frac{T \times 100}{T_{ult}}$**	**e mm/km for 10 years (87600hrs)**	**e mm/km for 24 hrs**	**Balance Creep $e_{10Y} - e_{24H}$ mm/km**
200	22.21	486.9	131.1	355.8
300	22.19	486.3	130.9	355.4
400	21.10	455.5	122.6	332.9
500	20.55	440.1	118.5	321.6

Average value of balance creep = 341.4mm/km = 0.034%

Therefore, Percentage of creep at everyday temperature is 0.034% for Zebra-ACSR conductor.

In order to allow the above balance creep of 341.4mm to happen in 87576 hr the conductor tension to be increased than the final tension of the conductor at everyday temperature.

Difference in tension is given by

$$\Delta T = \frac{12CT_1^3}{W^2S^2}$$

Where W Unit weight of conductor (kg/m)

S Equivalent Span (m)

C Percentage Creep

T_1 Final Tension of Conductor at 32°C (Daily operating Temperature)

Accordingly tension to be applied as the initial tension calculated by

$$T_2 = T_1 + \Delta T$$

The above increased initial tension T2 will be maintained at the site condition above initial tension to be calculated using the Equation (4) of Transmission Line Structures by S. Murthy and AR Santhakumar [7].

$$\frac{W^2ES^2}{24T_2^2} - \frac{T_2}{A} = \frac{W^2ES^2}{24T_1^2} - \frac{T_1}{A} + aET$$

$$t = \frac{\frac{W^2EAS^2}{24}\left({}^{1}/_{T_2^2} - {}^{1}/_{T_1^2} \right) - (T_2 - T_1)}{aEA}$$

$$\frac{W^2EAS^2}{24} = 377320.7S^2$$

Table 3.4.3 : Creep Calculation Result

Span (m)	Final Tension at 32°C T_1 (kg)	Tension Increase for 0.034% creep ΔT (kg)	Initial Tension at 32°C $T_1 + \Delta T$ T_2 (kg)	Tempera. Difference t °C
200	2950.89	985.62	3936.51	-26.55
300	2948.87	437.16	3386.03	-21.00
400	2803.77	211.36	3015.13	-19.02
500	2731.11	125.02	2856.13	-18.38

Therefore, the average Temperature difference is -22°C

Accordingly the temperature difference, for 10 years creep for Zebra conductor is (-) 22°C.

4.0 PROFILE DESIGN

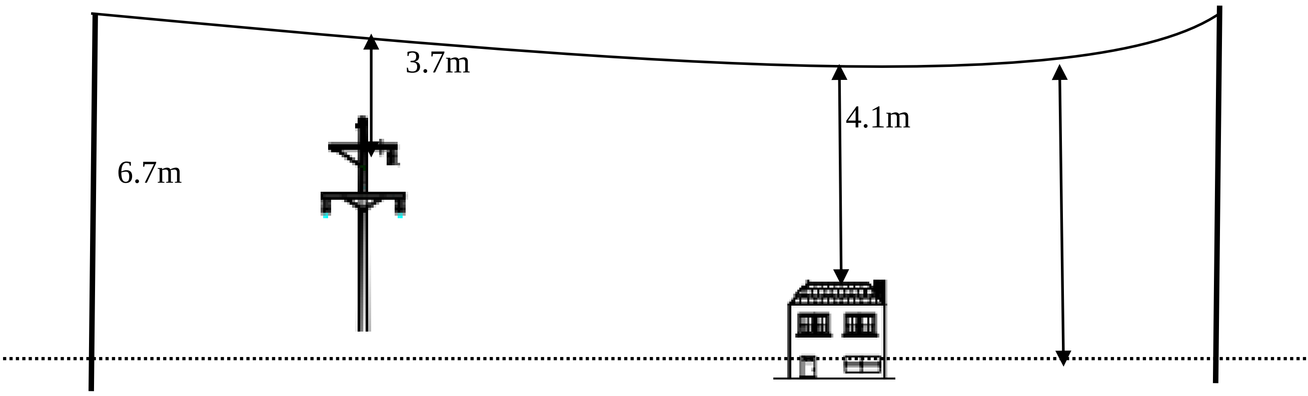
4.1 Clearances to Ground, objects under the line and at crossings

As per the CEB specification the line clearances to the ground, objects are described as follows,

Table 4.1: Line Clearances as per the CEB specification.

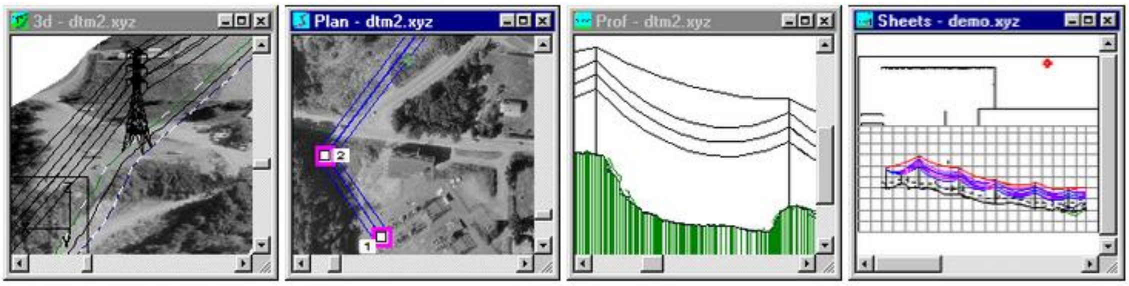
132 kV LINE CLEARANCES

		132 kV
Minimum Clearance from Conductor: To Ground	m	6.7
Metal Clad or Roofed Buildings, or other Buildings or Structures upon which a man may stand	m	4.1
To earthed cradle Guard Wires	m	4
To Electric power Line Wires (Line to Earth)		3.7
To be added to the above Clearance to Allow for Survey and sagging error	m	0.3
Minimum horizontal spacing between outermost conductor of adjacent power line in still air	m	15.3
Spacing between P + T Line and cradle guard	m	1.8



4.2 PLS-CADD Software

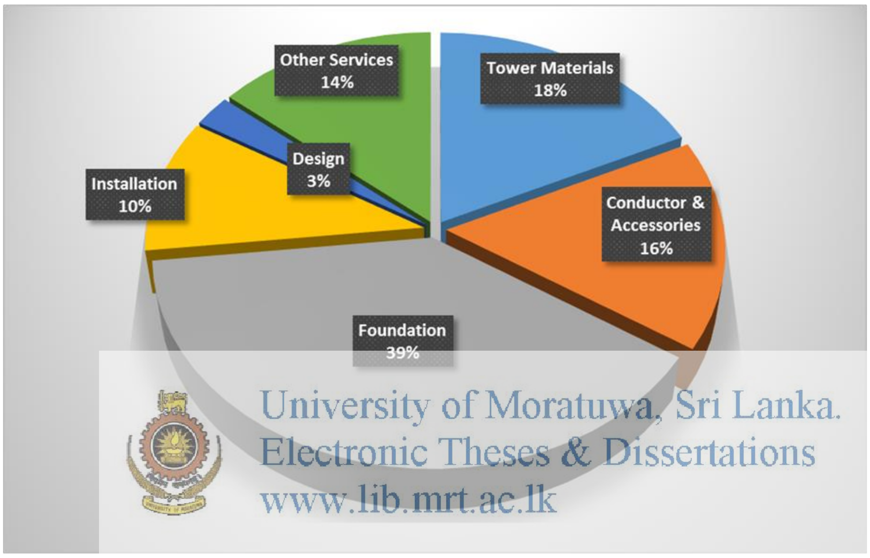
PLS-CADD is an overhead power line design program which is easy to design graphical user interface. It integrates all aspects of line design into a single stand-alone program with a simple, logical, consistent interface also used to design the plane, profile, route selection process.

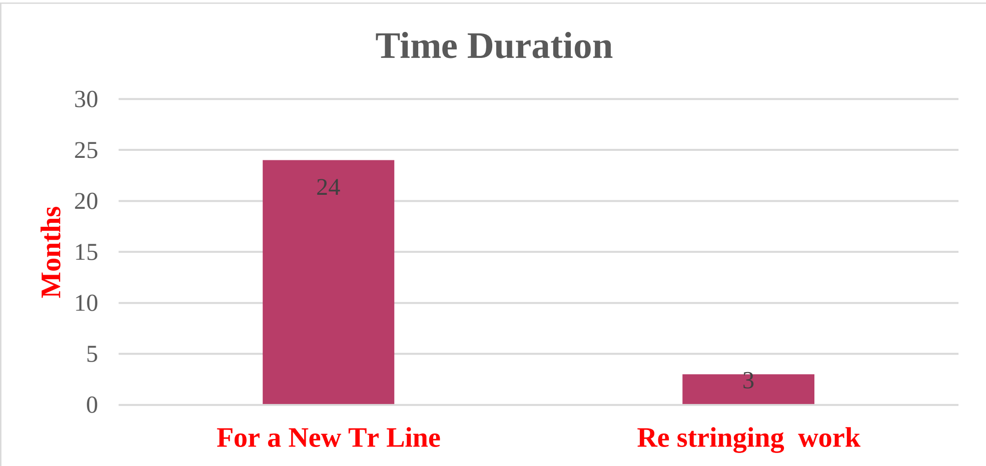


PLS-CADD software is used to design the profile. The detail profile design of a section of Vavuniya Kilinochchi Transmission Line is attached as Appendix J. For this Design actual survey data is important therefore I obtained the survey data from our office. Those data's loaded in to PLS CADD software then the profile design was carried out for this design the above calculations such as creep, sag tension, conductor data and earth wire technical data.

5.0 COST and TIME IMPACTS OF A NEW TRANSMISSION LINE CONSTRUCTION

The detailed cost and time structure for construction of a new transmission is mentioned bellow. This average data is take from several CEB projects for a construction of around 60km length double circuit transmission line.





Conclusion

The study of tower and profile design for different conductor was analysed with the help of PLS tower and PLS -CADD software and different cases based on the tower types were analysed to obtain the optimum use of the existing transmission line and maximum cost and the time benefit.

As the objective of the study was to obtain an optimum electrical and mechanical of equilibrium between the cost and the current rating of the existing transmission line with varying the different conductor. This computed with varying cost of ta new transmission line project including the prices of steel, different cost of land depending on location and environmental impacts.

Further, the study also based on the temperature rise of the conductorand the proposed new low loss conductor can be operated up to 90°C which is more suitable for countries like Sri Lanka.

This study conform that any transmission line designed based on the CEB specifications using the ACSR Zebra can be replaced by a Low loss, high rating conductor. The detailed analyses of Tower and Profile shows that modifications are required for some towers.

Therefore, it is recommended to select the low loss conductor within the economical range of sizes given above to reap maximum financial benefit. Apart from the financial benefit the important aspect of the above recommendation is to be highlighted here as a non-cash benefit where an immense gain is realized in terms of environmental impact. Similarly, the new design of towers and profile could be analysed for different parameters, shapes, sizes and configuration in order to ascertain benefits over cost and environmental advantages through further studies.

Reference List

[1] Prasad Rao, N. Samuel Knight, G.M. Mohan, S.J. and Lakshmanan, N. (2012) Studies on failure of transmission line towers in testing. Journal of Engineering Structures. Vol. 35 & Vol.25

[2] Abdullah Fakhir Mohammed, Mustafa özakca and Nildemtaysi. (2012) Optimal design of transmission Towers using genetic algorithm. Journal of ConstructionalTechnologies.Vol. 4, No 2, pp. 115-123.

[3] R. Thrash, A. Murrah, M. Lancaster, and K. Nuckles, "Overhead conductor manual," 2nd ed: Southwire, 2007.

[4] ASCE 52. 1971. Guide for Design of Steel Transmission Towers. American Society of Civil Engineers. 1971. [5] BS EN 60071-1: Insulation co-ordination - Definitions, principles and rules," British Standards, 2006

[6] IEEE Guide for Determining the effects of high-temperature operation on conductors, connectors, and accessories," IEEE Std. 1283-2004, pp.1-28, 2005.

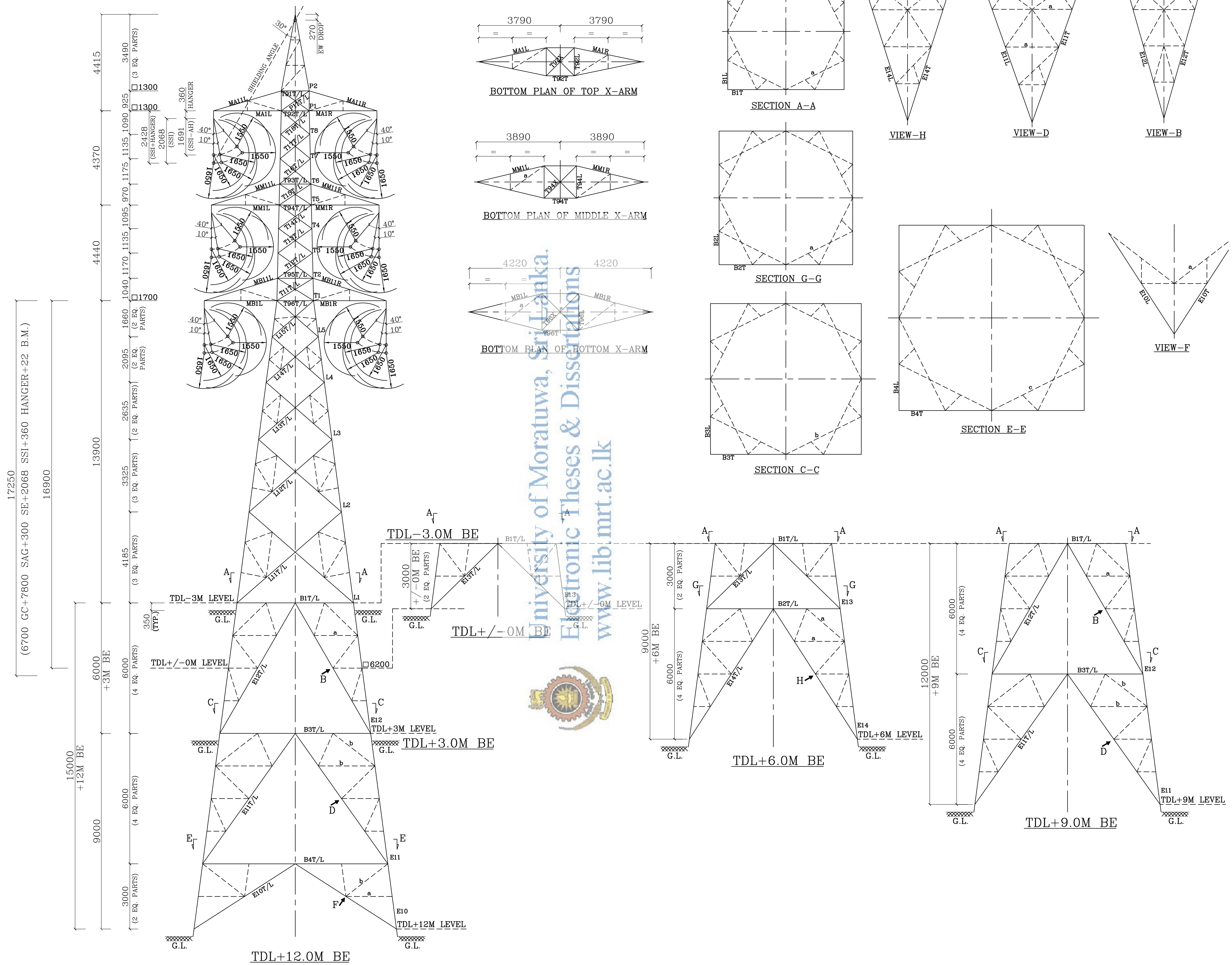
[7] Murthy, S.S., Santhakumar, A.R., 1990. Transmission Line Structures. McGraw-Hill Book Co. Singapore, pp. 179-180.

[8] Ceylon Electricity Board. Transmission Development Plan 2011-2021

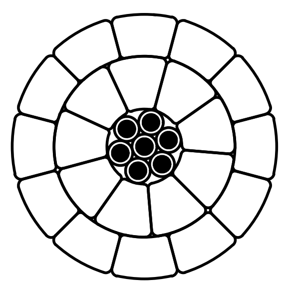
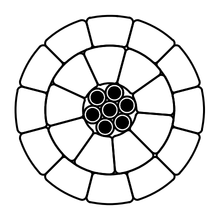
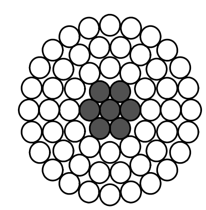
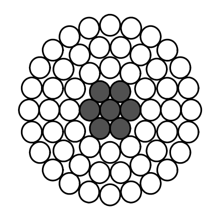
[9] Bradbury,J.,Dey,p., Orawski, G.Pickup, KH, *L*ong-Term Creep assessment for overhead –line conductors.

[10] Abdullah Fakhir Mohammed, Mustafa özakca and Nildemtaysi. (2012) Optimal design of transmission Towers using genetic algorithm. Journal of Constructional Technologies.Vol. 4, No 2, pp. 115-123

Appendix A Existing 132kV Tower Details



Appendix B

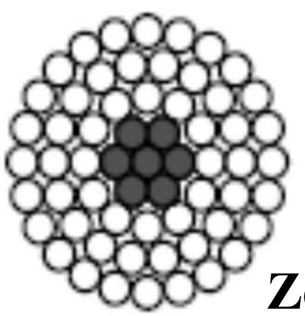
Specification Comparison of Conductors						
			Adoption in this project	Reference		
Description		Unit	Low Loss TACSR/AS 550mm^2	Low Loss ACSR/AS 550mm^2	TACSR/AS "Zebra"	ACSR "Zebra"
Nominal Diameter (*)		–	28.62	28.62	28.62	28.62
Cross Sectional Area (*)	AL	mm^2	550.4	550.4	428.9	428.9
	Core		40.08	40.08	55.59	55.59
	Total		590.5	590.5	484.5	484.5
Nominal Weight (*)		kg/km	1,814	1,814	1,555	1,621
Ultimate Tensile Strength (*)		kN	140.9	140.9	130.4	131.9
DC Resistant at 20°C (*)		Ω/km	0.0526	0.0519	0.0657	0.0674
Max. Allowable Temperature		°C	150	90	150	90
Current(A)		66.15°C	757	762	–	–
		75°C	–	875	767	757
		90°C	–	1,077	–	930
		136.1°C	1,514	N/A	–	N/A
		150°C	1,622	N/A	1,423	N/A
Cross Section		–				

Note : Specific values (marked:(*)) for above conductors are calculated in accordance with IEC 61089-1991 for ACSR "Zebra" & TACSR/AS "Zebra" and in accordance with IEC 62219-2002 for Low Loss ACSR/AS 550mm^2 & Low Loss TACSR/AS 550mm^2.

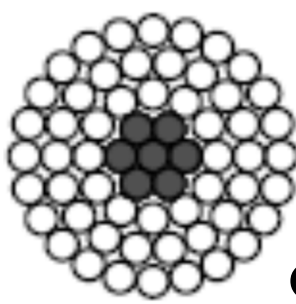
Comparison of conductor specifications

For the Zebra conductors

Option	Conductor Type	Diameter (mm)	Cross section Area (mm^2)	Weight (kg/km)	Calculated DC Resistance @ 20°C Ohms/km	Current Rating (A)
Zebra	ACSR	28.62	428	1621	0.0674	760
Rubus	AAAC	31.50	500	1620	0.0566	940
Camel	ACSR	30.18	475.2	1797	0.0611	820
Option 1	**TACSR/AS**	**28.62**	**428**	**1555**	**0.0657**	**1420**
Option 2	**Low Loss TACSR**	**28.62**	**550**	**1814**	**0.0519**	**1070**



Zebra



Option 1

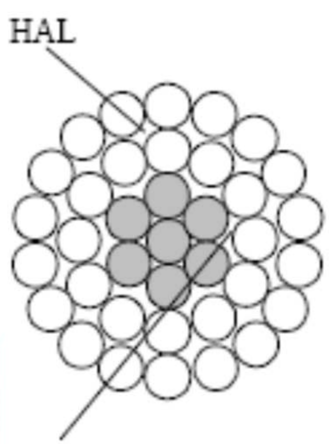
Option 2

Comparison of conductor specifications

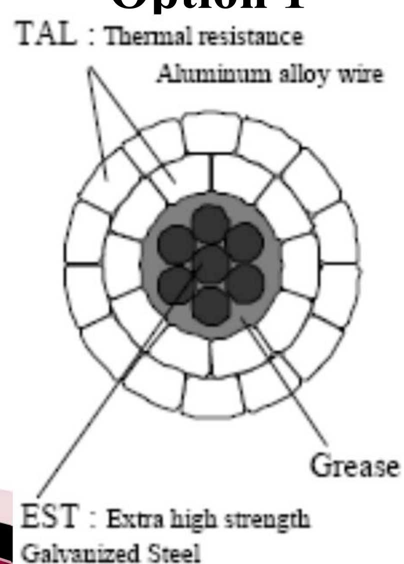
For the Lynx conductor

Option	Conductor Type	Diameter (mm)	Cross section Area (mm²)	Weight (kg/km)	Calculated DC Resistance @ 20°C Ohms/km	Current Rating (A)
Lynx	ACSR	19.55	183	865	0.1576	450
Panther	ACSR	21	200	1001	0.1362	490
Option 1	**GTACSR**	19.2	210	851	0.140	**875**
Option 2	**GZTACSR**	18.5	195	803	0.150	**920**

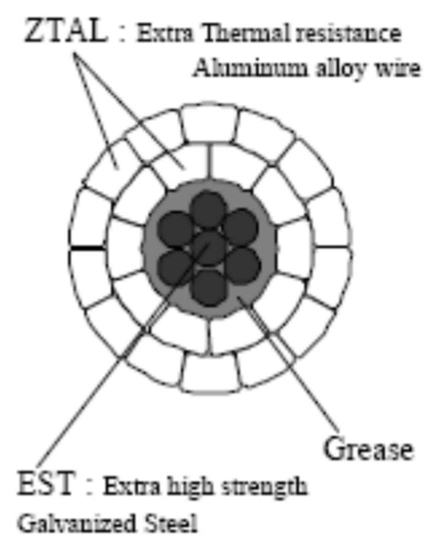
Lynx



Option 1



Option 2



Appendix C
Sag Tension Calculation

Wind force on conductor per meter run,

$p = 970 \times 28.62 \times 10^{-3}$ N/m
= 27.7614 N/m

Wind force on conductor = 27.7614 N/m **27.76** N/m

Loading factor at 15 ^{o} C

With wind, $Q1 = \frac{(p^2 + w^2)^{1/2}}{w}$

Where, p - wind force on conductor per meter run
w - Weight of the conductor per meter

$Q1 = \frac{\{(27.7614/9.80665)^2 + 1.631\}^{1/2}}{1.631}$

Q1 = 2.0031 **2.00**

Loading factor at given temperature without wind,

$Q2 = \frac{\{0 + 1.631^2\}^{1/2}}{1.631}$

Q2 = 1.0 **1.00**

<u>Maximum allowable working tension of the conductor</u>

Maximum working tension of ZEBRA conductor = UTS / 2.5

= 52760 N

(Note : UTS of Insulator = 160kN, Maximum WT = 160/3 = 53.3 kN > 51.000 kN)

However in order to satisfy the design condition at 32^{o}C , UTS/4.5
the maximum allowable working tension is assumed as = 51000 N

Maximum allowable working stress of the conductor

$f_1 = \frac{51000}{484.5}$ N/mm²

= 105.2632 N/mm² **105.26** N/mm²

Weight of conductor with grease/m/mm²

$$\S = \frac{1.631 \times 9.80665}{484.5} \quad N/m/mm^2$$

$$\S = 0.033013 \; N/m/mm^2 \qquad \textbf{0.03} \; N/m/mm^2$$

Then the working stress f_2 can be determined by the following formula

$$f_2^2[f_2-(f_1- \frac{a^2 \S^2 Q_1^2 E}{24f_1^2} - æ\, t\, E)] = \frac{a^2 \S^2 Q_2^2 E}{24}$$

Where
a = Conductor span in meters
E = Modulus of elasticity in N/mm²
æ = Coefficient of linear expansion in per ^oC
t = Temperature difference (t_{req} - t_{min})

Then the Sag can be determined by the following formular ;

$$Sag = \frac{a^2 \S Q_2}{8f_2}$$

Co-ordinates of the curves can be determined by the following formular

$$Sag_{req\ at\ 15\ ^oC} = \frac{\text{Equivalent Span Sag at } 15^oC}{(\text{ Equivalent Span })^2} \times (\text{Required Span })^2$$

SAG at 15°C with wind load

Initial Tension = 51000 N

$$Sag = \frac{w \times span^2 \times Q1}{8 \times T}$$

w - unit wt of conductor N/m
T - Initial Tension N

$$Sag = \frac{1.631 \times 9.80665 \times 300^{2 \times 2.0031}}{8 \times 51000}$$

$$= 7.06754 \; m \qquad \textbf{7.07} \; m$$

SAG at 15°C without wind load **For Equivalent span (m) = 300**

$$f_2^2[f_2-(f_1- \frac{a^2 \S^2 Q_1^2 E}{24f_1^2} - æ\, t\, E)] = \frac{a^2 \S^2 Q_2^2 E}{24}$$

$$t = (15 - 15)\,^oC$$
$$0 \; ^oC$$

$$(f_1-\frac{a^2 \S^2 Q_1^2 E}{24f_1^2} - æ\, t\, E)] = 105.2632 - \{\frac{300^2 \times 0.033013^2 \times 2.0031^2 \times 69 \times 10^3}{24 \times 105.2632^2})$$

$- 0.0000193 \times 0 \times 69 \times 10^3$

$= 105.2632 - 102.1196$

$= 3.1436$

$\frac{a^2 \S^2 Q_2^2 E}{24} = \frac{300^2 \times 0.033013^2 \times 1^2 \times 69 \times 10^3}{24}$

$= 281995.429$

Therefore the equation,

$f_2^3 - 3.1436 f_2^2 = 281995.4292$

Solving by Newton Raphsan methods

$f_2 = \{281995.4292 + 3.1436 f_2^2\}^{1/3}$

Starting $f_2 = 66.7$

$f_2 = 66.64299$

$f_2 = 66.64120$

$f_2 = 66.64114$

$f_2 = 66.64114$

$f_2 = 66.64114$

$f_2 = 66.64114$

$f_2 = 66.64114$

$f_2 = 66.64114$ N/mm²

Then $T = 66.64114 \times 484.5$ N

32287.632 N **32287.63** N

$Sag = \frac{300^2 \times 0.033013 \times 1}{8 \times 66.64114}$

5.5730 m **5.57** m

SAG at 32°C without wind load **For Equivalent span (m) = 300**

$f_2^2[f_2-(f_1- \frac{a^2 \S^2 Q_1^2 E}{24f_1^2} - æ\, t\, E)] = \frac{a^2 \S^2 Q_2^2 E}{24}$

$t = (32 - 15)\ ^oC$

$17\ ^oC$

$(f_1-\frac{a^2 \S^2 Q_1^2 E}{24f_1^2} - æ\, t\, E)] = 105.2632 - \{\frac{300^2 \times 0.033013^2 \times 2.0031^2 \times 69 \times 10^3}{24 \times 105.2632^2}\}$

$-0.0000193*17*69*10^3$

= 105.2632- 102.1196 -22.6389

= -19.4953

$\frac{a^2\ §^2\ Q_2^2\ E}{24}$ = $\frac{300^2 \times 0.033013^2 \times 1^2 \times 69 \times 10^3}{24}$

= 281995.429

Therefore the equation,

$f_2^3 + 19.4953 f_2^2 = 281995.4292$

Solving by Newton Raphsan methods

$f_2 = \{281995.4292 - 19.4953 f_2^2\}^{1/3}$

Starting

f_2 = 59.679000

f_2 = 59.679881

f_2 = 59.679689

f_2 = 59.679731

f_2 = 59.679722

f_2 = 59.679724

f_2 = 59.679724

f_2 = 59.679724

Then T = 59.679724 x 484.5 N

= 28914.826 N **28914.83** N

Note : at 32°C Tension should be less UTS/4.5 = 29311.1 N Ok

Sag = $\frac{300^2 \times 0.033013 \times 1}{8 \times 59.679724}$

6.2231 m **6.22** m

<u>SAG at 75°C without wind load</u> **For Equivalent span (m) = 300**

$f_2^2[f_2-(f_1- \frac{a^2\ §^2\ Q_1^2\ E}{24 f_1^2} - æ\ t\ E)] = \frac{a^2\ §^2\ Q_2^2\ E}{24}$

t = (75 - 15) °C

60 °C

$(f_1-\frac{a^2\ §^2\ Q_1^2\ E}{24 f_1^2} - æ\ t\ E)]$ = 105.2632- $\{\frac{300^2 \times 0.033013^2 \times 2.0031^2 \times 69 \times 10^3}{24 \times 105.2632^2}\}$

$- 0.0000193 \times 60 \times 69 \times 10^3$

= 105.2632- 102.120 -79.902

= -76.7584

$\frac{a^2\ §^2\ Q_2^2\ E}{}$ = $\frac{300^2 \times 0.033013^2 \times 1^2 \times 69 \times 10^3}{}$

24 24

= 281995.429

Therefore the equation,

$$f_2^3 + 76.7584\ f_2^2 = 281995.4292$$

Solving by Newton Raphsan methods

$f_2 =$ $\{281995.4292 - 76.7584 f_2^2\}^{1/3}$

Starting $f_2 =$ 47.616234

$f_2 =$ 47.6162340

$f_2 =$ 47.6162340

$f_2 =$ 47.6162340

$f_2 =$ 47.6162340

$f_2 =$ 47.6162340

$f_2 =$ 47.6162340

$f_2 =$ 47.6162340

$f_2 =$ 47.6162340

Then T = 47.6162340 x 484.5 N

23070.065 N **23070.07** N

$$Sag = \frac{300^2 \times 0.03303 \times 1}{8 \times 47.6162340}$$

7.7997 m **7.80** m

Sag Tension Calculation of Proposed Low Loss Conductor

Wind force on conductor per meter run,

$p = 970 \times 28.62 \times 10^{-3}$ N/m

= 27.7614 N/m

Wind force on conductor = 27.7614 N/m **27.76** N/m

Loading factor at 15 ^{o} C

With wind, $Q1 = \frac{(p^2 + w^2)^{1/2}}{w}$

Where, p - wind force on conductor per meter run

w - Weight of the conductor per meter

$Q1 = \frac{\{(27.7614/9.80665)^2 + 1.631\}^{1/2}}{1.814}$

Q1 = 1.8535 **1.85**

Loading factor at given temperature without wind,

$Q2 = \frac{\{0 + 1.631^2\}^{1/2}}{1.814}$

Q2 = 1.0 **1.00**

<u>Maximum allowable working tension of the conductor</u>

Maximum working tension of Proposed Low Loss conductor = UTS / 2.5

= 56360 N

(Note : UTS of Insulator = 160kN, Maximum WT = 160/3 = 53.3 kN > 51.000 kN)

However in order to satisfy the design condition at 32^{o}C , UTS/4.5

the maximum allowable working tension is assumed as = 51000 N

Maximum allowable working stress of the conductor

$f_1 = \frac{51000}{484.5}$ N/mm²

= 105.2632 N/mm² **105.26** N/mm²

Weight of conductor with grease/m/mm²

$\S = \frac{1.631 \times 9.80665}{484.5}$ N/m/mm^2

$§ =$ 0.036717 N/m/mm^2 **0.04** N/m/mm^2

Then the working stress f_2 can be determined by the following formula

$$f_2^2[f_2-(f_1-\frac{a^2 §^2 Q_1^2 E}{24f_1^2} - æ\, t\, E)] = \frac{a^2 §^2 Q_2^2 E}{24}$$

Where
a = Conductor span in meters
E = Modulus of elasticity in N/mm²
æ = Coefficient of linear expansion in per ^oC
t = Temperature difference (t_{req} - t_{min})

Then the Sag can be determined by the following formular ;

$$Sag = \frac{a^2 § Q_2}{8f_2}$$

Co-ordinates of the curves can be determined by the following formular

$$Sag_{req\ at\ 15\ ^oC} = \frac{\text{Equivalent Span Sag at }15^oC}{(\text{Equivalent Span})^2} \times (\text{Required Span})^2$$

SAG at 15^{o}C with wind load

Initial Tension = 51000 N

$$Sag = \frac{w \times span^2 \times Q1}{8 \times T}$$

w - unit wt of conductor N/m
T - Initial Tension N

$$Sag = \frac{1.631 \times 9.80665 \times 300^{2 \times 2.0031}}{8 \times 51000}$$

= 7.27325 m **7.27** m

SAG at 15^{o}C without wind load **For Equivalent span (m) = 300**

$$f_2^2[f_2-(f_1-\frac{a^2 §^2 Q_1^2 E}{24f_1^2} - æ\, t\, E)] = \frac{a^2 §^2 Q_2^2 E}{24}$$

t = (15 - 15) ^{o} C
0 ^{o}C

$$(f_1-\frac{a^2 §^2 Q_1^2 E}{24f_1^2} - æ\, t\, E)] = 105.2632 - \{\frac{300^2 \times 0.033013^2 \times 2.0031^2 \times 69 \times 10^3}{24 \times 105.2632^2})$$

$$- 0.0000193 \times 0 \times 69 \times 10^3$$

$= \quad 105.2632- \quad 111.2859$

$= \quad -6.0227$

$$\frac{a^2 §^2 Q_2^2 E}{24} = \frac{300^2 \times 0.033013^2 \times 1^2 \times 69 \times 10^3}{24}$$

$= \quad 358936.786$

Therefore the equation,

$$f_2^3 - 3.1436 f_2^2 = 281995.4292$$

Solving by Newton Raphsan methods

	$f_2 =$	$\{281995.4292+3.1436 f_2^2\}^{1/3}$	
Starting	$f_2 =$	66.7	
	$f_2 =$	69.25346	
	$f_2 =$	69.10784	
	$f_2 =$	69.11630	
	$f_2 =$	69.11581	
	$f_2 =$	69.11584	
	$f_2 =$	69.11584	
	$f_2 =$	69.11584	
	$f_2 =$	69.11584	N/mm²

Then $\quad T = \quad 69.11584 \times 484.5 \quad$ N

$33486.624 \quad$ N $\qquad$ **33486.62** N

$$Sag = \frac{300^2 \times 0.033013 \times 1}{8 \times 66.64114}$$

5.9764 m $\qquad$ **5.98** m

<u>SAG at 32°C without wind load</u> $\qquad$ **For Equivalent span (m) = 300**

$$f_2^2[f_2-(f_1- \frac{a^2 §^2 Q_1^2 E}{24f_1^2} - æ\, t\, E)] = \frac{a^2 §^2 Q_2^2 E}{24}$$

$t = \quad (32 - 15)\ ^oC$

$17 \quad ^oC$

$$(f_1-\frac{a^2 §^2 Q_1^2 E}{24f_1^2} - æ\, t\, E)] = 105.2632 - \{\frac{300^2 \times 0.033013^2 \times 2.0031^2 \times 69 \times 10^3}{24 \times 105.2632^2})$$

$-0.0000193*17*69*10^3$

$= \quad 105.2632- \quad 111.2859 \qquad -24.14$

$= \quad -30.1627$

$\frac{a^2 \S^2 Q_2^2 E}{24} = \frac{300^2 \times 0.033013^2 \times 1^2 \times 69 \times 10^3}{24}$

$= 358936.786$

Therefore the equation,

$f_2^3 + 19.4953 f_2^2 = 281995.4292$

Solving by Newton Raphsan methods

$f_2 = \{281995.4292 - 19.4953 f_2^2\}^{1/3}$

Starting

$f_2 =$ 59.679000
$f_2 =$ 63.122612
$f_2 =$ 62.036966
$f_2 =$ 62.389931
$f_2 =$ 62.276284
$f_2 =$ 62.312992
$f_2 =$ 62.301148
$f_2 =$ 62.304971

Then T = 62.304971 x 484.5 N

= 30186.758 N **30186.76** N

Note : at 32°C Tension should be less UTS/4.5 = 31311.1 N **Ok**

Sag $= \frac{300^2 \times 0.033013 \times 1}{8 \times 59.679724}$

6.6297 m **6.63** m

SAG at 75°C without wind load **For Equivalent span (m) = 300**

$f_2^2[f_2 - (f_1 - \frac{a^2 \S^2 Q_1^2 E}{24 f_1^2} - æ\, t\, E)] = \frac{a^2 \S^2 Q_2^2 E}{24}$

t = (75 - 15) °C

60 °C

$(f_1 - \frac{a^2 \S^2 Q_1^2 E}{24 f_1^2} - æ\, t\, E)] = 105.2632 - \{\frac{300^2 \times 0.033013^2 \times 2.0031^2 \times 69 \times 10^3}{24 \times 105.2632^2}\}$

$- 0.0000193 \times 60 \times 69 \times 10^3$

= 105.2632- 111.286 -85.2

= -91.2227

$\frac{a^2 \S^2 Q_2^2 E}{24} = \frac{300^2 \times 0.033013^2 \times 1^2 \times 69 \times 10^3}{24}$

$= 358936.786$

Therefore the equation,

$$f_2^3 + 76.7584\, f_2^2 = 281995.4292$$

Solving by Newton Raphsan methods

	$f_2 =$	$\{281995.4292 - 76.7584 f_2^2\}^{1/3}$
Starting	$f_2 =$	47.616234
	$f_2 =$	52.4523327
	$f_2 =$	48.5055184
	$f_2 =$	51.8043689
	$f_2 =$	49.0987901
	$f_2 =$	51.3539141
	$f_2 =$	49.4985096
	$f_2 =$	51.0419075
	$\mathbf{f_2 =}$	49.7694532

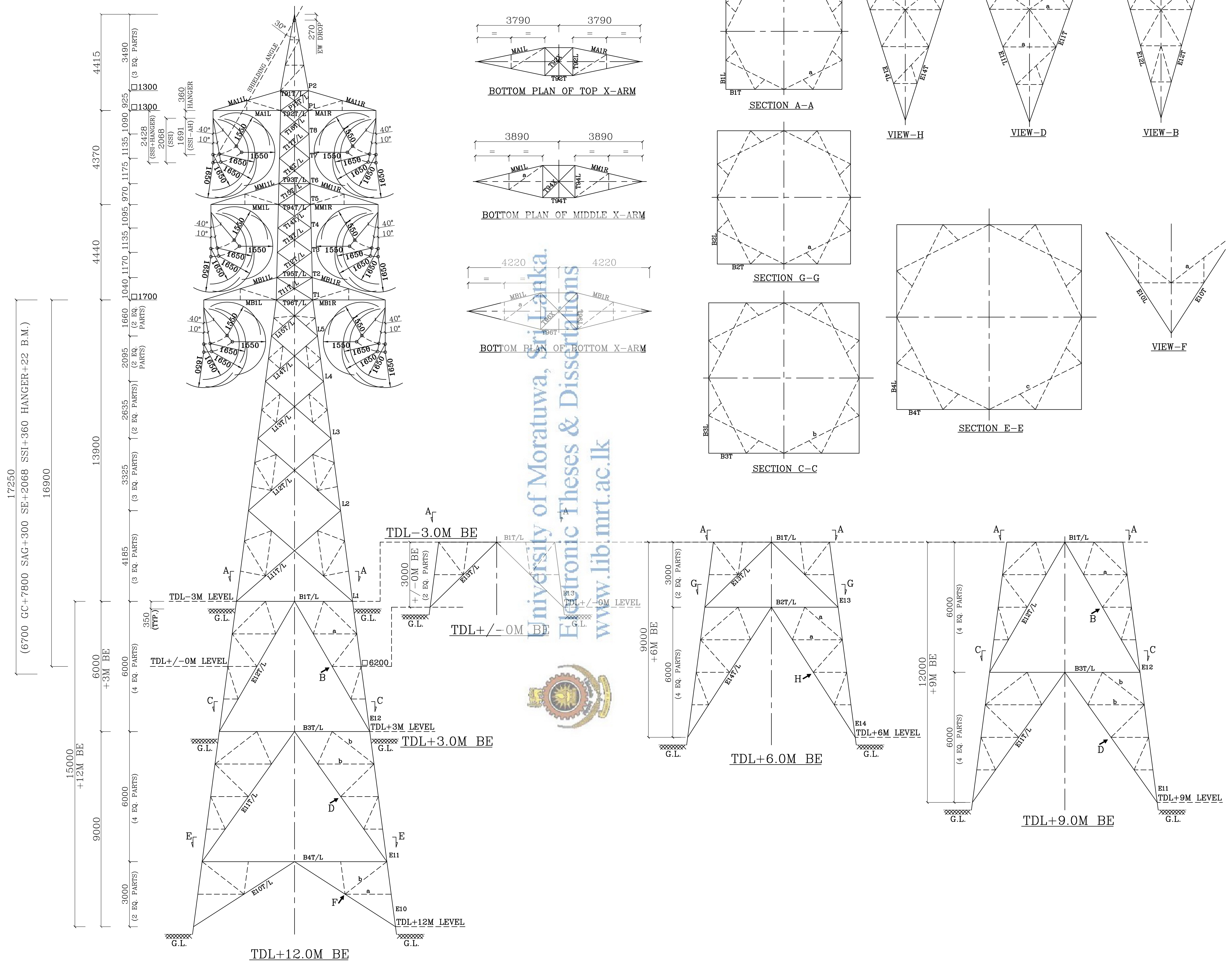
Then T = 49.7694532 x 484.5 N

24113.300 N **24113.30** N

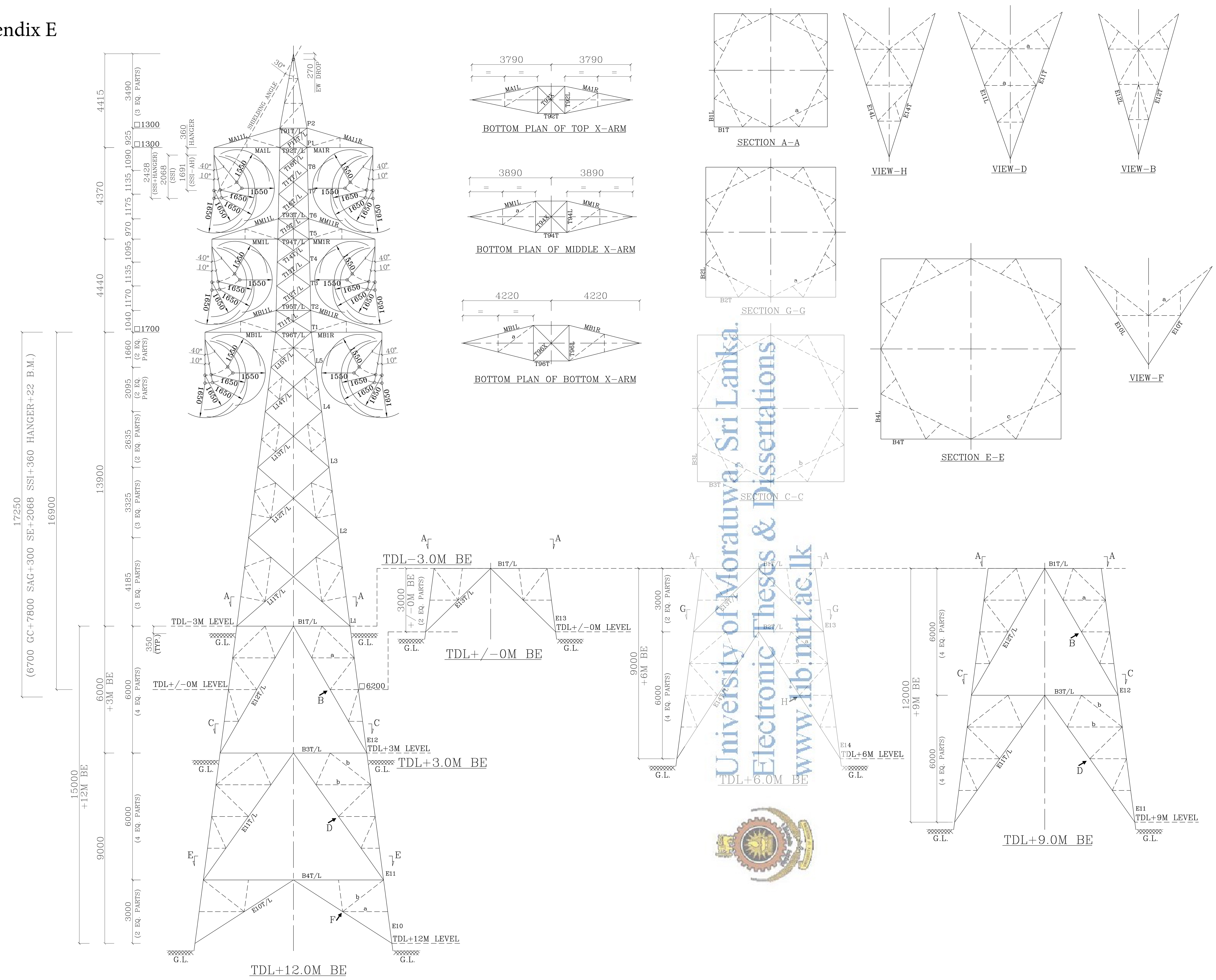
$$\text{Sag} = \frac{300^2 \times 0.03303 \times 1}{8 \times 47.6162340}$$

8.2995 m **8.30** m

Appendix D


17250
(6700 GC+7800 SAG+300 SE+2068 SSI+360 HANGER+22 B.M.)
16900
15000
+12M BE
9000
6000
+3M BE
13900
4440
4370
4415
3000 (2 EQ. PARTS)
6000 (4 EQ. PARTS)
4185 (3 EQ. PARTS)
3325 (3 EQ. PARTS)
2635 (2 EQ. PARTS)
2095 (2 EQ. PARTS)
1660 (2 EQ. PARTS)
1040 1170 1135 1095 970 1175 1135 1090 925
3490 (3 EQ. PARTS)
350 (TYP.)
2428 (SSI+HANGER)
2068 (SSI)
1691 (SSI-AH)
360 HANGER
SHIELDING ANGLE
30°
270 EW DROP
TDL-3M LEVEL
TDL+/-0M LEVEL
TDL+3M LEVEL
TDL+12M LEVEL
TDL+12.0M BE
TDL-3.0M BE
TDL+/-0M BE
TDL+3.0M BE
TDL+6.0M BE
TDL+9.0M BE
TDL+6M LEVEL
TDL+9M LEVEL
3000
+/-0M BE
(2 EQ. PARTS)
9000
+6M BE
12000
+9M BE
G.L.
BOTTOM PLAN OF TOP X-ARM
BOTTOM PLAN OF MIDDLE X-ARM
BOTTOM PLAN OF BOTTOM X-ARM
3790
3890
4220
SECTION A-A
SECTION G-G
SECTION C-C
SECTION E-E
VIEW-H
VIEW-D
VIEW-B
VIEW-F

Appendix E



LIST OF DESIGN MEMBERS					
Mem. code		Section Selected mm X mm X mm	Fy N/mm²	No. of Bolts	Shear
T95L	L	50 X 50 X 5	275	1	
MB11L	L	55 X 55 X 5	275	2	
MB1L	L	75 X 75 X 6	275	3	
MB11R	L	55 X 55 X 5	275	2	
MB1R	L	75 X 75 X 6	275	3	
L5	HL	100 X 100 X 7	355	6	
L15T	L	50 X 50 X 5	275	2	
L15L	L	50 X 50 X 5	275	2	
T96T	L	55 X 55 X 5	275	2	
T96L	L	45 X 45 X 5	275	1	
T96X	L	45 X 45 X 5	275	1	
L4	HL	100 X 100 X 7	355	6	
L14T	L	45 X 45 X 5	275	2	
L14L	L	45 X 45 X 5	275	2	
L3	HL	100 X 100 X 7	355	6	
L13T	L	50 X 50 X 5	275	2	
L13L	L	50 X 50 X 5	275	2	
L2	HL	100 X 100 X 7	355	8	
L12T	L	50 X 50 X 5	275	2	
L12L	L	50 X 50 X 5	275	2	
L1	HL	100 X 100 X 8	355	6	DS
L11T	L	55 X 55 X 5	275	2	
L11L	L	55 X 55 X 5	275	2	
E12	HL	110 X 110 X 8	355	6	DS
E12T	L	55 X 55 X 5	275	2	
E12L	L	55 X 55 X 5	275	2	
B1T	L	55 X 55 X 5	275	2	
B1L	L	55 X 55 X 5	275	2	
E11	HL	110 X 110 X 8	355	6	DS
E11T	L	55 X 55 X 5	275	2	
E11L	L	55 X 55 X 5	275	2	
B3T	L	55 X 55 X 5	275	2	
B3L	L	55 X 55 X 5	275	2	
E10	HL	110 X 110 X 8	355	6	DS
E10T	L	65 X 65 X 5	275	2	
E10L	L	65 X 65 X 5	275	2	
B4T	L	60 X 60 X 5	275	2	
B4L	L	60 X 60 X 5	275	2	
E13	HL	110 X 110 X 8	355	6	DS
E13T	L	60 X 60 X 5	275	2	
E13L	L	60 X 60 X 5	275	2	
E14	HL	110 X 110 X 8	355	6	DS
E14T	L	55 X 55 X 5	275	2	
E14L	L	55 X 55 X 5	275	2	
B2T	L	55 X 55 X 5	275	2	
B2L	L	55 X 55 X 5	275	2	

LIST OF DESIGN MEMBERS					
Mem. code		Section Selected mm X mm X mm	Fy N/mm²	No. of Bolts	Shear
P2	HL	65 X 65 X 6	355	6	
P1	HL	65 X 65 X 6	355	6	
P11T	L	45 X 45 X 5	275	1	
P11L	L	45 X 45 X 5	275	1	
T91T	L	55 X 55 X 5	275	1	
T91L	L	45 X 45 X 5	275	1	
MA11L	L	60 X 60 X 5	275	2	
MA1L	L	70 X 70 X 6	275	3	
MA11R	L	60 X 60 X 5	275	2	
MA1R	L	70 X 70 X 6	275	3	
T8	HL	75 X 75 X 6	355	6	
T18T	L	45 X 45 X 5	275	2	
T18L	L	45 X 45 X 5	275	2	
T92T	L	55 X 55 X 5	275	2	
T92L	L	45 X 45 X 5	275	1	
T92X	L	45 X 45 X 5	275	1	
T7	HL	75 X 75 X 6	355	6	
T17T	L	45 X 45 X 5	275	2	
T17L	L	45 X 45 X 5	275	2	
T6	HL	75 X 75 X 6	355	6	
T16T	L	45 X 45 X 5	275	2	
T16L	L	45 X 45 X 5	275	2	
T5	HL	75 X 75 X 6	355	6	
T15T	L	45 X 45 X 5	275	2	
T15L	L	45 X 45 X 5	275	2	
T93T	L	45 X 45 X 5	275	1	
T93L	L	45 X 45 X 5	275	1	
MM11L	L	55 X 55 X 5	275	2	
MM1L	L	70 X 70 X 6	275	3	
MM11R	L	55 X 55 X 5	275	2	
MM1R	L	70 X 70 X 6	275	3	
T4	HL	100 X 100 X 6	355	6	
T14T	L	50 X 50 X 5	275	2	
T14L	L	45 X 45 X 5	275	2	
T94T	L	55 X 55 X 5	275	2	
T94L	L	45 X 45 X 5	275	1	
T94X	L	45 X 45 X 5	275	1	
T3	HL	100 X 100 X 6	355	6	
T13T	L	50 X 50 X 5	275	2	
T13L	L	45 X 45 X 5	275	2	
T2	HL	100 X 100 X 6	355	6	
T12T	L	50 X 50 X 5	275	2	
T12L	L	45 X 45 X 5	275	2	
T1	HL	100 X 100 X 6	355	6	
T11T	L	45 X 45 X 5	275	2	
T11L	L	45 X 45 X 5	275	2	
T95T	L	45 X 45 X 5	275	1	

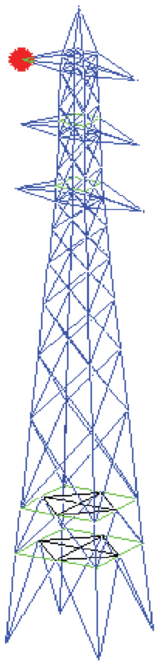
REDUNDANT MEMBERS		
SYMBOL	ANGLE SECTION	BOLTS
UNNOTED	L 45X45X5	1
a	L 50X50X5	1
b	L 55X55X5	1
c	L 60X60X5	1

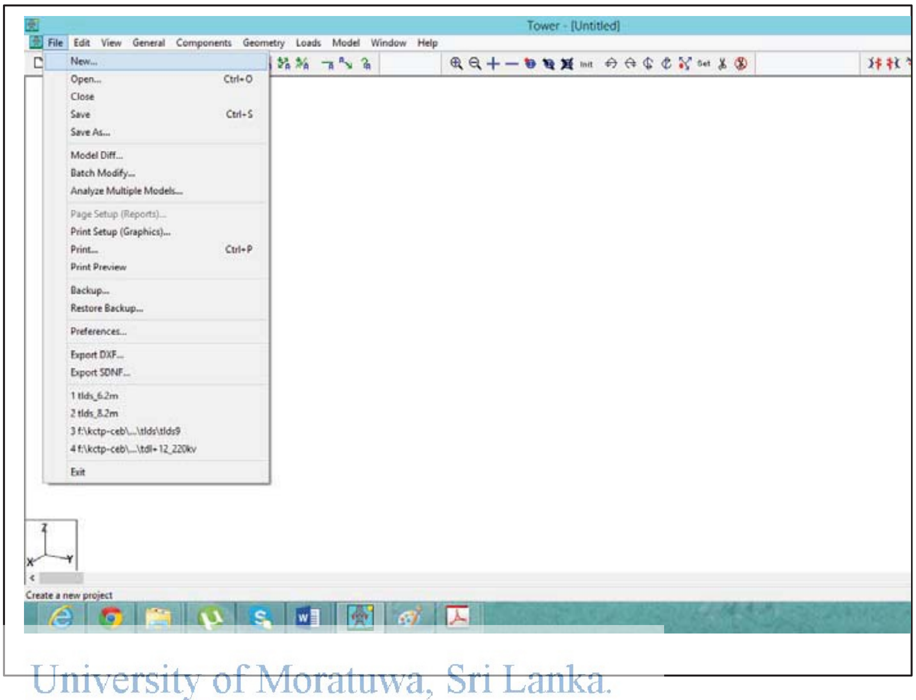
Appendix F

Modeling & Analysis in PLS - Tower

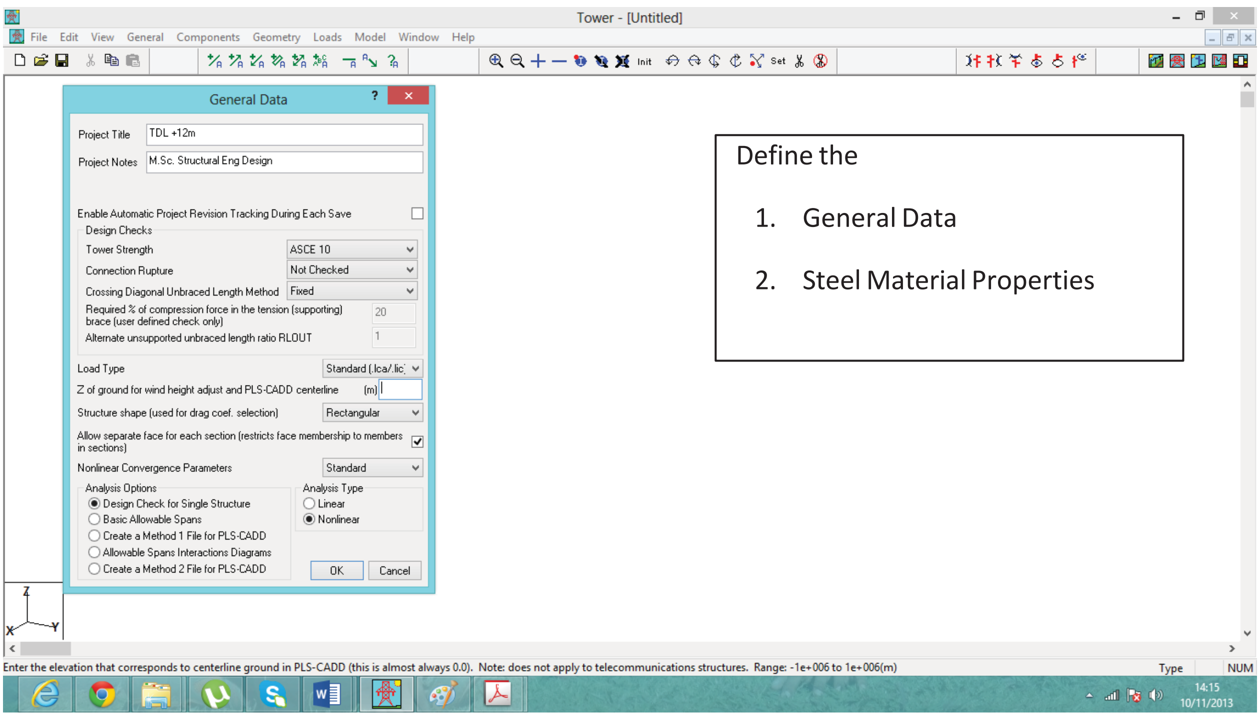
Step by Step instruction and method for modeling and analysis of PLS – Tower

Open New Job

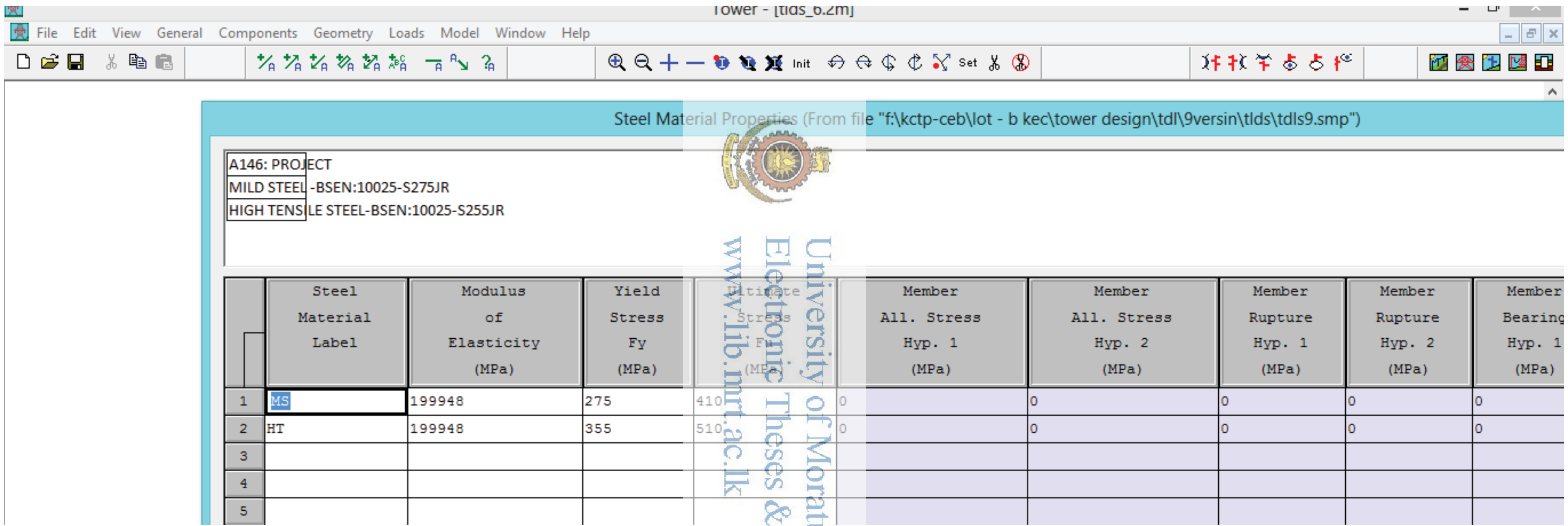




1. General Data (General>General Data)

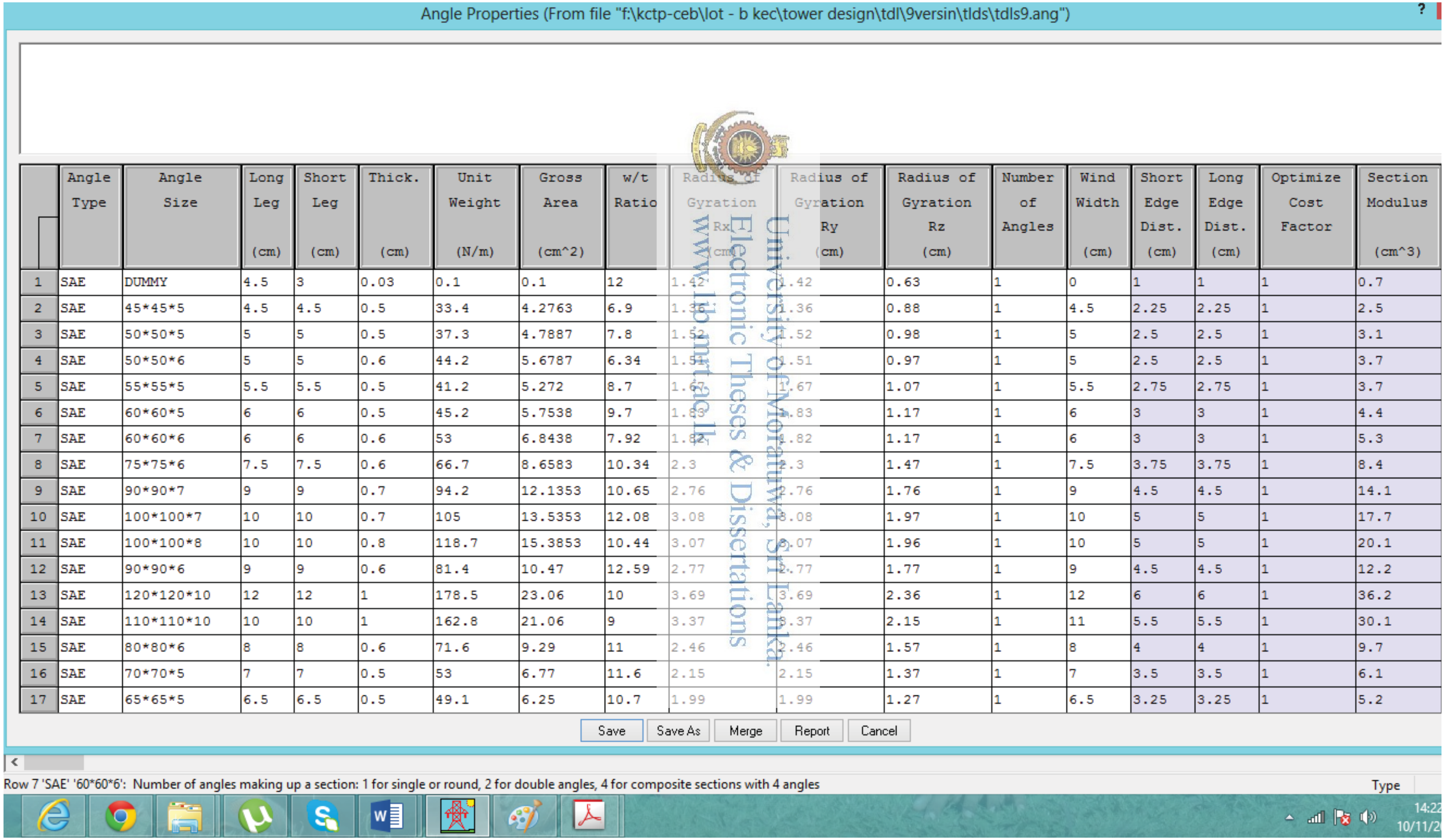


2. Steel Material Properties (Component> Steel Material)



	Steel Material Label	Modulus of Elasticity (MPa)	Yield Stress Fy (MPa)	Ultimate Stress Fu (MPa)	Member All. Stress Hyp. 1 (MPa)	Member All. Stress Hyp. 2 (MPa)	Member Rupture Hyp. 1 (MPa)	Member Rupture Hyp. 2 (MPa)	Member Bearing Hyp. 1 (MPa)
1	MS	199948	275	410	0	0	0	0	0
2	HT	199948	355	510	0	0	0	0	0
3									
4									
5									

3. Define of Angle Properties (Component> Angle……….)



Angle Properties (From file "f:\kctp-ceb\lot - b kec\tower design\tdl\9versin\tlds\tdls9.ang")

	Angle Type	Angle Size	Long Leg (cm)	Short Leg (cm)	Thick. (cm)	Unit Weight (N/m)	Gross Area (cm^2)	w/t Ratio	Radius of Gyration Rx (cm)	Radius of Gyration Ry (cm)	Radius of Gyration Rz (cm)	Number of Angles	Wind Width (cm)	Short Edge Dist. (cm)	Long Edge Dist. (cm)	Optimize Cost Factor	Section Modulus (cm^3)
1	SAE	DUMMY	4.5	3	0.03	0.1	0.1	12	1.42	1.42	0.63	1	0	1	1	1	0.7
2	SAE	45*45*5	4.5	4.5	0.5	33.4	4.2763	6.9	1.36	1.36	0.88	1	4.5	2.25	2.25	1	2.5
3	SAE	50*50*5	5	5	0.5	37.3	4.7887	7.8	1.52	1.52	0.98	1	5	2.5	2.5	1	3.1
4	SAE	50*50*6	5	5	0.6	44.2	5.6787	6.34	1.51	1.51	0.97	1	5	2.5	2.5	1	3.7
5	SAE	55*55*5	5.5	5.5	0.5	41.2	5.272	8.7	1.67	1.67	1.07	1	5.5	2.75	2.75	1	3.7
6	SAE	60*60*5	6	6	0.5	45.2	5.7538	9.7	1.83	1.83	1.17	1	6	3	3	1	4.4
7	SAE	60*60*6	6	6	0.6	53	6.8438	7.92	1.82	1.82	1.17	1	6	3	3	1	5.3
8	SAE	75*75*6	7.5	7.5	0.6	66.7	8.6583	10.34	2.3	2.3	1.47	1	7.5	3.75	3.75	1	8.4
9	SAE	90*90*7	9	9	0.7	94.2	12.1353	10.65	2.76	2.76	1.76	1	9	4.5	4.5	1	14.1
10	SAE	100*100*7	10	10	0.7	105	13.5353	12.08	3.08	3.08	1.97	1	10	5	5	1	17.7
11	SAE	100*100*8	10	10	0.8	118.7	15.3853	10.44	3.07	3.07	1.96	1	10	5	5	1	20.1
12	SAE	90*90*6	9	9	0.6	81.4	10.47	12.59	2.77	2.77	1.77	1	9	4.5	4.5	1	12.2
13	SAE	120*120*10	12	12	1	178.5	23.06	10	3.69	3.69	2.36	1	12	6	6	1	36.2
14	SAE	110*110*10	10	10	1	162.8	21.06	9	3.37	3.37	2.15	1	11	5.5	5.5	1	30.1
15	SAE	80*80*6	8	8	0.6	71.6	9.29	11	2.46	2.46	1.57	1	8	4	4	1	9.7
16	SAE	70*70*5	7	7	0.5	53	6.77	11.6	2.15	2.15	1.37	1	7	3.5	3.5	1	6.1
17	SAE	65*65*5	6.5	6.5	0.5	49.1	6.25	10.7	1.99	1.99	1.27	1	6.5	3.25	3.25	1	5.2

Save | Save As | Merge | Report | Cancel

Row 7 'SAE' '60*60*6': Number of angles making up a section: 1 for single or round, 2 for double angles, 4 for composite sections with 4 angles

Type

4. Define the Bolt Properties (Component> Bolt.........)

Bolt Properties (From file "f:\kctp-ceb\lot - b kec\tower design\tdl\9versin\tlds\tdls9.blt")

	Bolt Label	Bolt Diameter (cm)	Hole Diameter (cm)	Ultimate Shear Capacity (kN)	Default End Distance (cm)	Default Bolt Spacing (cm)	Shear Capacity Hyp. 1 (kN)	Shear Capacity Hyp. 2 (kN)
1	M16	1.6	1.75	60	2.5	4	0	0
2								

5. Define Joints Geometry (Geometry>Primary Joint)

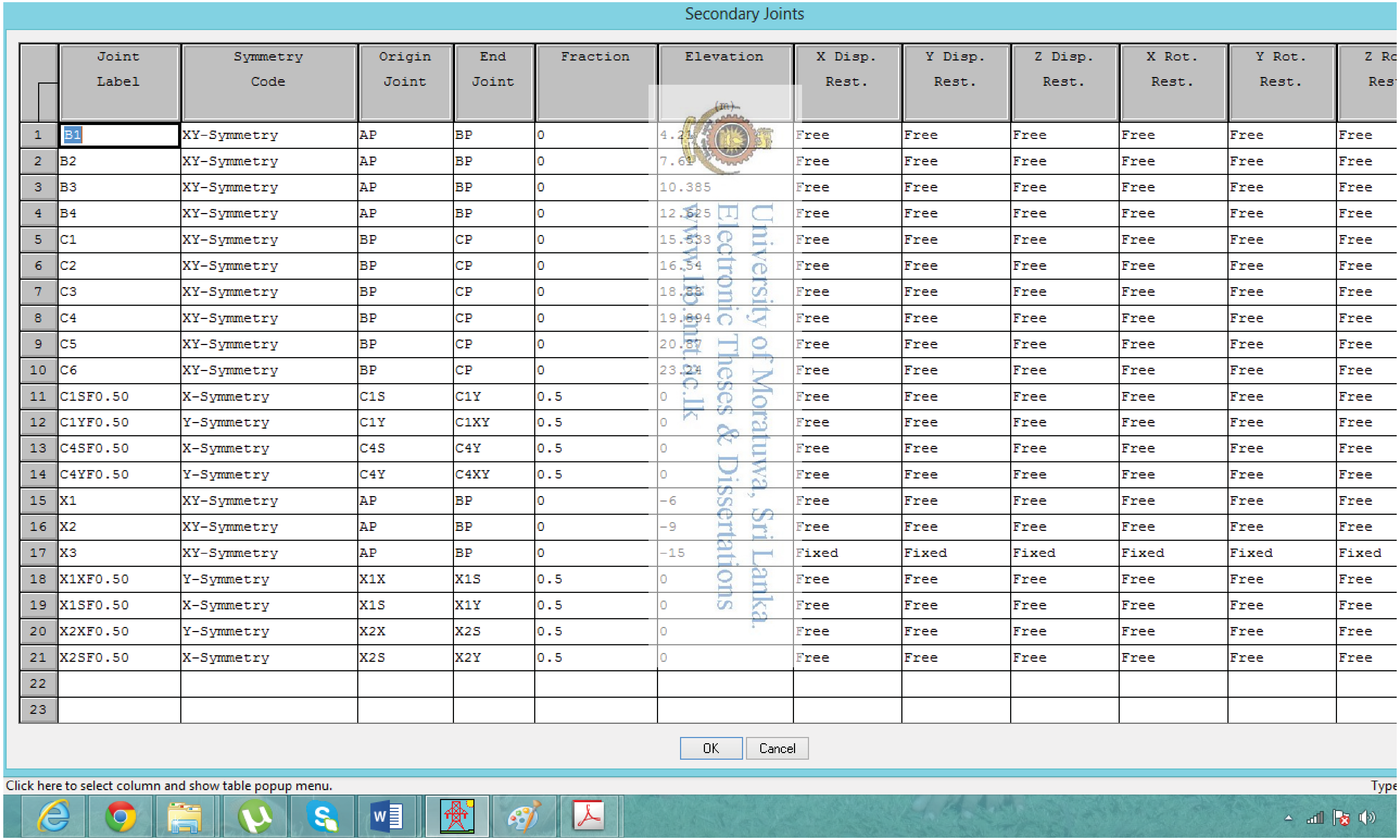
Tower - [tdls-6.2m]

File Edit View General Components Geometry Loads Model Window Help

Joints Geometry

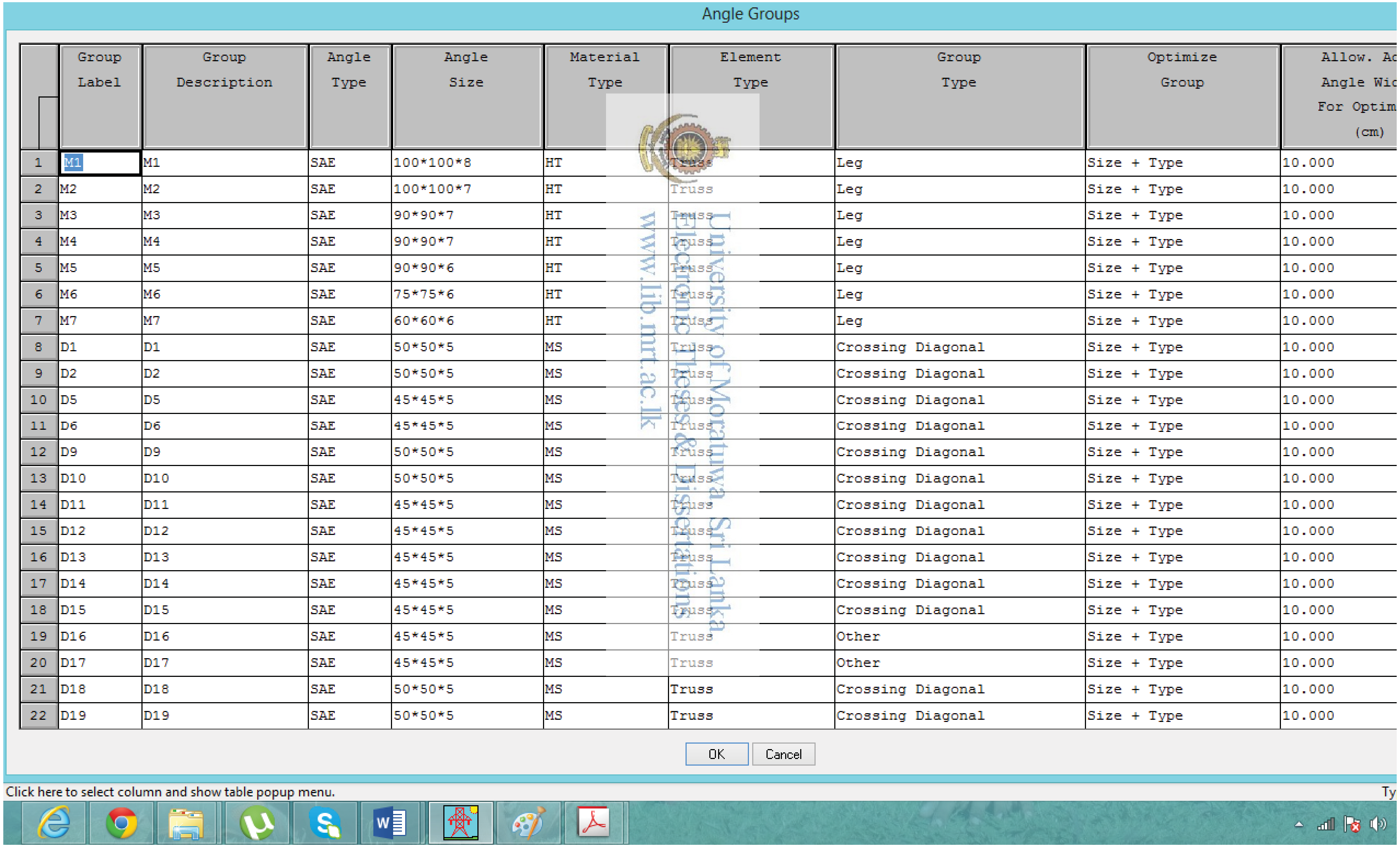
	Joint Label	Symmetry Code	X Coord. (m)	Y Coord. (m)	Z Coord. (m)	X Disp. Rest.	Y Disp. Rest.	Z Disp. Rest.	X Rot. Rest.	Y Rot. Rest.	Z Rot. Rest.
1	A	XY-Symmetry	2.031116389	2.031116389	0	Free	Free	Free	Free	Free	Free
2	B	XY-Symmetry	1	1	14.47	Free	Free	Free	Free	Free	Free
3	C	XY-Symmetry	0.75	0.75	24.32	Free	Free	Free	Free	Free	Free
4	JA	None	0	0	27.47	Free	Free	Free	Free	Free	Free
5	CA	X-Symmetry	0	4.24	14.47	Free	Free	Free	Free	Free	Free
6	CC	X-Symmetry	0	3.937	18.88	Free	Free	Free	Free	Free	Free
7	CE	X-Symmetry	0	3.85	23.24	Free	Free	Free	Free	Free	Free

6. Define Joints Geometry (Geometry>Secondary Joint)



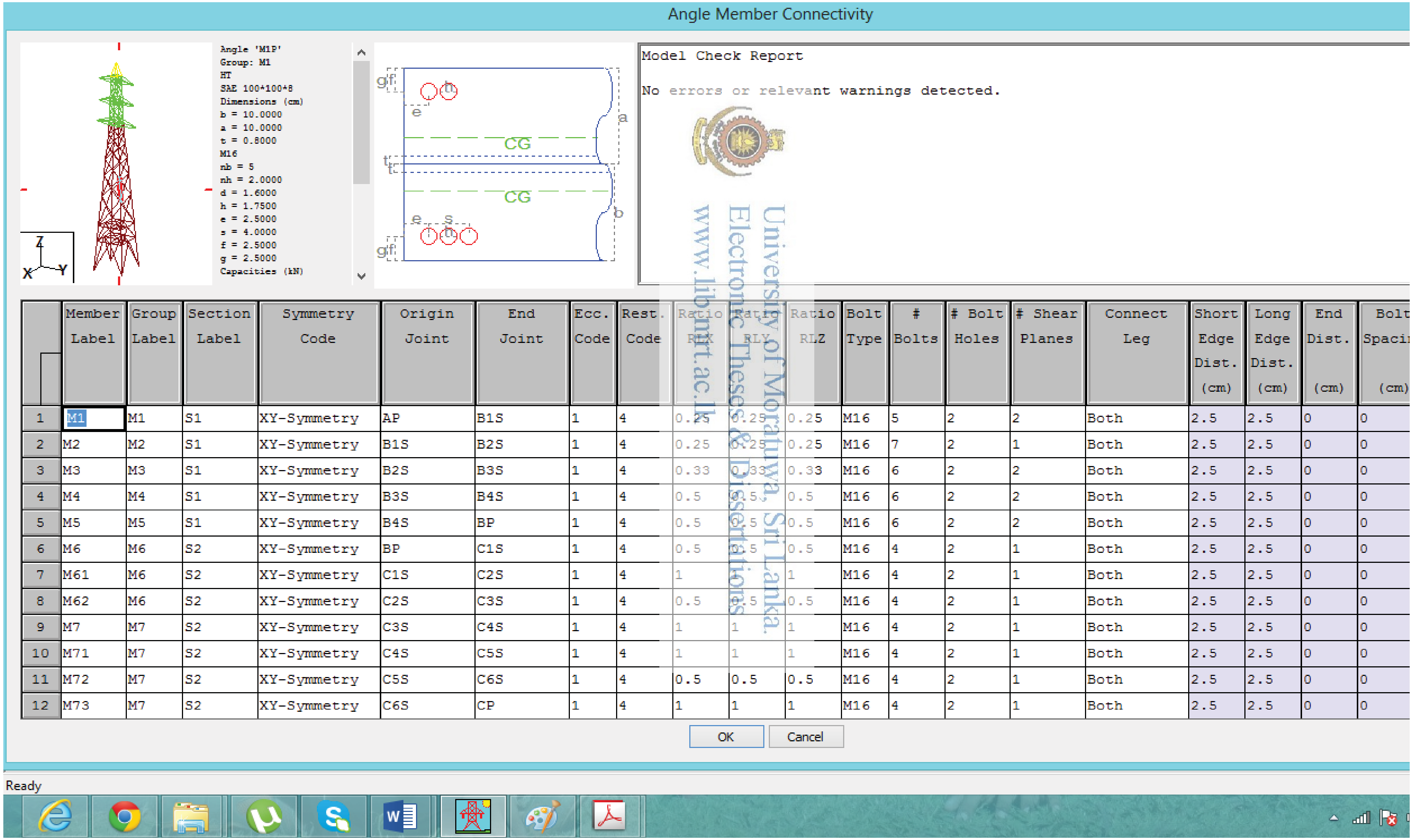
	Joint Label	Symmetry Code	Origin Joint	End Joint	Fraction	Elevation (m)	X Disp. Rest.	Y Disp. Rest.	Z Disp. Rest.	X Rot. Rest.	Y Rot. Rest.	Z Ro[t]. Res[t].
1	B1	XY-Symmetry	AP	BP	0	4.21	Free	Free	Free	Free	Free	Free
2	B2	XY-Symmetry	AP	BP	0	7.61	Free	Free	Free	Free	Free	Free
3	B3	XY-Symmetry	AP	BP	0	10.385	Free	Free	Free	Free	Free	Free
4	B4	XY-Symmetry	AP	BP	0	12.625	Free	Free	Free	Free	Free	Free
5	C1	XY-Symmetry	BP	CP	0	15.533	Free	Free	Free	Free	Free	Free
6	C2	XY-Symmetry	BP	CP	0	16.54	Free	Free	Free	Free	Free	Free
7	C3	XY-Symmetry	BP	CP	0	18.88	Free	Free	Free	Free	Free	Free
8	C4	XY-Symmetry	BP	CP	0	19.894	Free	Free	Free	Free	Free	Free
9	C5	XY-Symmetry	BP	CP	0	20.87	Free	Free	Free	Free	Free	Free
10	C6	XY-Symmetry	BP	CP	0	23.24	Free	Free	Free	Free	Free	Free
11	C1SF0.50	X-Symmetry	C1S	C1Y	0.5	0	Free	Free	Free	Free	Free	Free
12	C1YF0.50	Y-Symmetry	C1Y	C1XY	0.5	0	Free	Free	Free	Free	Free	Free
13	C4SF0.50	X-Symmetry	C4S	C4Y	0.5	0	Free	Free	Free	Free	Free	Free
14	C4YF0.50	Y-Symmetry	C4Y	C4XY	0.5	0	Free	Free	Free	Free	Free	Free
15	X1	XY-Symmetry	AP	BP	0	-6	Free	Free	Free	Free	Free	Free
16	X2	XY-Symmetry	AP	BP	0	-9	Free	Free	Free	Free	Free	Free
17	X3	XY-Symmetry	AP	BP	0	-15	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
18	X1XF0.50	Y-Symmetry	X1X	X1S	0.5	0	Free	Free	Free	Free	Free	Free
19	X1SF0.50	X-Symmetry	X1S	X1Y	0.5	0	Free	Free	Free	Free	Free	Free
20	X2XF0.50	Y-Symmetry	X2X	X2S	0.5	0	Free	Free	Free	Free	Free	Free
21	X2SF0.50	X-Symmetry	X2S	X2Y	0.5	0	Free	Free	Free	Free	Free	Free
22												
23												

7. Define Angle Group (Geometry>Angle Group..)



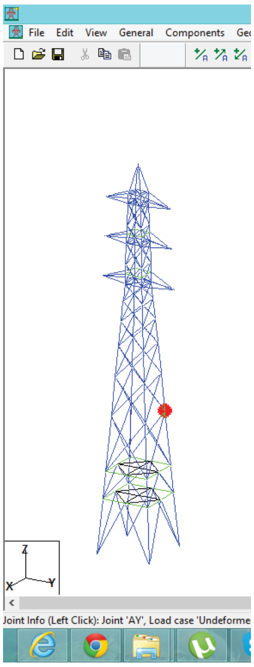
	Group Label	Group Description	Angle Type	Angle Size	Material Type	Element Type	Group Type	Optimize Group	Allow. Ac Angle Wic For Optim (cm)
1	M1	M1	SAE	100*100*8	HT	Truss	Leg	Size + Type	10.000
2	M2	M2	SAE	100*100*7	HT	Truss	Leg	Size + Type	10.000
3	M3	M3	SAE	90*90*7	HT	Truss	Leg	Size + Type	10.000
4	M4	M4	SAE	90*90*7	HT	Truss	Leg	Size + Type	10.000
5	M5	M5	SAE	90*90*6	HT	Truss	Leg	Size + Type	10.000
6	M6	M6	SAE	75*75*6	HT	Truss	Leg	Size + Type	10.000
7	M7	M7	SAE	60*60*6	HT	Truss	Leg	Size + Type	10.000
8	D1	D1	SAE	50*50*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
9	D2	D2	SAE	50*50*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
10	D5	D5	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
11	D6	D6	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
12	D9	D9	SAE	50*50*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
13	D10	D10	SAE	50*50*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
14	D11	D11	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
15	D12	D12	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
16	D13	D13	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
17	D14	D14	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
18	D15	D15	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
19	D16	D16	SAE	45*45*5	MS	Truss	Other	Size + Type	10.000
20	D17	D17	SAE	45*45*5	MS	Truss	Other	Size + Type	10.000
21	D18	D18	SAE	50*50*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
22	D19	D19	SAE	50*50*5	MS	Truss	Crossing Diagonal	Size + Type	10.000

8. Define Angle Member

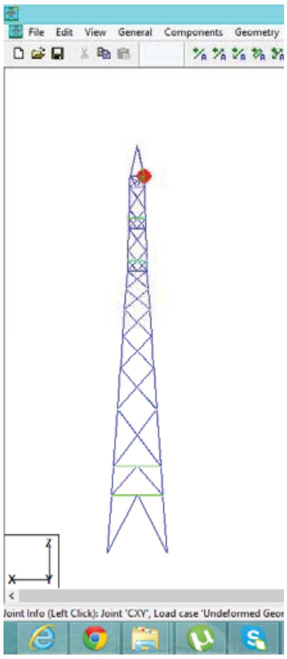


	Member Label	Group Label	Section Label	Symmetry Code	Origin Joint	End Joint	Ecc. Code	Rest. Code	Ratio RLX	Ratio RLY	Ratio RLZ	Bolt Type	# Bolts	# Bolt Holes	# Shear Planes	Connect Leg	Short Edge Dist. (cm)	Long Edge Dist. (cm)	End Dist. (cm)	Bolt Spaci (cm)
1	M1	M1	S1	XY-Symmetry	AP	B1S	1	4	0.25	0.25	0.25	M16	5	2	2	Both	2.5	2.5	0	0
2	M2	M2	S1	XY-Symmetry	B1S	B2S	1	4	0.25	0.25	0.25	M16	7	2	1	Both	2.5	2.5	0	0
3	M3	M3	S1	XY-Symmetry	B2S	B3S	1	4	0.33	0.33	0.33	M16	6	2	2	Both	2.5	2.5	0	0
4	M4	M4	S1	XY-Symmetry	B3S	B4S	1	4	0.5	0.5	0.5	M16	6	2	2	Both	2.5	2.5	0	0
5	M5	M5	S1	XY-Symmetry	B4S	BP	1	4	0.5	0.5	0.5	M16	6	2	2	Both	2.5	2.5	0	0
6	M6	M6	S2	XY-Symmetry	BP	C1S	1	4	0.5	0.5	0.5	M16	4	2	1	Both	2.5	2.5	0	0
7	M61	M6	S2	XY-Symmetry	C1S	C2S	1	4	1	[illegible]	1	M16	4	2	1	Both	2.5	2.5	0	0
8	M62	M6	S2	XY-Symmetry	C2S	C3S	1	4	0.5	0.5	0.5	M16	4	2	1	Both	2.5	2.5	0	0
9	M7	M7	S2	XY-Symmetry	C3S	C4S	1	4	1	1	1	M16	4	2	1	Both	2.5	2.5	0	0
10	M71	M7	S2	XY-Symmetry	C4S	C5S	1	4	1	1	1	M16	4	2	1	Both	2.5	2.5	0	0
11	M72	M7	S2	XY-Symmetry	C5S	C6S	1	4	0.5	0.5	0.5	M16	4	2	1	Both	2.5	2.5	0	0
12	M73	M7	S2	XY-Symmetry	C6S	CP	1	4	1	1	1	M16	4	2	1	Both	2.5	2.5	0	0

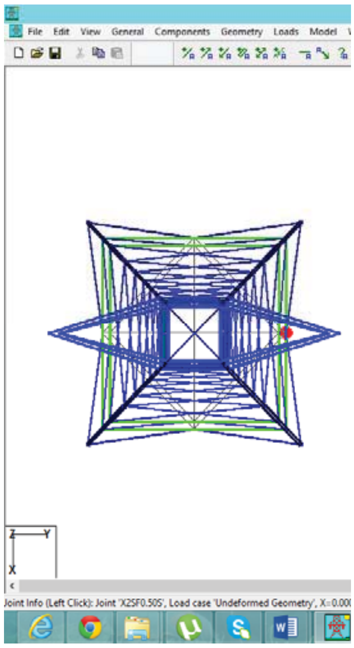
9. Model View



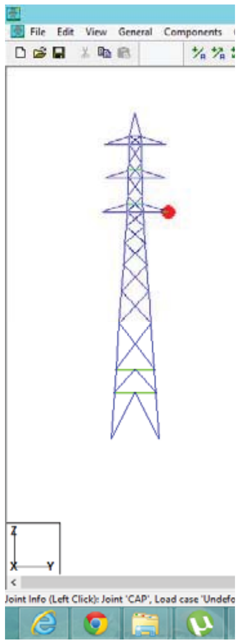
Isometric View



View from Left /Right



View from Top



View from Front

10. Define the Load Cases (Load>Vector Load(LCA File)...)

Vector Load Cases - [f:\kctp-ceb\lot - b kec\tower design\tdl\9versin\tlds\tdls9.lca]

☑ Wind loads on insulators and insulator weights included in Point Loads

Edit Loading Method Parameters — Note that SF stands for Strength Factor, NOT Safety Factor

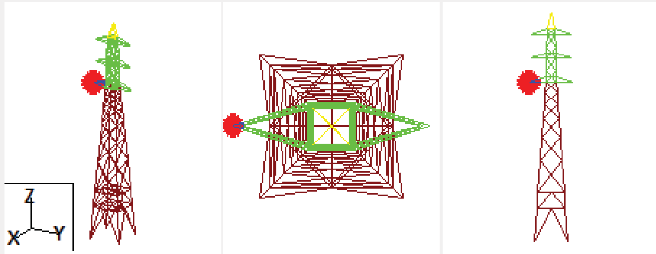
	Load Case Description	Dead Load Factor	Wind Area Factor	SF for Steel Poles Tubular Arms and Towers	SF for Wood Poles	SF for Conc. Ult.	SF for Conc. First Crack	SF for Conc. Zero Tens.	SF for Guys and Cables	SF for Non Tubular Arms	SF for Braces	SF for Insuls.	SF For Found.	Point Loads	Wind/Ice Model	Trans. Wind Pressure (Pa)	Longit. Wind Pressure (Pa)	Ice Thick. (cm)
1	b001-NCMX	2	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
2	b002-NCMN	2	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
3	b003-PKMX	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
4	b004PKMN	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
5	b005-1LMX	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
6	b006-1LMN	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
7	b007-2LMX	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
8	b008-2LMN	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
9	b009-3LMX	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
10	b010-3LMN	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
11	b011-1RMX	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
12	b012-1RMN	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
13	b013-2RMX	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
14	b014-2R MN	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
15	b015-3RMX	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
16	b016-3RMN	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
17	b017-NCLSMX	2	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
18	b018-NCLSMN	2	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000
19	b019-PKLSMX	1.25	1	1	1	1	0	0	1	1	1	1	1	Edit (15	Wind on Face	0	0	0.000

Save | Save As | Merge | Cancel

Row 15 'b015-3RMX': Strength factor to be used for insulators: 0 will prevent this component from being checked, 0.5 will halve its strength Range: 0 to 3.4e+038 — Type

11. Point Load

Point Loads - [b001-NCMX]



Model Check Report

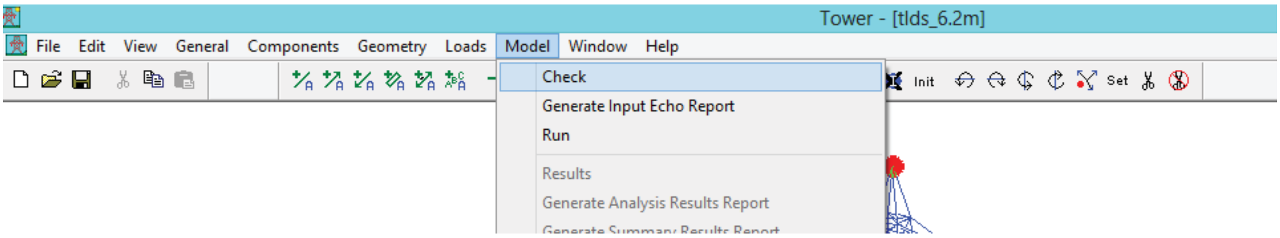
No errors or relevant warnings detected.

	Joint Label	Vertical Load (N)	Transverse Load (N)	Longitudinal Load (N)	Load Comment
1	AP	0	8784	0	AP
2	AX	0	8784	0	AX
3	AY	0	8784	0	AY
4	AXY	0	8784	0	AXY
5	CAX	23670	30941	0	CAX
6	CAP	23670	30941	0	CAP
7	CCX	23670	25348	0	CCX
8	CCP	23670	25348	0	CCP
9	CEX	23670	24420	0	CEX
10	CEP	23670	24420	0	CEP
11	JAP	9200	10197	0	JAP
12	X2S	0	6375	0	X2S
13	X2X	0	6375	0	X2X
14	X2Y	0	6375	0	X2Y
15	X2XY	0	6375	0	X2XY

OK Cancel

Row 14 'X2Y': Longitudinal is along the X axis (positive coming out of the screen) Section

12. Check the Model (Model>check)

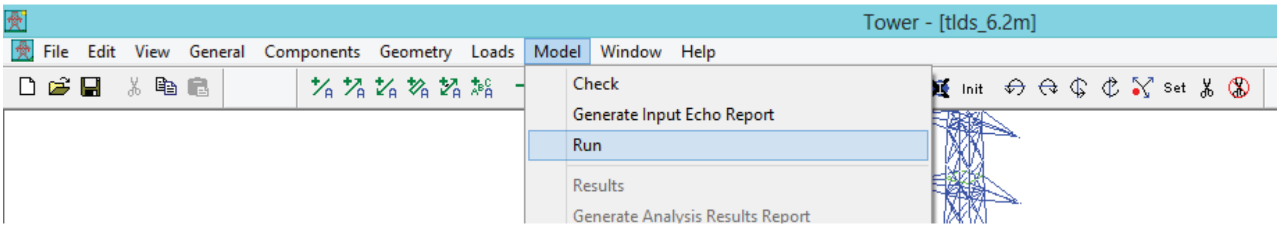


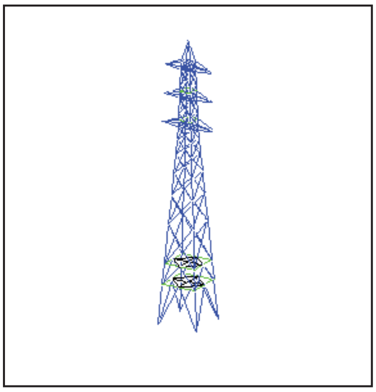
Results:

```
Tower Version 9.20    14:36:10 10 November 2013

Check of model "132 kv D/C tower type TDLS"
    Checking 19 Joints
    Checking 1 Bolt properties
    Checking 276 Angle elements
    Checking 64 Angle groups
    Checking 3 Equipment properties
    Checking load case "b001-NCMX"
        Checking 15 concentrated loads
    Checking load case "b002-NCMN"
        Checking 15 concentrated loads
    Checking load case "b003-PKMX"
        Checking 15 concentrated loads
    Checking load case "b004-PKMN"
        Checking 15 concentrated loads
    Checking load case "b005-1LMX"
        Checking 15 concentrated loads
    Checking load case "b006-1LMN"
        Checking 15 concentrated loads
    Checking load case "b007-2LMX"
        Checking 15 concentrated loads
    Checking load case "b008-2LMN"
        Checking 15 concentrated loads
    Checking load case "b009-3LMX"
        Checking 15 concentrated loads
    Checking load case "b010-3LMN"
        Checking 15 concentrated loads
    Checking load case "b011-1RMX"
        Checking 15 concentrated loads
    Checking load case "b012-1RMN"
        Checking 15 concentrated loads
    Checking load case "b013-2RMX"
        Checking 15 concentrated loads
    Checking load case "b014-2R MN"
        Checking 15 concentrated loads
    Checking load case "b015-3RMX"
        Checking 15 concentrated loads
    Checking load case "b016-3RMN"
        Checking 15 concentrated loads
    Checking load case "b017-NCLSMX"
        Checking 15 concentrated loads
    Checking load case "b018-NCLSMN"
        Checking 15 concentrated loads
    Checking load case "b019-PKLSMX"
        Checking 15 concentrated loads
    Checking load case "b020-PKLSMN"
        Checking 15 concentrated loads
```

```
    Checking load case "b021-1LLSMX"
        Checking 15 concentrated loads
    Checking load case "b022-1LLSMN"
        Checking 15 concentrated loads
    Checking load case "b023-2LLSMX"
        Checking 15 concentrated loads
    Checking load case "b024-2LLSMN"
        Checking 15 concentrated loads
    Checking load case "b025-3LLSMX"
        Checking 15 concentrated loads
    Checking load case "b026-3LLSMN"
        Checking 15 concentrated loads
    Checking load case "b027-NCRSMX"
        Checking 15 concentrated loads
    Checking load case "b028-NCRSMN"
        Checking 15 concentrated loads
    Checking load case "b029-PKRSMX"
        Checking 15 concentrated loads
    Checking load case "b030-PKRSMN"
        Checking 15 concentrated loads
    Checking load case "b031-1RRSMX"
        Checking 15 concentrated loads
    Checking load case "b032-1RRSMN"
        Checking 15 concentrated loads
    Checking load case "b033-2RRSMX"
        Checking 15 concentrated loads
    Checking load case "b034-2RRSMN"
        Checking 15 concentrated loads
    Checking load case "b035-3RRSMX"
        Checking 15 concentrated loads
    Checking load case "b036-3RRSMN"
        Checking 15 concentrated loads
    Checking 68 Secondary Joints
    Checking 3 sections

    Checking 1 Clamp properties
    Checking 15 Clamp insulators
Checking 15 PLS-CADD links
Total of 0 errors detected while checking


Checking if a model for analysis can be built...
Model built successfully.

Checking view...

Joint Errors report: (Joint errors shown in red in current geometry view)
  0 Errors detected


Joint Warnings report: (Joint warnings shown in green in current geometry view)
  0 Warnings detected


Member Warnings report: (Member warnings shown in green in current geometry
view)
  0 Warnings detected
```

13. Analysis the Model (Model> Run)





Joints Geometry:

Joint Label	Symmetry Code	X Coord. (m)	Y Coord. (m)	Z Coord. (m)	X Disp. Rest.	Y Disp. Rest.	Z Disp. Rest.	X Rot. Rest.	Y Rot. Rest.	Z Rot. Rest.
AP	XY-Symmetry	2.031	2.031	0	Free	Free	Free	Free	Free	Free
BP	XY-Symmetry	1	1	14.47	Free	Free	Free	Free	Free	Free
CP	XY-Symmetry	0.75	0.75	24.32	Free	Free	Free	Free	Free	Free
JAP	None	0	0	27.47	Free	Free	Free	Free	Free	Free
CAP	X-Symmetry	0	-4.24	14.47	Free	Free	Free	Free	Free	Free
CCP	X-Symmetry	0	-3.937	18.88	Free	Free	Free	Free	Free	Free
CEP	X-Symmetry	0	-3.85	23.24	Free	Free	Free	Free	Free	Free
AX	X-GenXY	2.031	-2.031	0	Free	Free	Free	Free	Free	Free
AXY	XY-GenXY	-2.031	-2.031	0	Free	Free	Free	Free	Free	Free
AY	Y-GenXY	-2.031	2.031	0	Free	Free	Free	Free	Free	Free
BX	X-GenXY	1	-1	14.47	Free	Free	Free	Free	Free	Free
BXY	XY-GenXY	-1	-1	14.47	Free	Free	Free	Free	Free	Free
BY	Y-GenXY	-1	1	14.47	Free	Free	Free	Free	Free	Free
CX	X-GenXY	0.75	-0.75	24.32	Free	Free	Free	Free	Free	Free
CXY	XY-GenXY	-0.75	-0.75	24.32	Free	Free	Free	Free	Free	Free
CY	Y-GenXY	-0.75	0.75	24.32	Free	Free	Free	Free	Free	Free
CAX	X-Gen	0	-4.24	14.47	Free	Free	Free	Free	Free	Free
CCX	X-Gen	0	-3.937	18.88	Free	Free	Free	Free	Free	Free
CEX	X-Gen	0	-3.85	23.24	Free	Free	Free	Free	Free	Free

Secondary Joints:

Joint Label	Symmetry Code	Origin Joint	End Joint	Fraction	Elevation (m)	X Disp. Rest.	Y Disp. Rest.	Z Disp. Rest.	X Rot. Rest.	Y Rot. Rest.	Z Rot. Rest.
B1S	XY-Symmetry	AP	BP	0	4.21	Free	Free	Free	Free	Free	Free
B2S	XY-Symmetry	AP	BP	0	7.61	Free	Free	Free	Free	Free	Free
B3S	XY-Symmetry	AP	BP	0	10.39	Free	Free	Free	Free	Free	Free
B4S	XY-Symmetry	AP	BP	0	12.63	Free	Free	Free	Free	Free	Free
C1S	XY-Symmetry	BP	CP	0	15.53	Free	Free	Free	Free	Free	Free
C2S	XY-Symmetry	BP	CP	0	16.54	Free	Free	Free	Free	Free	Free
C3S	XY-Symmetry	BP	CP	0	18.88	Free	Free	Free	Free	Free	Free
C4S	XY-Symmetry	BP	CP	0	19.89	Free	Free	Free	Free	Free	Free
C5S	XY-Symmetry	BP	CP	0	20.87	Free	Free	Free	Free	Free	Free
C6S	XY-Symmetry	BP	CP	0	23.24	Free	Free	Free	Free	Free	Free
C1SF0.50S	X-Symmetry	C1S	C1Y	0.5	0	Free	Free	Free	Free	Free	Free
C1YF0.50S	Y-Symmetry	C1Y	C1XY	0.5	0	Free	Free	Free	Free	Free	Free
C4SF0.50S	X-Symmetry	C4S	C4Y	0.5	0	Free	Free	Free	Free	Free	Free
C4YF0.50S	Y-Symmetry	C4Y	C4XY	0.5	0	Free	Free	Free	Free	Free	Free
X1S	XY-Symmetry	AP	BP	0	-6	Free	Free	Free	Free	Free	Free
X2S	XY-Symmetry	AP	BP	0	-9	Free	Free	Free	Free	Free	Free
X3S	XY-Symmetry	AP	BP	0	-15	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
X1XF0.50S	Y-Symmetry	X1X	X1S	0.5	0	Free	Free	Free	Free	Free	Free
X1SF0.50S	X-Symmetry	X1S	X1Y	0.5	0	Free	Free	Free	Free	Free	Free
X2XF0.50S	Y-Symmetry	X2X	X2S	0.5	0	Free	Free	Free	Free	Free	Free
X2SF0.50S	X-Symmetry	X2S	X2Y	0.5	0	Free	Free	Free	Free	Free	Free
B1X	X-GenXY	AP	BP	0	4.21	Free	Free	Free	Free	Free	Free
B1XY	XY-GenXY	AP	BP	0	4.21	Free	Free	Free	Free	Free	Free
B1Y	Y-GenXY	AP	BP	0	4.21	Free	Free	Free	Free	Free	Free

Secondary Joints:

Joint Label	Symmetry Code	Origin Joint	End Joint	Fraction	Elevation (m)	X Disp. Rest.	Y Disp. Rest.	Z Disp. Rest.	X Rot. Rest.	Y Rot. Rest.	Z Rot. Rest.
B2X	X-GenXY	AP	BP	0	7.61	Free	Free	Free	Free	Free	Free
B2XY	XY-GenXY	AP	BP	0	7.61	Free	Free	Free	Free	Free	Free
B2Y	Y-GenXY	AP	BP	0	7.61	Free	Free	Free	Free	Free	Free
B3X	X-GenXY	AP	BP	0	10.39	Free	Free	Free	Free	Free	Free
B3XY	XY-GenXY	AP	BP	0	10.39	Free	Free	Free	Free	Free	Free
B3Y	Y-GenXY	AP	BP	0	10.39	Free	Free	Free	Free	Free	Free
B4X	X-GenXY	AP	BP	0	12.63	Free	Free	Free	Free	Free	Free
B4XY	XY-GenXY	AP	BP	0	12.63	Free	Free	Free	Free	Free	Free
B4Y	Y-GenXY	AP	BP	0	12.63	Free	Free	Free	Free	Free	Free
C1X	X-GenXY	BP	CP	0	15.53	Free	Free	Free	Free	Free	Free
C1XY	XY-GenXY	BP	CP	0	15.53	Free	Free	Free	Free	Free	Free
C1Y	Y-GenXY	BP	CP	0	15.53	Free	Free	Free	Free	Free	Free
C2X	X-GenXY	BP	CP	0	16.54	Free	Free	Free	Free	Free	Free
C2XY	XY-GenXY	BP	CP	0	16.54	Free	Free	Free	Free	Free	Free
C2Y	Y-GenXY	BP	CP	0	16.54	Free	Free	Free	Free	Free	Free
C3X	X-GenXY	BP	CP	0	18.88	Free	Free	Free	Free	Free	Free

Joint Label	Symmetry Code	Origin Joint	End Joint	Fraction	Elevation (m)	X Disp. Rest.	Y Disp. Rest.	Z Disp. Rest.	X Rot. Rest.	Y Rot. Rest.	Z Rot. Rest.
C3XY	XY-GenXY	BP	CP	0	18.88	Free	Free	Free	Free	Free	Free
C3Y	Y-GenXY	BP	CP	0	18.88	Free	Free	Free	Free	Free	Free
C4X	X-GenXY	BP	CP	0	19.89	Free	Free	Free	Free	Free	Free
C4XY	XY-GenXY	BP	CP	0	19.89	Free	Free	Free	Free	Free	Free
C4Y	Y-GenXY	BP	CP	0	19.89	Free	Free	Free	Free	Free	Free
C5X	X-GenXY	BP	CP	0	20.87	Free	Free	Free	Free	Free	Free
C5XY	XY-GenXY	BP	CP	0	20.87	Free	Free	Free	Free	Free	Free
C5Y	Y-GenXY	BP	CP	0	20.87	Free	Free	Free	Free	Free	Free
C6X	X-GenXY	BP	CP	0	23.24	Free	Free	Free	Free	Free	Free
C6XY	XY-GenXY	BP	CP	0	23.24	Free	Free	Free	Free	Free	Free
C6Y	Y-GenXY	BP	CP	0	23.24	Free	Free	Free	Free	Free	Free
C1SF0.50X	X-Gen	C1S	C1Y	0.5	0	Free	Free	Free	Free	Free	Free
C1YF0.50Y	Y-Gen	C1Y	C1XY	0.5	0	Free	Free	Free	Free	Free	Free
C4SF0.50X	X-Gen	C4S	C4Y	0.5	0	Free	Free	Free	Free	Free	Free
C4YF0.50Y	Y-Gen	C4Y	C4XY	0.5	0	Free	Free	Free	Free	Free	Free
X1X	X-GenXY	AP	BP	0	-6	Free	Free	Free	Free	Free	Free
X1XY	XY-GenXY	AP	BP	0	-6	Free	Free	Free	Free	Free	Free
X1Y	Y-GenXY	AP	BP	0	-6	Free	Free	Free	Free	Free	Free
X2X	X-GenXY	AP	BP	0	-9	Free	Free	Free	Free	Free	Free
X2XY	XY-GenXY	AP	BP	0	-9	Free	Free	Free	Free	Free	Free
X2Y	Y-GenXY	AP	BP	0	-9	Free	Free	Free	Free	Free	Free
X3X	X-GenXY	AP	BP	0	-15	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
X3XY	XY-GenXY	AP	BP	0	-15	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
X3Y	Y-GenXY	AP	BP	0	-15	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
X1XF0.50Y	Y-Gen	X1X	X1S	0.5	0	Free	Free	Free	Free	Free	Free
X1SF0.50X	X-Gen	X1S	X1Y	0.5	0	Free	Free	Free	Free	Free	Free
X2XF0.50Y	Y-Gen	X2X	X2S	0.5	0	Free	Free	Free	Free	Free	Free
X2SF0.50X	X-Gen	X2S	X2Y	0.5	0	Free	Free	Free	Free	Free	Free

Angle Groups:

Group Label	Group Description	Angle Type	Angle Size	Material Type	Element Type	Group Type	Optimize Group	Allow. Add. Angle Width For Optimize (cm)
M1	M1	SAE	100*100*8	HT	Truss	Leg	Size + Type	10.000
M2	M2	SAE	100*100*7	HT	Truss	Leg	Size + Type	10.000
M3	M3	SAE	90*90*7	HT	Truss	Leg	Size + Type	10.000
M4	M4	SAE	90*90*7	HT	Truss	Leg	Size + Type	10.000
M5	M5	SAE	90*90*6	HT	Truss	Leg	Size + Type	10.000
M6	M6	SAE	75*75*6	HT	Truss	Leg	Size + Type	10.000
M7	M7	SAE	60*60*6	HT	Truss	Leg	Size + Type	10.000
D1	D1	SAE	50*50*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D2	D2	SAE	50*50*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D5	D5	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D6	D6	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D9	D9	SAE	50*50*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D10	D10	SAE	50*50*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D11	D11	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D12	D12	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D13	D13	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D14	D14	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D15	D15	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D16	D16	SAE	45*45*5	MS	Truss	Other	Size + Type	10.000
D17	D17	SAE	45*45*5	MS	Truss	Other	Size + Type	10.000
D18	D18	SAE	50*50*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D19	D19	SAE	50*50*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D20	D20	SAE	45*45*5	MS	Truss	Crossing Diagonal	Size + Type	10.000
D21	D21	SAE	45*45*5	MS	Truss	Other	Size + Type	10.000
D22	D22	SAE	45*45*5	MS	Truss	Other	Size + Type	10.000

Angle Groups:

Group Label	Group Description	Angle Type	Angle Size	Material Type	Element Type	Group Type	Optimize Group	Allow. Add. Angle Width For Optimize (cm)
D23	D23	SAE	50*50*5	MS	Truss Crossing	Diagonal	Size + Type	10.000
D24	D24	SAE	50*50*5	MS	Truss Crossing	Diagonal	Size + Type	10.000
D25	D25	SAE	45*45*5	MS	Truss Crossing	Diagonal	Size + Type	10.000
D26	D26	SAE	45*45*5	MS	Truss Crossing	Diagonal	Size + Type	10.000
D27	D27	SAE	45*45*5	MS	Truss Crossing	Diagonal	Size + Type	10.000
D28	D28	SAE	45*45*5	MS	Truss Crossing	Diagonal	Size + Type	10.000
D30	D30	SAE	50*50*5	MS	Truss Crossing	Diagonal	Size + Type	10.000
D31	D31	SAE	50*50*5	MS	Truss Crossing	Diagonal	Size + Type	10.000
D38	D38	SAE	50*50*5	MS	Truss	Other	Size + Type	10.000
D39	D39	SAE	45*45*5	MS	Truss	Other	Size + Type	10.000
D42	D42	SAE	60*60*5	MS	Truss	Other	Size + Type	10.000
D43	D43	SAE	50*50*5	MS	Truss	Other	Size + Type	10.000
H1	H1	SAE	50*50*5	MS	Truss	Other	Size + Type	10.000
H2	H2	SAE	50*50*5	MS	Truss	Other	Size + Type	10.000
H3	H3	SAE	45*45*5	MS	Beam	Other	Size + Type	10.000
H4	H4	SAE	45*45*5	MS	Beam	Other	Size + Type	10.000
H5	H5	SAE	50*50*5	MS	Truss	Other	Size + Type	10.000
H6	H6	SAE	50*50*5	MS	Truss	Other	Size + Type	10.000
H7	H7	SAE	45*45*5	MS	Beam	Other	Size + Type	10.000
H8	H8	SAE	45*45*5	MS	Beam	Other	Size + Type	10.000
H9	H9	SAE	50*50*5	MS	Truss	Other	Size + Type	10.000
H10	H10	SAE	50*50*5	MS	Truss	Other	Size + Type	10.000

Group Label	Group Description	Angle Type	Angle Size	Material Type	Element Type	Group Type	Optimize Group	Allow. Add. Angle Width For Optimize (cm)
H11	H11	SAE	50*50*5	MS	Truss	Other	Size + Type	10.000
H12	H12	SAE	50*50*5	MS	Truss	Other	Size + Type	10.000
H13	H13	SAE	60*60*5	MS	Beam	Other	Size + Type	10.000
H14	H14	SAE	60*60*5	MS	Beam	Other	Size + Type	10.000
H17	H17	SAE	60*60*5	MS	Beam	Other	Size + Type	10.000
H18	H18	SAE	60*60*5	MS	Beam	Other	Size + Type	10.000
B1	B1	SAE	75*75*6	MS	Truss	Other	Size + Type	10.000
B2	B2	SAE	70*70*6	MS	Truss	Other	Size + Type	10.000
B3	B3	SAE	60*60*6	HT	Truss	Other	Size + Type	10.000
T1	T1	SAE	50*50*5	MS	Truss	Other	Size + Type	10.000
T2	T2	SAE	45*45*5	MS	Truss	Other	Size + Type	10.000
T3	T3	SAE	45*45*5	MS	Truss	Other	Size + Type	10.000
P1	P1	SAE	50*50*6	MS	Truss	Other	Size + Type	10.000
M8	M8	SAE	120*120*8	HT	Truss	Leg	Size + Type	10.000
M10	M10	SAE	100*100*8	HT	Truss	Leg	Size + Type	10.000
M12	M12	SAE	100*100*10	HT	Truss	Leg	Size + Type	10.000
DUMM	DUMM	SAE	DUMMY	MS		Fictitious	Size + Type	10.000

Appendix G

Successfully performed linear analysis

Member check option: ASCE 10
Connection rupture check: Not Checked
Crossing diagonal check: Fixed

Loads from file: d:\msc ei\msc research project\pls tower design\tower design\tacsr _as \tdl.lca

*** Analysis Results:

Maximum element usage is 93.48% for Angle "H10Y" in load case "b009-3LMX"
Maximum insulator usage is 5.06% for Clamp "CA0" in load case "b005-1LMX"

Summary of Joint Support Reactions For All Load Cases:

Load Case	Joint Label	Long. Force (kN)	Tran. Force (kN)	Vert. Force (kN)	Shear Force (kN)	Tran. Moment (kN-m)	Long. Moment (kN-m)	Vert. Moment (kN-m)	Bending Moment (kN-m)	Found. Usage %
b001-NCMX	X3S	-50.20	-62.66	386.39	80.29	-0.00	-0.00	-0.00	0.00	0.00
b001-NCMX	X3X	35.93	-48.35	-277.79	60.24	-0.00	-0.00	-0.00	0.00	0.00
b001-NCMX	X3XY	-36.25	-50.46	-282.38	62.13	-0.00	-0.00	-0.00	0.00	0.00
b001-NCMX	X3Y	50.52	-64.77	390.99	82.14	-0.00	-0.00	-0.00	0.00	0.00
b002-NCMN	X3S	-49.38	-63.64	380.54	80.55	-0.00	-0.00	-0.00	0.00	0.00
b002-NCMN	X3X	38.28	-52.48	-297.59	64.96	-0.00	-0.00	-0.00	0.00	0.00
b002-NCMN	X3XY	-38.28	-52.48	-297.59	64.96	-0.00	-0.00	-0.00	0.00	0.00
b002-NCMN	X3Y	49.38	-63.64	380.54	80.55	-0.00	-0.00	-0.00	0.00	0.00
b003-PKMX	X3S	-38.99	-48.90	308.10	62.55	-0.00	-0.00	-0.00	0.00	0.00
b003-PKMX	X3X	15.02	-22.99	-109.71	27.46	-0.00	-0.00	-0.00	0.00	0.00
b003-PKMX	X3XY	-28.44	-38.32	-228.32	47.73	-0.00	-0.00	-0.00	0.00	0.00
b003-PKMX	X3Y	25.56	-33.57	189.49	42.20	-0.00	-0.00	-0.00	0.00	0.00
b004PKMN	X3S	-36.75	-46.60	290.26	59.34	-0.00	-0.00	-0.00	0.00	0.00
b004PKMN	X3X	17.26	-25.30	-127.54	30.62	-0.00	-0.00	-0.00	0.00	0.00
b004PKMN	X3XY	-29.83	-39.64	-238.53	49.61	-0.00	-0.00	-0.00	0.00	0.00
b004PKMN	X3Y	24.18	-32.25	179.27	40.31	-0.00	-0.00	-0.00	0.00	0.00
b005-1LMX	X3S	-38.69	-55.16	318.90	67.37	-0.00	-0.00	-0.00	0.00	0.00
b005-1LMX	X3X	5.11	-26.36	-98.17	26.85	-0.00	-0.00	-0.00	0.00	0.00
b005-1LMX	X3XY	-38.20	-34.21	-238.67	51.28	-0.00	-0.00	-0.00	0.00	0.00
b005-1LMX	X3Y	25.45	-26.30	175.44	36.60	-0.00	-0.00	-0.00	0.00	0.00
b006-1LMN	X3S	-36.86	-53.40	304.76	64.88	-0.00	-0.00	-0.00	0.00	0.00
b006-1LMN	X3X	6.81	-28.12	-111.31	28.93	-0.00	-0.00	-0.00	0.00	0.00
b006-1LMN	X3XY	-39.90	-35.97	-251.81	53.72	-0.00	-0.00	-0.00	0.00	0.00
b006-1LMN	X3Y	23.62	-24.54	161.31	34.06	-0.00	-0.00	-0.00	0.00	0.00
b007-2LMX	X3S	-38.98	-56.19	328.72	68.38	-0.00	-0.00	-0.00	0.00	0.00
b007-2LMX	X3X	5.39	-24.64	-86.74	25.22	-0.00	-0.00	-0.00	0.00	0.00
b007-2LMX	X3XY	-37.71	-35.93	-248.57	52.09	-0.00	-0.00	-0.00	0.00	0.00
b007-2LMX	X3Y	24.96	-25.27	164.10	35.52	-0.00	-0.00	-0.00	0.00	0.00
b008-2LMN	X3S	-37.15	-54.42	314.62	65.90	-0.00	-0.00	-0.00	0.00	0.00
b008-2LMN	X3X	7.10	-26.40	-99.92	27.34	-0.00	-0.00	-0.00	0.00	0.00
b008-2LMN	X3XY	-39.42	-37.69	-261.75	54.54	-0.00	-0.00	-0.00	0.00	0.00
b008-2LMN	X3Y	23.14	-23.51	150.00	32.99	-0.00	-0.00	-0.00	0.00	0.00

b009-3LMX	X3S	-39.03	-57.49	338.72	69.48	-0.00	-0.00	-0.00	0.00	0.00
b009-3LMX	X3X	5.45	-23.22	-75.74	23.86	-0.00	-0.00	-0.00	0.00	0.00
b009-3LMX	X3XY	-37.47	-37.34	-258.12	52.90	-0.00	-0.00	-0.00	0.00	0.00
b009-3LMX	X3Y	24.72	-23.98	152.65	34.44	-0.00	-0.00	-0.00	0.00	0.00
b010-3LMN	X3S	-37.21	-55.72	324.62	67.00	-0.00	-0.00	-0.00	0.00	0.00
b010-3LMN	X3X	7.16	-24.99	-88.93	25.99	-0.00	-0.00	-0.00	0.00	0.00
b010-3LMN	X3XY	-39.18	-39.11	-271.31	55.35	-0.00	-0.00	-0.00	0.00	0.00
b010-3LMN	X3Y	22.90	-22.21	138.56	31.90	-0.00	-0.00	-0.00	0.00	0.00
b011-1RMX	X3S	-48.44	-44.66	316.10	65.89	-0.00	-0.00	-0.00	0.00	0.00
b011-1RMX	X3X	14.86	-15.86	-95.37	21.73	-0.00	-0.00	-0.00	0.00	0.00
b011-1RMX	X3XY	-28.10	-44.71	-238.82	52.81	-0.00	-0.00	-0.00	0.00	0.00
b011-1RMX	X3Y	15.35	-36.81	175.60	39.88	-0.00	-0.00	-0.00	0.00	0.00
b012-1RMN	X3S	-46.74	-42.89	302.95	63.44	-0.00	-0.00	-0.00	0.00	0.00
b012-1RMN	X3X	16.69	-17.62	-109.50	24.27	-0.00	-0.00	-0.00	0.00	0.00
b012-1RMN	X3XY	-29.93	-46.47	-252.96	55.28	-0.00	-0.00	-0.00	0.00	0.00
b012-1RMN	X3Y	13.65	-35.04	162.45	37.61	-0.00	-0.00	-0.00	0.00	0.00
b013-2RMX	X3S	-47.97	-46.37	326.09	66.72	-0.00	-0.00	-0.00	0.00	0.00
b013-2RMX	X3X	14.39	-14.83	-84.12	20.66	-0.00	-0.00	-0.00	0.00	0.00
b013-2RMX	X3XY	-28.40	-45.74	-248.74	53.84	-0.00	-0.00	-0.00	0.00	0.00
b013-2RMX	X3Y	15.65	-35.09	164.27	38.42	-0.00	-0.00	-0.00	0.00	0.00
b014-2R MN	X3S	-46.27	-44.61	312.91	64.27	-0.00	-0.00	-0.00	0.00	0.00
b014-2R MN	X3X	16.21	-16.59	-98.22	23.20	-0.00	-0.00	-0.00	0.00	0.00
b014-2R MN	X3XY	-30.22	-47.50	-262.84	56.30	-0.00	-0.00	-0.00	0.00	0.00
b014-2R MN	X3Y	13.95	-33.33	151.09	36.13	-0.00	-0.00	-0.00	0.00	0.00
b015-3RMX	X3S	-33.29	-41.42	253.43	53.14	-0.00	-0.00	-0.00	0.00	0.00
b015-3RMX	X3X	20.60	-28.64	-156.60	35.28	-0.00	-0.00	-0.00	0.00	0.00
b015-3RMX	X3XY	-22.01	-31.93	-174.86	38.78	-0.00	-0.00	-0.00	0.00	0.00
b015-3RMX	X3Y	30.15	-40.04	235.54	50.12	-0.00	-0.00	-0.00	0.00	0.00
b016-3RMN	X3S	-31.59	-39.66	240.24	50.70	-0.00	-0.00	-0.00	0.00	0.00
b016-3RMN	X3X	22.43	-30.40	-170.69	37.78	-0.00	-0.00	-0.00	0.00	0.00
b016-3RMN	X3XY	-23.83	-33.69	-188.95	41.27	-0.00	-0.00	-0.00	0.00	0.00
b016-3RMN	X3Y	28.45	-38.28	222.35	47.69	-0.00	-0.00	-0.00	0.00	0.00
b017-NCLSMX	X3S	-34.04	-48.83	261.90	59.52	-0.00	-0.00	-0.00	0.00	0.00
b017-NCLSMX	X3X	21.66	-36.39	-169.00	42.35	-0.00	-0.00	-0.00	0.00	0.00
b017-NCLSMX	X3XY	-21.66	-36.39	-169.00	42.35	-0.00	-0.00	-0.00	0.00	0.00
b017-NCLSMX	X3Y	34.04	-48.83	261.90	59.52	-0.00	-0.00	-0.00	0.00	0.00
b018-NCLSMN	X3S	-33.66	-47.29	258.98	58.04	-0.00	-0.00	-0.00	0.00	0.00
b018-NCLSMN	X3X	24.36	-37.93	-189.93	45.08	-0.00	-0.00	-0.00	0.00	0.00
b018-NCLSMN	X3XY	-24.36	-37.93	-189.93	45.08	-0.00	-0.00	-0.00	0.00	0.00
b018-NCLSMN	X3Y	33.66	-47.29	258.98	58.04	-0.00	-0.00	-0.00	0.00	0.00
b019-PKLSMX	X3S	-27.14	-37.32	215.94	46.14	-0.00	-0.00	-0.00	0.00	0.00
b019-PKLSMX	X3X	6.89	-15.26	-47.35	16.74	-0.00	-0.00	-0.00	0.00	0.00
b019-PKLSMX	X3XY	-19.46	-29.61	-158.34	35.43	-0.00	-0.00	-0.00	0.00	0.00
b019-PKLSMX	X3Y	14.57	-22.97	104.95	27.21	-0.00	-0.00	-0.00	0.00	0.00
b020-PKLSMN	X3S	-27.36	-36.87	218.10	45.91	-0.00	-0.00	-0.00	0.00	0.00
b020-PKLSMN	X3X	8.13	-15.71	-56.45	17.69	-0.00	-0.00	-0.00	0.00	0.00
b020-PKLSMN	X3XY	-21.56	-31.04	-175.06	37.79	-0.00	-0.00	-0.00	0.00	0.00
b020-PKLSMN	X3Y	13.93	-21.54	99.49	25.65	-0.00	-0.00	-0.00	0.00	0.00
b021-1LLSMX	X3S	-21.30	-31.06	165.85	37.66	-0.00	-0.00	-0.00	0.00	0.00
b021-1LLSMX	X3X	11.48	-21.68	-95.36	24.53	-0.00	-0.00	-0.00	0.00	0.00
b021-1LLSMX	X3XY	-14.72	-22.45	-109.15	26.84	-0.00	-0.00	-0.00	0.00	0.00
b021-1LLSMX	X3Y	20.00	-28.22	151.78	34.59	-0.00	-0.00	-0.00	0.00	0.00
b022-1LLSMN	X3S	-21.07	-30.16	164.09	36.79	-0.00	-0.00	-0.00	0.00	0.00
b022-1LLSMN	X3X	13.03	-22.57	-107.38	26.06	-0.00	-0.00	-0.00	0.00	0.00
b022-1LLSMN	X3XY	-16.28	-23.34	-121.17	28.45	-0.00	-0.00	-0.00	0.00	0.00
b022-1LLSMN	X3Y	19.77	-27.33	150.02	33.73	-0.00	-0.00	-0.00	0.00	0.00
b023-2LLSMX	X3S	-26.93	-43.72	233.01	51.34	-0.00	-0.00	-0.00	0.00	0.00
b023-2LLSMX	X3X	-1.71	-16.92	-27.81	17.01	-0.00	-0.00	-0.00	0.00	0.00
b023-2LLSMX	X3XY	-27.72	-27.20	-175.17	38.83	-0.00	-0.00	-0.00	0.00	0.00
b023-2LLSMX	X3Y	14.17	-15.56	83.10	21.05	-0.00	-0.00	-0.00	0.00	0.00
b024-2LLSMN	X3S	-26.70	-42.82	231.28	50.47	-0.00	-0.00	-0.00	0.00	0.00
b024-2LLSMN	X3X	-0.16	-17.81	-39.86	17.81	-0.00	-0.00	-0.00	0.00	0.00
b024-2LLSMN	X3XY	-29.28	-28.09	-187.23	40.57	-0.00	-0.00	-0.00	0.00	0.00
b024-2LLSMN	X3Y	13.95	-14.67	81.37	20.24	-0.00	-0.00	-0.00	0.00	0.00
b025-3LLSMX	X3S	-26.97	-44.90	242.05	52.38	-0.00	-0.00	-0.00	0.00	0.00
b025-3LLSMX	X3X	-1.67	-15.63	-17.72	15.72	-0.00	-0.00	-0.00	0.00	0.00
b025-3LLSMX	X3XY	-27.49	-28.49	-183.81	39.59	-0.00	-0.00	-0.00	0.00	0.00
b025-3LLSMX	X3Y	13.94	-14.38	72.61	20.03	-0.00	-0.00	-0.00	0.00	0.00
b026-3LLSMN	X3S	-26.75	-44.01	240.34	51.50	-0.00	-0.00	-0.00	0.00	0.00
b026-3LLSMN	X3X	-0.11	-16.52	-29.79	16.52	-0.00	-0.00	-0.00	0.00	0.00
b026-3LLSMN	X3XY	-29.05	-29.38	-195.88	41.31	-0.00	-0.00	-0.00	0.00	0.00

b026-3LLSMN	X3Y	13.72	-13.49	70.89	19.24	-0.00	-0.00	-0.00	0.00	0.00
b027-NCRSMX	X3S	-37.87	-48.83	291.49	61.79	-0.00	-0.00	-0.00	0.00	0.00
b027-NCRSMX	X3X	25.48	-36.39	-198.60	44.42	-0.00	-0.00	-0.00	0.00	0.00
b027-NCRSMX	X3XY	-25.48	-36.39	-198.60	44.42	-0.00	-0.00	-0.00	0.00	0.00
b027-NCRSMX	X3Y	37.87	-48.83	291.49	61.79	-0.00	-0.00	-0.00	0.00	0.00
b028-NCRSMN	X3S	-35.16	-47.28	270.57	58.93	-0.00	-0.00	-0.00	0.00	0.00
b028-NCRSMN	X3X	25.86	-37.93	-201.52	45.91	-0.00	-0.00	-0.00	0.00	0.00
b028-NCRSMN	X3XY	-25.86	-37.93	-201.52	45.91	-0.00	-0.00	-0.00	0.00	0.00
b028-NCRSMN	X3Y	35.16	-47.28	270.57	58.93	-0.00	-0.00	-0.00	0.00	0.00
b029-PKRSMX	X3S	-29.53	-37.32	234.43	47.59	-0.00	-0.00	-0.00	0.00	0.00
b029-PKRSMX	X3X	9.29	-15.26	-65.85	17.86	-0.00	-0.00	-0.00	0.00	0.00
b029-PKRSMX	X3XY	-21.85	-29.61	-176.84	36.80	-0.00	-0.00	-0.00	0.00	0.00
b029-PKRSMX	X3Y	16.97	-22.97	123.44	28.56	-0.00	-0.00	-0.00	0.00	0.00
b030-PKRSMN	X3S	-27.86	-36.38	221.53	45.82	-0.00	-0.00	-0.00	0.00	0.00
b030-PKRSMN	X3X	9.50	-16.20	-67.50	18.78	-0.00	-0.00	-0.00	0.00	0.00
b030-PKRSMN	X3XY	-22.06	-30.55	-178.49	37.68	-0.00	-0.00	-0.00	0.00	0.00
b030-PKRSMN	X3Y	15.30	-22.03	110.54	26.82	-0.00	-0.00	-0.00	0.00	0.00
b031-1RRSMX	X3S	-24.49	-30.02	182.88	38.75	-0.00	-0.00	-0.00	0.00	0.00
b031-1RRSMX	X3X	14.67	-20.64	-112.39	25.33	-0.00	-0.00	-0.00	0.00	0.00
b031-1RRSMX	X3XY	-15.97	-23.48	-126.47	28.39	-0.00	-0.00	-0.00	0.00	0.00
b031-1RRSMX	X3Y	21.24	-29.25	169.10	36.15	-0.00	-0.00	-0.00	0.00	0.00
b032-1RRSMN	X3S	-22.94	-29.13	170.86	37.08	-0.00	-0.00	-0.00	0.00	0.00
b032-1RRSMN	X3X	14.90	-21.54	-114.15	26.19	-0.00	-0.00	-0.00	0.00	0.00
b032-1RRSMN	X3XY	-16.20	-24.37	-128.23	29.26	-0.00	-0.00	-0.00	0.00	0.00
b032-1RRSMN	X3Y	19.69	-28.36	157.08	34.53	-0.00	-0.00	-0.00	0.00	0.00
b033-2RRSMX	X3S	-37.50	-34.78	249.01	51.14	-0.00	-0.00	-0.00	0.00	0.00
b033-2RRSMX	X3X	8.85	-7.98	-43.80	11.92	-0.00	-0.00	-0.00	0.00	0.00
b033-2RRSMX	X3XY	-21.61	-36.14	-193.72	42.11	-0.00	-0.00	-0.00	0.00	0.00
b033-2RRSMX	X3Y	8.06	-24.50	101.64	25.79	-0.00	-0.00	-0.00	0.00	0.00
b034-2RRSMN	X3S	-35.94	-33.89	236.95	49.40	-0.00	-0.00	-0.00	0.00	0.00
b034-2RRSMN	X3X	9.08	-8.88	-45.53	12.70	-0.00	-0.00	-0.00	0.00	0.00
b034-2RRSMN	X3XY	-21.84	-37.03	-195.44	42.99	-0.00	-0.00	-0.00	0.00	0.00
b034-2RRSMN	X3Y	6.51	-23.61	89.58	24.49	-0.00	-0.00	-0.00	0.00	0.00
b035-3RRSMX	X3S	-37.27	-36.07	257.67	51.86	-0.00	-0.00	-0.00	0.00	0.00
b035-3RRSMX	X3X	8.63	-6.80	-33.34	10.99	-0.00	-0.00	-0.00	0.00	0.00
b035-3RRSMX	X3XY	-21.66	-37.32	-202.78	43.15	-0.00	-0.00	-0.00	0.00	0.00
b035-3RRSMX	X3Y	8.11	-23.21	91.58	24.59	-0.00	-0.00	-0.00	0.00	0.00
b036-3RRSMN	X3S	-35.71	-35.18	245.61	50.13	-0.00	-0.00	-0.00	0.00	0.00
b036-3RRSMN	X3X	8.85	-7.69	-35.06	11.73	-0.00	-0.00	-0.00	0.00	0.00
b036-3RRSMN	X3XY	-21.88	-38.21	-204.50	44.03	-0.00	-0.00	-0.00	0.00	0.00
b036-3RRSMN	X3Y	6.55	-22.32	79.51	23.26	-0.00	-0.00	-0.00	0.00	0.00

Summary of Joint Support Reactions For All Load Cases in Direction of Leg:

Load Case	Support Joint	Origin Joint	Member	Leg Force In Leg Dir. (kN)	Residual Shear Perpendicular To Leg (kN)	Residual Shear Horizontal To Leg (kN)	Total Long. Force (kN)	Total Tran. Force (kN)	Total Vert. Force (kN)
b001-NCMX	X3S	X2S	M12P	394.443	12.617	12.725	-50.20	-62.66	386.39
b001-NCMX	X3X	X2X	M12X	-283.973	12.350	12.451	35.93	-48.35	-277.79
b001-NCMX	X3XY	X2XY	M12XY	-288.803	13.862	13.972	-36.25	-50.46	-282.38
b001-NCMX	X3Y	X2Y	M12Y	399.273	14.125	14.241	50.52	-64.77	390.99
b002-NCMN	X3S	X2S	M12P	388.709	14.338	14.458	-49.38	-63.64	380.54
b002-NCMN	X3X	X2X	M12X	-304.278	13.916	14.027	38.28	-52.48	-297.59
b002-NCMN	X3XY	X2XY	M12XY	-304.278	13.916	14.027	-38.28	-52.48	-297.59
b002-NCMN	X3Y	X2Y	M12Y	388.709	14.338	14.458	49.38	-63.64	380.54

b003-PKMX	X3S	X2S	M12P	314.256	9.063	9.124	-38.99	-48.90	308.10
b003-PKMX	X3X	X2X	M12X	-112.751	8.767	8.852	15.02	-22.99	-109.71
b003-PKMX	X3XY	X2XY	M12XY	-233.086	8.825	8.880	-28.44	-38.32	-228.32
b003-PKMX	X3Y	X2Y	M12Y	193.921	9.054	9.146	25.56	-33.57	189.49
b004PKMN	X3S	X2S	M12P	296.131	9.057	9.118	-36.75	-46.60	290.26
b004PKMN	X3X	X2X	M12X	-130.877	8.762	8.847	17.26	-25.30	-127.54
b004PKMN	X3XY	X2XY	M12XY	-243.479	8.817	8.873	-29.83	-39.64	-238.53
b004PKMN	X3Y	X2Y	M12Y	183.528	9.048	9.139	24.18	-32.25	179.27
b005-1LMX	X3S	X2S	M12P	325.632	14.099	14.173	-38.69	-55.16	318.90
b005-1LMX	X3X	X2X	M12X	-100.569	15.613	15.632	5.11	-26.36	-98.17
b005-1LMX	X3XY	X2XY	M12XY	-243.984	7.973	8.089	-38.20	-34.21	-238.67
b005-1LMX	X3Y	X2Y	M12Y	179.164	4.496	4.569	25.45	-26.30	175.44
b006-1LMN	X3S	X2S	M12P	311.270	14.161	14.236	-36.86	-53.40	304.76
b006-1LMN	X3X	X2X	M12X	-113.939	15.669	15.688	6.81	-28.12	-111.31
b006-1LMN	X3XY	X2XY	M12XY	-257.354	7.999	8.116	-39.90	-35.97	-251.81
b006-1LMN	X3Y	X2Y	M12Y	164.801	4.546	4.620	23.62	-24.54	161.31
b007-2LMX	X3S	X2S	M12P	335.458	14.088	14.148	-38.98	-56.19	328.72
b007-2LMX	X3X	X2X	M12X	-89.148	14.604	14.636	5.39	-24.64	-86.74
b007-2LMX	X3XY	X2XY	M12XY	-253.878	6.656	6.762	-37.71	-35.93	-248.57
b007-2LMX	X3Y	X2Y	M12Y	167.812	5.447	5.537	24.96	-25.27	164.10
b008-2LMN	X3S	X2S	M12P	321.131	14.145	14.205	-37.15	-54.42	314.62
b008-2LMN	X3X	X2X	M12X	-102.554	14.658	14.690	7.10	-26.40	-99.92
b008-2LMN	X3XY	X2XY	M12XY	-267.285	6.689	6.797	-39.42	-37.69	-261.75
b008-2LMN	X3Y	X2Y	M12Y	153.485	5.490	5.581	23.14	-23.51	150.00
b009-3LMX	X3S	X2S	M12P	345.467	14.464	14.509	-39.03	-57.49	338.72
b009-3LMX	X3X	X2X	M12X	-78.151	14.071	14.118	5.45	-23.22	-75.74
b009-3LMX	X3XY	X2XY	M12XY	-263.428	5.633	5.726	-37.47	-37.34	-258.12
b009-3LMX	X3Y	X2Y	M12Y	156.357	6.449	6.555	24.72	-23.98	152.65
b010-3LMN	X3S	X2S	M12P	331.150	14.519	14.564	-37.21	-55.72	324.62
b010-3LMN	X3X	X2X	M12X	-91.568	14.126	14.174	7.16	-24.99	-88.93
b010-3LMN	X3XY	X2XY	M12XY	-276.845	5.673	5.767	-39.18	-39.11	-271.31
b010-3LMN	X3Y	X2Y	M12Y	142.040	6.486	6.592	22.90	-22.21	138.56
b011-1RMX	X3S	X2S	M12P	322.783	8.369	8.493	-48.44	-44.66	316.10
b011-1RMX	X3X	X2X	M12X	-97.719	4.279	4.348	14.86	-15.86	-95.37
b011-1RMX	X3XY	X2XY	M12XY	-244.188	14.050	14.120	-28.10	-44.71	-238.82
b011-1RMX	X3Y	X2Y	M12Y	179.368	15.885	15.908	15.35	-36.81	

175.60

b012-1RMN	X3S	X2S	M12P	309.412	8.341	8.464	-46.74	-42.89	302.95
b012-1RMN	X3X	X2X	M12X	-112.082	4.229	4.297	16.69	-17.62	-109.50
b012-1RMN	X3XY	X2XY	M12XY	-258.550	13.987	14.057	-29.93	-46.47	-252.96
b012-1RMN	X3Y	X2Y	M12Y	165.997	15.828	15.851	13.65	-35.04	162.45
b013-2RMX	X3S	X2S	M12P	332.772	7.089	7.203	-47.97	-46.37	326.09
b013-2RMX	X3X	X2X	M12X	-86.462	5.209	5.295	14.39	-14.83	-84.12
b013-2RMX	X3XY	X2XY	M12XY	-254.108	14.045	14.101	-28.40	-45.74	-248.74
b013-2RMX	X3Y	X2Y	M12Y	168.042	14.903	14.940	15.65	-35.09	164.27
b014-2R MN	X3S	X2S	M12P	319.366	7.054	7.168	-46.27	-44.61	312.91
b014-2R MN	X3X	X2X	M12X	-100.789	5.166	5.251	16.21	-16.59	-98.22
b014-2R MN	X3XY	X2XY	M12XY	-268.435	13.989	14.044	-30.22	-47.50	-262.84
b014-2R MN	X3Y	X2Y	M12Y	154.635	14.848	14.885	13.95	-33.33	151.09
b015-3RMX	X3S	X2S	M12P	258.800	8.609	8.689	-33.29	-41.42	253.43
b015-3RMX	X3X	X2X	M12X	-160.312	8.335	8.409	20.60	-28.64	-156.60
b015-3RMX	X3XY	X2XY	M12XY	-178.866	9.282	9.348	-22.01	-31.93	-174.86
b015-3RMX	X3Y	X2Y	M12Y	240.622	9.530	9.604	30.15	-40.04	235.54
b016-3RMN	X3S	X2S	M12P	245.384	8.552	8.630	-31.59	-39.66	240.24
b016-3RMN	X3X	X2X	M12X	-174.629	8.278	8.351	22.43	-30.40	-170.69
b016-3RMN	X3XY	X2XY	M12XY	-193.183	9.225	9.291	-23.83	-33.69	-188.95
b016-3RMN	X3Y	X2Y	M12Y	227.205	9.472	9.545	28.45	-38.28	222.35
b017-NCLSMX	X3S	X2S	M12P	268.165	14.857	14.982	-34.04	-48.83	261.90
b017-NCLSMX	X3X	X2X	M12X	-173.625	14.435	14.550	21.66	-36.39	-169.00
b017-NCLSMX	X3XY	X2XY	M12XY	-173.625	14.435	14.550	-21.66	-36.39	-169.00
b017-NCLSMX	X3Y	X2Y	M12Y	268.165	14.857	14.982	34.04	-48.83	261.90
b018-NCLSMN	X3S	X2S	M12P	265.047	13.703	13.818	-33.66	-47.29	258.98
b018-NCLSMN	X3X	X2X	M12X	-194.751	13.281	13.387	24.36	-37.93	-189.93
b018-NCLSMN	X3XY	X2XY	M12XY	-194.751	13.281	13.387	-24.36	-37.93	-189.93
b018-NCLSMN	X3Y	X2Y	M12Y	265.047	13.703	13.818	33.66	-47.29	258.98
b019-PKLSMX	X3S	X2S	M12P	220.612	9.381	9.445	-27.14	-37.32	215.94
b019-PKLSMX	X3X	X2X	M12X	-49.398	9.086	9.173	6.89	-15.26	-47.35
b019-PKLSMX	X3XY	X2XY	M12XY	-162.001	9.141	9.199	-19.46	-29.61	-158.34
b019-PKLSMX	X3Y	X2Y	M12Y	108.009	9.371	9.464	14.57	-22.97	104.95
b020-PKLSMN	X3S	X2S	M12P	222.708	8.668	8.726	-27.36	-36.87	218.10
b020-PKLSMN	X3X	X2X	M12X	-58.557	8.372	8.454	8.13	-15.71	-56.45
b020-PKLSMN	X3XY	X2XY	M12XY	-178.892	8.432	8.484	-21.56	-31.04	-175.06

b020-PKLSMN	X3Y	X2Y	M12Y	102.373	8.660	8.748	13.93	-21.54	99.49
b021-1LLSMX	X3S	X2S	M12P	169.805	9.547	9.623	-21.30	-31.06	165.85
b021-1LLSMX	X3X	X2X	M12X	-98.021	9.328	9.390	11.48	-21.68	-95.36
b021-1LLSMX	X3XY	X2XY	M12XY	-112.092	8.285	8.363	-14.72	-22.45	-109.15
b021-1LLSMX	X3Y	X2Y	M12Y	155.435	8.542	8.618	20.00	-28.22	151.78
b022-1LLSMN	X3S	X2S	M12P	167.932	8.889	8.960	-21.07	-30.16	164.09
b022-1LLSMN	X3X	X2X	M12X	-110.158	8.673	8.730	13.03	-22.57	-107.38
b022-1LLSMN	X3XY	X2XY	M12XY	-124.229	7.630	7.702	-16.28	-23.34	-121.17
b022-1LLSMN	X3Y	X2Y	M12Y	153.562	7.885	7.956	19.77	-27.33	150.02
b023-2LLSMX	X3S	X2S	M12P	238.192	13.908	13.971	-26.93	-43.72	233.01
b023-2LLSMX	X3X	X2X	M12X	-29.286	14.310	14.347	-1.71	-16.92	-27.81
b023-2LLSMX	X3XY	X2XY	M12XY	-179.301	6.716	6.827	-27.72	-27.20	-175.17
b023-2LLSMX	X3Y	X2Y	M12Y	85.522	5.826	5.920	14.17	-15.56	83.10
b024-2LLSMN	X3S	X2S	M12P	236.354	13.264	13.322	-26.70	-42.82	231.28
b024-2LLSMN	X3X	X2X	M12X	-41.458	13.697	13.728	-0.16	-17.81	-39.86
b024-2LLSMN	X3XY	X2XY	M12XY	-191.473	6.298	6.400	-29.28	-28.09	-187.23
b024-2LLSMN	X3Y	X2Y	M12Y	83.684	5.302	5.389	13.95	-14.67	81.37
b025-3LLSMX	X3S	X2S	M12P	247.242	14.234	14.283	-26.97	-44.90	242.05
b025-3LLSMX	X3X	X2X	M12X	-19.207	13.866	13.917	-1.67	-15.63	-17.72
b025-3LLSMX	X3XY	X2XY	M12XY	-187.934	5.932	6.029	-27.49	-28.49	-183.81
b025-3LLSMX	X3Y	X2Y	M12Y	75.026	6.652	6.762	13.94	-14.38	72.61
b026-3LLSMN	X3S	X2S	M12P	245.414	13.602	13.646	-26.75	-44.01	240.34
b026-3LLSMN	X3X	X2X	M12X	-31.389	13.231	13.277	-0.11	-16.52	-29.79
b026-3LLSMN	X3XY	X2XY	M12XY	-200.116	5.429	5.519	-29.05	-29.38	-195.88
b026-3LLSMN	X3Y	X2Y	M12Y	73.198	6.181	6.283	13.72	-13.49	70.89
b027-NCRSMX	X3S	X2S	M12P	297.766	11.063	11.157	-37.87	-48.83	291.49
b027-NCRSMX	X3X	X2X	M12X	-203.225	10.641	10.725	25.48	-36.39	-198.60
b027-NCRSMX	X3XY	X2XY	M12XY	-203.225	10.641	10.725	-25.48	-36.39	-198.60
b027-NCRSMX	X3Y	X2Y	M12Y	297.766	11.063	11.157	37.87	-48.83	291.49
b028-NCRSMN	X3S	X2S	M12P	276.639	12.217	12.320	-35.16	-47.28	270.57
b028-NCRSMN	X3X	X2X	M12X	-206.344	11.796	11.889	25.86	-37.93	-201.52
b028-NCRSMN	X3XY	X2XY	M12XY	-206.344	11.796	11.889	-25.86	-37.93	-201.52
b028-NCRSMN	X3Y	X2Y	M12Y	276.639	12.217	12.320	35.16	-47.28	270.57
b029-PKRSMX	X3S	X2S	M12P	239.113	7.019	7.064	-29.53	-37.32	234.43
b029-PKRSMX	X3X	X2X	M12X	-67.899	6.726	6.793	9.29	-15.26	-65.85
b029-PKRSMX	X3XY	X2XY	M12XY	-180.501	6.788	6.827	-21.85	-29.61	

									-176.84
b029-PKRSMX	X3Y	X2Y	M12Y	126.510	7.017	7.091	16.97	-22.97	123.44
b030-PKRSMN	X3S	X2S	M12P	226.088	7.737	7.788	-27.86	-36.38	221.53
b030-PKRSMN	X3X	X2X	M12X	-69.669	7.443	7.517	9.50	-16.20	-67.50
b030-PKRSMN	X3XY	X2XY	M12XY	-182.271	7.502	7.547	-22.06	-30.55	-178.49
b030-PKRSMN	X3Y	X2Y	M12Y	113.485	7.732	7.812	15.30	-22.03	110.54
b031-1RRSMX	X3S	X2S	M12P	186.834	6.381	6.447	-24.49	-30.02	182.88
b031-1RRSMX	X3X	X2X	M12X	-115.050	6.070	6.122	14.67	-20.64	-112.39
b031-1RRSMX	X3XY	X2XY	M12XY	-129.420	7.090	7.142	-15.97	-23.48	-126.47
b031-1RRSMX	X3Y	X2Y	M12Y	172.763	7.376	7.426	21.24	-29.25	169.10
b032-1RRSMN	X3S	X2S	M12P	174.697	7.033	7.105	-22.94	-29.13	170.86
b032-1RRSMN	X3X	X2X	M12X	-116.923	6.727	6.785	14.90	-21.54	-114.15
b032-1RRSMN	X3XY	X2XY	M12XY	-131.294	7.747	7.804	-16.20	-24.37	-128.23
b032-1RRSMN	X3Y	X2Y	M12Y	160.626	8.032	8.087	19.69	-28.36	157.08
b033-2RRSMX	X3S	X2S	M12P	254.138	5.832	5.918	-37.50	-34.78	249.01
b033-2RRSMX	X3X	X2X	M12X	-45.231	3.886	3.949	8.85	-7.98	-43.80
b033-2RRSMX	X3XY	X2XY	M12XY	-197.901	11.575	11.616	-21.61	-36.14	-193.72
b033-2RRSMX	X3Y	X2Y	M12Y	104.122	12.420	12.446	8.06	-24.50	101.64
b034-2RRSMN	X3S	X2S	M12P	241.966	6.144	6.240	-35.94	-33.89	236.95
b034-2RRSMN	X3X	X2X	M12X	-47.069	4.304	4.376	9.08	-8.88	-45.53
b034-2RRSMN	X3XY	X2XY	M12XY	-199.739	12.210	12.256	-21.84	-37.03	-195.44
b034-2RRSMN	X3Y	X2Y	M12Y	91.950	13.028	13.058	6.51	-23.61	89.58
b035-3RRSMX	X3S	X2S	M12P	262.797	4.763	4.840	-37.27	-36.07	257.67
b035-3RRSMX	X3X	X2X	M12X	-34.762	4.910	4.986	8.63	-6.80	-33.34
b035-3RRSMX	X3XY	X2XY	M12XY	-206.979	11.977	12.006	-21.66	-37.32	-202.78
b035-3RRSMX	X3Y	X2Y	M12Y	94.070	11.930	11.969	8.11	-23.21	91.58
b036-3RRSMN	X3S	X2S	M12P	250.615	5.166	5.251	-35.71	-35.18	245.61
b036-3RRSMN	X3X	X2X	M12X	-36.590	5.267	5.352	8.85	-7.69	-35.06
b036-3RRSMN	X3XY	X2XY	M12XY	-208.806	12.594	12.628	-21.88	-38.21	-204.50
b036-3RRSMN	X3Y	X2Y	M12Y	81.888	12.562	12.607	6.55	-22.32	79.51

Overturning Moment Summary For All Load Cases:

Load Case	**Transverse Moment (kN-m)**	**Longitudinal Moment (kN-m)**	**Resultant Moment (kN-m)**
b001-NCMX	6431.576	-0.000	6431.576
b002-NCMN	6521.575	-0.000	6521.575
b003-PKMX	4018.067	1140.682	4176.843
b004PKMN	4018.067	1067.386	4157.424

b005-1LMX	3996.709	1365.390	4223.502
b006-1LMN	3987.170	1365.390	4214.477
b007-2LMX	3982.034	1569.690	4280.247
b008-2LMN	3973.177	1569.690	4272.009
b009-3LMX	3968.125	1771.669	4345.667
b010-3LMN	3959.464	1771.669	4337.760
b011-1RMX	3971.272	1365.390	4199.440
b012-1RMN	3980.811	1365.390	4208.461
b013-2RMX	3958.416	1569.690	4258.284
b014-2R MN	3967.273	1569.690	4266.518
b015-3RMX	3945.029	173.825	3948.857
b016-3RMN	3953.690	173.825	3957.509
b017-NCLSMX	4143.928	-0.000	4143.928
b018-NCLSMN	4317.087	-0.000	4317.087
b019-PKLSMX	2532.047	1067.386	2747.831
b020-PKLSMN	2640.272	1140.683	2876.142
b021-1LLSMX	2510.689	133.963	2514.260
b022-1LLSMN	2609.375	133.963	2612.811
b023-2LLSMX	2496.014	1429.470	2876.364
b024-2LLSMN	2595.382	1429.470	2963.003
b025-3LLSMX	2482.105	1613.406	2960.393
b026-3LLSMN	2581.669	1613.406	3044.354
b027-NCRSMX	4713.189	-0.000	4713.189
b028-NCRSMN	4540.030	-0.000	4540.030
b029-PKRSMX	2887.842	1067.386	3078.789
b030-PKRSMN	2779.617	1067.386	2977.513
b031-1RRSMX	2841.047	133.963	2844.203
b032-1RRSMN	2742.361	133.963	2745.631
b033-2RRSMX	2828.190	1429.470	3168.918
b034-2RRSMN	2728.822	1429.470	3080.561
b035-3RRSMX	2814.804	1613.406	3244.410
b036-3RRSMN	2715.240	1613.406	3158.419

*** Overall summary for all load cases - Usage = Maximum Stress / Allowable Stress
Printed capacities do not include the strength factor entered for each loadcase.

Group Summary (Compression Portion):

Group Label	Group Desc.	Angle Type	Angle Size	Steel Strength (MPa)	Max Usage %	Max Use In Comp. %	Comp. Control Member	Comp. Force (kN)	Comp. Control Load Case	L/R Comp. Capacity (kN)	Comp. Conn. Shear Capacity (kN)	Comp. Conn. Bearing Capacity (kN)	RLX	RLY	RLZ	L/R Comp.	Length Comp. Member (m)	Comp. Curve No.	No. Of Bolts
M1	M1	SAE	100*100*7	355.0	83.12	83.12	M1P	-329.636	b001-NCMX	396.599	720.000	514.080	0.250	0.250	0.250	54.31	4.280	1	6
M2	M2	SAE	90*90*7	355.0	89.45	89.45	M2P	-322.034	b001-NCMX	384.104	360.000	514.080	0.250	0.250	0.250	49.10	3.456	1	6
M3	M3	SAE	90*90*7	355.0	78.84	78.84	M3P	-296.929	b001-NCMX	376.600	720.000	514.080	0.330	0.330	0.330	52.89	2.821	1	6
M4	M4	SAE	90*90*7	355.0	81.95	81.95	M4Y	-286.610	b001-NCMX	349.724	720.000	514.080	0.500	0.500	0.500	64.69	2.277	1	6
M5	M5	SAE	90*90*6	355.0	83.46	83.46	M5P	-250.469	b009-3LMX	300.091	720.000	440.640	0.500	0.500	0.500	52.98	1.876	1	6
M6	M6	SAE	75*75*6	355.0	93.26	93.26	M6P	-223.827	b009-3LMX	289.275	240.000	293.760	0.500	0.500	0.500	36.18	1.064	1	4
M7	M7	SAE	60*60*6	355.0	73.39	73.39	M7P	-118.000	b003-PKMX	160.780	240.000	293.760	1.000	1.000	1.000	86.72	1.015	1	4
D1	D1	SAE	50*50*5	275.0	69.43	69.43	D1P	-20.258	b012-1RMN	29.179	120.000	98.400	0.450	0.450	0.276	198.64	6.710	5	2
D2	D2	SAE	50*50*5	275.0	65.98	65.98	D2Y	-19.252	b009-3LMX	29.179	120.000	98.400	0.450	0.450	0.276	198.64	6.710	5	2
D5	D5	SAE	45*45*5	275.0	80.47	80.47	D5X	-24.782	b005-1LMX	30.796	120.000	98.400	0.450	0.450	0.276	179.71	5.431	5	2
D6	D6	SAE	45*45*5	275.0	71.68	71.68	D6P	-22.075	b012-1RMN	30.796									

120.000	98.400	0.450	0.450	0.276	179.71	5.431	5	2		
D9	D9	SAE	50*50*5	275.0	73.54	73.54	D9P	-30.755	b012-1RMN	41.823
120.000	98.400	0.550	0.550	0.220	159.73	4.414	5	2		
D10	D10	SAE	50*50*5	275.0	69.87	69.87	D10Y	-29.223	b009-3LMX	41.823
120.000	98.400	0.550	0.550	0.220	159.73	4.414	5	2		
D11	D11	SAE	45*45*5	275.0	85.90	85.90	D11X	-37.706	b005-1LMX	43.896
120.000	98.400	0.550	0.550	0.220	144.43	3.571	5	2		
D12	D12	SAE	45*45*5	275.0	76.50	76.50	D12P	-33.579	b012-1RMN	43.896
120.000	98.400	0.550	0.550	0.220	144.43	3.571	5	2		
D13	D13	SAE	45*45*5	275.0	78.90	78.90	D13P	-47.121	b012-1RMN	59.725
120.000	98.400	0.550	0.550	0.220	117.71	2.911	3	2		
D14	D14	SAE	45*45*5	275.0	74.96	74.96	D14Y	-44.770	b009-3LMX	59.725
120.000	98.400	0.550	0.550	0.220	117.71	2.911	3	2		
D15	D15	SAE	45*45*5	275.0	60.21	60.21	D15X	-22.268	b011-1RMX	36.983
120.000	98.400	0.500	0.500	0.500	160.71	2.828	5	2		
D16	D16	SAE	45*45*5	275.0	72.72	72.72	D162P	-48.911	b014-2R MN	67.264
120.000	98.400	1.000	1.000	0.500	101.68	1.383	3	2		
D17	D17	SAE	45*45*5	275.0	82.75	82.75	D172Y	-55.661	b008-2LMN	67.264
120.000	98.400	1.000	1.000	0.500	101.68	1.383	3	2		
D18	D18	SAE	50*50*5	275.0	75.13	75.13	D18X	-58.045	b007-2LMX	77.257
120.000	98.400	0.500	0.500	0.250	97.85	2.975	3	2		
D19	D19	SAE	50*50*5	275.0	85.47	85.47	D19P	-66.034	b013-2RMX	77.257
120.000	98.400	0.500	0.500	0.250	97.85	2.975	3	2		
D20	D20	SAE	45*45*5	275.0	47.18	47.18	D20P	-21.103	b013-2RMX	44.732
120.000	98.400	0.500	0.500	0.500	142.72	2.512	5	2		
D21	D21	SAE	45*45*5	275.0	75.48	75.48	D212X	-53.168	b009-3LMX	70.436
120.000	98.400	1.000	1.000	0.500	94.58	1.286	3	2		
D22	D22	SAE	45*45*5	275.0	75.69	75.69	D222Y	-53.312	b009-3LMX	70.436
120.000	98.400	1.000	1.000	0.500	94.58	1.286	3	2		
D23	D23	SAE	50*50*5	275.0	86.43	86.43	D23X	-68.270	b010-3LMN	78.986
120.000	98.400	0.500	0.500	0.250	94.36	2.869	3	2		
D24	D24	SAE	50*50*5	275.0	81.45	81.45	D24Y	-64.331	b010-3LMN	78.986
120.000	98.400	0.500	0.500	0.250	94.36	2.869	3	2		
D25	D25	SAE	45*45*5	275.0	30.77	30.77	D25X	-16.940	b009-3LMX	55.061
120.000	98.400	0.500	0.500	0.500	124.93	2.199	5	2		
D26	D26	SAE	45*45*5	275.0	36.26	36.26	D26P	-17.842	b035-3RRSM	65.146
60.000	49.200	0.500	0.500	0.500	106.30	1.871	3	1		
D27	D27	SAE	45*45*5	275.0	50.19	47.52	D27Y	-23.380	b027-NCRSM	65.146
60.000	49.200	0.500	0.500	0.500	106.30	1.871	3	1		
D28	D28	SAE	45*45*5	275.0	16.07	11.98	D28P	-6.970	b036-3RRSM	58.173
120.000	98.400	0.500	0.500	0.500	120.53	2.121	5	2		
D30	D30	SAE	50*50*5	275.0	66.60	66.60	D30XY	-18.843	b012-1RMN	28.292
120.000	98.400	0.450	0.450	0.280	202.31	6.834	5	2		
D31	D31	SAE	50*50*5	275.0	51.90	51.90	D31X	-14.684	b005-1LMX	28.292
120.000	98.400	0.450	0.450	0.280	202.31	6.834	5	2		
D38	D38	SAE	50*50*5	275.0	64.02	64.02	D38XY	-28.678	b011-1RMX	44.797
120.000	98.400	0.320	0.320	0.160	153.07	7.271	5	2		
D39	D39	SAE	45*45*5	275.0	60.85	60.85	D39P	-20.320	b011-1RMX	33.395
120.000	98.400	0.320	0.320	0.160	171.08	7.271	5	2		
D42	D42	SAE	55*55*5	275.0	80.59	80.59	D42XY	-29.134	b017-NCLSM	36.149
120.000	98.400	0.400	0.400	0.200	185.10	7.728	5	2		
D43	D43	SAE	50*50*5	275.0	52.83	52.83	D43P	-14.816	b011-1RMX	28.044
120.000	98.400	0.400	0.400	0.200	203.37	7.728	5	2		
H1	H1	SAE	50*50*5	275.0	32.05	22.07	H1P	-12.559	b002-NCMN	56.908
120.000	98.400	1.000	1.000	0.500	131.58	2.000	5	2		
H2	H2	SAE	50*50*5	275.0	74.90	74.90	H2Y	-42.625	b011-1RMX	56.908
120.000	98.400	1.000	1.000	0.500	131.58	2.000	5	2		
H3	H3	SAE	45*45*5	275.0	18.61	18.61	FH327X	-11.751	b005-1LMX	63.147
120.000	98.400	1.000	1.000	1.000	110.57	0.973	3	2		
H4	H4	SAE	45*45*5	275.0	45.10	16.70	H4Y	-10.544	b012-1RMN	63.147
120.000	98.400	1.000	1.000	1.000	110.57	0.973	3	2		
H5	H5	SAE	50*50*5	275.0	20.01	0.00	H5X	0.000		67.347
120.000	98.400	1.000	1.000	0.500	116.85	1.776	3	2		
H6	H6	SAE	50*50*5	275.0	67.01	67.01	H6Y	-45.132	b013-2RMX	67.347
120.000	98.400	1.000	1.000	0.500	116.85	1.776	3	2		
H7	H7	SAE	45*45*5	275.0	16.17	16.17	FH741X	-11.147	b007-2LMX	68.926
120.000	98.400	1.000	1.000	1.000	97.99	0.862	3	2		
H8	H8	SAE	45*45*5	275.0	45.30	16.43	H8Y	-11.326	b014-2R MN	68.926
120.000	98.400	1.000	1.000	1.000	97.99	0.862	3	2		
H9	H9	SAE	50*50*5	275.0	18.29	0.00	H9X	0.000		75.014
120.000	98.400	1.000	1.000	0.500	102.29	1.555	3	2		

```
   H10    H10    SAE    50*50*5     275.0 93.48   93.48     H10Y  -39.528 b009-3LMX    42.284
120.000        98.400 1.000 1.000 1.000 158.66   1.555       5       2
   H11    H11    SAE    50*50*5     275.0 36.37   36.37     H11X  -16.295 b001-NCMX    44.803
120.000        98.400 1.000 1.000 1.000 153.06   1.500       5       2
   H12    H12    SAE    50*50*5     275.0 31.72   11.38     H12Y   -5.097b036-3RRSM    44.803
120.000        98.400 1.000 1.000 1.000 153.06   1.500       5       2
   H13    H13    SAE    60*60*5     275.0 26.55   26.55     H13P  -16.616 b009-3LMX    62.595
120.000        98.400 0.500 0.500 0.500 139.22   3.258       5       2
   H14    H14    SAE    60*60*5     275.0 19.80   19.80 FH1473P  -12.392 b012-1RMN    62.595
120.000        98.400 0.500 0.500 0.500 139.22   3.258       5       2
   H17    H17    SAE    60*60*5     275.0 39.83   39.83     H17Y  -17.683b017-NCLSM    44.390
120.000        98.400 0.500 0.500 0.500 172.35   4.033       5       2
   H18    H18    SAE    60*60*5     275.0 20.26   20.26 FH1875X   -8.994 b006-1LMN    44.390
120.000        98.400 0.500 0.500 0.500 172.35   4.033       5       2
    B1     B1    SAE    75*75*6     275.0 74.08   74.08      B1P  -87.468 b005-1LMX   125.520
120.000       118.080 0.500 0.500 0.500 115.33   3.391       2       2
    B2     B2    SAE    70*70*6     275.0 77.42   77.42      B2P  -88.978 b007-2LMX   114.925
120.000       118.080 0.500 0.500 0.500 116.75   3.176       2       2
    B3     B3    SAE    60*60*6     355.0 83.26   83.26      B3P  -90.828 b009-3LMX   109.089
120.000       146.880 0.600 0.600 0.400 108.36   3.169       2       2
    T1     T1    SAE    50*50*5     275.0 44.73   44.73      T1X  -11.628 b012-1RMN    25.993
120.000        98.400 1.000 1.000 0.500 234.91   3.571       6       2
    T2     T2    SAE    45*45*5     275.0 57.74   57.74      T2X  -12.465b014-2R MN    21.589
120.000        98.400 1.000 1.000 0.500 246.36   3.350       6       2
    T3     T3    SAE    45*45*5     275.0 59.34   51.99      T3P  -22.280 b010-3LMN    42.852
120.000        98.400 0.600 0.600 0.400 153.06   3.367       6       2
    P1     P1    SAE    50*50*6     275.0 42.38   42.38      P1P  -36.705 b003-PKMX    86.600
120.000       118.080 0.500 0.500 0.330 113.08   3.324       1       2
    M8     M8    SAE 100*100*7      355.0 81.75   81.75      M8P -347.057 b001-NCMX   424.527
720.000       514.080 0.250 0.250 0.250  38.70   3.050       1       6
   M10    M10    SAE 100*100*7      355.0 86.85   86.85     M10P -352.709 b001-NCMX   406.134
720.000       514.080 0.160 0.160 0.160  49.54   6.099       1       6
   M12    M12    SAE 100*100*8      355.0 83.01   83.01     M12Y -374.414 b001-NCMX   451.029
720.000       587.520 0.200 0.200 0.200  62.24   6.099       1       6
  DUMM   DUMM    SAE      DUMMY     275.0  0.00    0.00   DUMMXY   -0.177 b001-NCMX     0.209
120.000         5.904 0.500 0.500 0.500 365.64   4.607       5       2
```


Group Summary (Tension Portion):

```
 Group Group Angle      Angle     Steel    Max     Max Tension Tension    Tension       Net
Tens. Conn. Tens. Conn. Tens. Conn. Length No. Of No. Of     Hole
 Label Desc.  Type        Size Strength Usage Use In Control    Force    Control  Section
Shear      Bearing      Rupture  Tens.   Bolts  Holes Diameter
                                                   Tens.  Member          Load Case Capacity
Capacity     Capacity     Capacity Member  Tens.
                                      (MPa)      %       %              (kN)                 (kN)
(kN)         (kN)         (kN)    (m)                      (cm)
-------------------------------------------------------------------------------------------
----------------------------------------------------------------
    M1     M1    SAE 100*100*7      355.0 83.12   64.05      M1X 252.073 b002-NCMN   393.528
720.000       514.080           0.000  4.280       6  2.000      1.75
    M2     M2    SAE    90*90*7     355.0 89.45   71.44     M2XY 245.629 b010-3LMN   343.828
360.000       514.080           0.000  3.456       6  2.000      1.75
    M3     M3    SAE    90*90*7     355.0 78.84   68.03     M3XY 233.902 b010-3LMN   343.828
720.000       514.080           0.000  2.821       6  2.000      1.75
    M4     M4    SAE    90*90*7     355.0 81.95   67.25     M4XY 231.211 b010-3LMN   343.828
720.000       514.080           0.000  2.277       6  2.000      1.75
    M5     M5    SAE    90*90*6     355.0 83.46   71.42     M5XY 212.203 b010-3LMN   297.135
720.000       440.640           0.000  1.876       6  2.000      1.75
    M6     M6    SAE    75*75*6     355.0 93.26   76.65    M61XY 178.464 b010-3LMN   232.820
240.000       293.760           0.000  1.008       4  2.000      1.75
    M7     M7    SAE    60*60*6     355.0 73.39   55.89    M71XY  94.123b029-PKRSM   168.405
240.000       293.760           0.000  0.977       4  2.000      1.75
    D1     D1    SAE    50*50*5     275.0 69.43   20.57     D1XY  19.923 b005-1LMX    96.864
120.000        98.400           0.000  6.710       2  1.000      1.75
    D2     D2    SAE    50*50*5     275.0 65.98   18.30      D2X  17.725 b012-1RMN    96.864
120.000        98.400           0.000  6.710       2  1.000      1.75
    D5     D5    SAE    45*45*5     275.0 80.47   29.34      D5Y  24.699 b012-1RMN    84.182
120.000        98.400           0.000  5.431       2  1.000      1.75
```

D6	D6	SAE	45*45*5	275.0	71.68	27.87	D6XY	23.460	b009-3LMX	84.182	120.000	98.400	0.000	5.431	2	1.000	1.75
D9	D9	SAE	50*50*5	275.0	73.54	31.45	D9XY	30.468	b005-1LMX	96.864	120.000	98.400	0.000	4.414	2	1.000	1.75
D10	D10	SAE	50*50*5	275.0	69.87	28.00	D10X	27.119	b012-1RMN	96.864	120.000	98.400	0.000	4.414	2	1.000	1.75
D11	D11	SAE	45*45*5	275.0	85.90	44.83	D11Y	37.743	b012-1RMN	84.182	120.000	98.400	0.000	3.571	2	1.000	1.75
D12	D12	SAE	45*45*5	275.0	76.50	42.59	D12XY	35.854	b009-3LMX	84.182	120.000	98.400	0.000	3.571	2	1.000	1.75
D13	D13	SAE	45*45*5	275.0	78.90	55.63	D13XY	46.831	b005-1LMX	84.182	120.000	98.400	0.000	2.911	2	1.000	1.75
D14	D14	SAE	45*45*5	275.0	74.96	49.53	D14X	41.692	b012-1RMN	84.182	120.000	98.400	0.000	2.911	2	1.000	1.75
D15	D15	SAE	45*45*5	275.0	60.21	17.57	D15X	14.793	b006-1LMN	84.182	120.000	98.400	0.000	2.828	2	1.000	1.75
D16	D16	SAE	45*45*5	275.0	72.72	58.49	D162XY	49.242	b007-2LMX	84.182	120.000	98.400	0.000	1.383	2	1.000	1.75
D17	D17	SAE	45*45*5	275.0	82.75	66.55	D172X	56.022	b013-2RMX	84.182	120.000	98.400	0.000	1.383	2	1.000	1.75
D18	D18	SAE	50*50*5	275.0	75.13	59.48	D18Y	57.618	b014-2R MN	96.864	120.000	98.400	0.000	2.975	2	1.000	1.75
D19	D19	SAE	50*50*5	275.0	85.47	67.69	D19XY	65.572	b008-2LMN	96.864	120.000	98.400	0.000	2.975	2	1.000	1.75
D20	D20	SAE	45*45*5	275.0	47.18	18.32	D20P	15.426	b008-2LMN	84.182	120.000	98.400	0.000	2.512	2	1.000	1.75
D21	D21	SAE	45*45*5	275.0	75.48	65.55	D212XY	55.184	b010-3LMN	84.182	120.000	98.400	0.000	1.286	2	1.000	1.75
D22	D22	SAE	45*45*5	275.0	75.69	61.77	D222XY	51.999	b010-3LMN	84.182	120.000	98.400	0.000	1.286	2	1.000	1.75
D23	D23	SAE	50*50*5	275.0	86.43	67.87	D23XY	65.741	b009-3LMX	96.864	120.000	98.400	0.000	2.869	2	1.000	1.75
D24	D24	SAE	50*50*5	275.0	81.45	68.05	D24XY	65.918	b009-3LMX	96.864	120.000	98.400	0.000	2.869	2	1.000	1.75
D25	D25	SAE	45*45*5	275.0	30.77	14.59	D25P	12.279	b010-3LMN	84.182	120.000	98.400	0.000	2.199	2	1.000	1.75
D26	D26	SAE	45*45*5	275.0	36.26	34.81	D26XY	17.128	b010-3LMN	84.182	60.000	49.200	0.000	1.871	1	1.000	1.75
D27	D27	SAE	45*45*5	275.0	50.19	50.19	D27X	24.694	b035-3RRSM	84.182	60.000	49.200	0.000	1.871	1	1.000	1.75
D28	D28	SAE	45*45*5	275.0	16.07	16.07	D28P	13.526	b009-3LMX	84.182	120.000	98.400	0.000	2.121	2	1.000	1.75
D30	D30	SAE	50*50*5	275.0	66.60	20.20	D30P	19.562	b009-3LMX	96.864	120.000	98.400	0.000	6.834	2	1.000	1.75
D31	D31	SAE	50*50*5	275.0	51.90	15.01	D31Y	14.535	b012-1RMN	96.864	120.000	98.400	0.000	6.834	2	1.000	1.75
D38	D38	SAE	50*50*5	275.0	64.02	28.77	D38Y	27.864	b011-1RMX	96.864	120.000	98.400	0.000	7.271	2	1.000	1.75
D39	D39	SAE	45*45*5	275.0	60.85	23.22	D39XY	19.546	b006-1LMN	84.182	120.000	98.400	0.000	7.271	2	1.000	1.75
D42	D42	SAE	55*55*5	275.0	80.59	27.90	D42Y	27.450	b017-NCLSM	108.826	120.000	98.400	0.000	7.728	2	1.000	1.75
D43	D43	SAE	50*50*5	275.0	52.83	14.27	D43XY	13.827	b006-1LMN	96.864	120.000	98.400	0.000	7.728	2	1.000	1.75
H1	H1	SAE	50*50*5	275.0	32.05	32.05	H1X	31.046	b001-NCMX	96.864	120.000	98.400	0.000	2.000	2	1.000	1.75
H2	H2	SAE	50*50*5	275.0	74.90	15.84	H2P	15.344	b006-1LMN	96.864	120.000	98.400	0.000	2.000	2	1.000	1.75
H3	H3	SAE	45*45*5	275.0	18.61	3.88	H3P	3.262	b012-1RMN	84.182	120.000	98.400	0.000	0.973	2	1.000	1.75
H4	H4	SAE	45*45*5	275.0	45.10	45.10	FH428P	37.966	b005-1LMX	84.182	120.000	98.400	0.000	0.973	2	1.000	1.75
H5	H5	SAE	50*50*5	275.0	20.01	20.01	H5X	19.384	b001-NCMX	96.864	120.000	98.400	0.000	1.776	2	1.000	1.75
H6	H6	SAE	50*50*5	275.0	67.01	23.07	H6P	22.342	b034-2RRSM	96.864	120.000	98.400	0.000	1.776	2	1.000	1.75
H7	H7	SAE	45*45*5	275.0	16.17	3.94	H7P	3.319	b014-2R MN	84.182	120.000	98.400	0.000	0.862	2	1.000	1.75
H8	H8	SAE	45*45*5	275.0	45.30	45.30	FH842P	38.131	b007-2LMX	84.182	120.000	98.400	0.000	0.862	2	1.000	1.75
H9	H9	SAE	50*50*5	275.0	18.29	18.29	H9X	17.720	b017-NCLSM	96.864							

120.000	98.400	0.000	1.555	2	1.000	1.75				
H10	H10	SAE	50*50*5	275.0	93.48	20.58	H10P	19.932	b036-3RRSM	96.864
120.000	98.400	0.000	1.555	2	1.000	1.75				
H11	H11	SAE	50*50*5	275.0	36.37	1.67	H11P	1.618	b018-NCLSM	96.864
120.000	98.400	0.000	1.500	2	1.000	1.75				
H12	H12	SAE	50*50*5	275.0	31.72	31.72	H12P	30.721	b001-NCMX	96.864
120.000	98.400	0.000	1.500	2	1.000	1.75				
H13	H13	SAE	60*60*5	275.0	26.55	15.90	FH1372Y	15.643	b012-1RMN	120.750
120.000	98.400	0.000	3.258	2	1.000	1.75				
H14	H14	SAE	60*60*5	275.0	19.80	12.34	H14X	12.146	b005-1LMX	120.750
120.000	98.400	0.000	3.258	2	1.000	1.75				
H17	H17	SAE	60*60*5	275.0	39.83	17.81	FH1774Y	17.523	b017-NCLSM	120.750
120.000	98.400	0.000	4.033	2	1.000	1.75				
H18	H18	SAE	60*60*5	275.0	20.26	9.01	H18P	8.869	b011-1RMX	120.750
120.000	98.400	0.000	4.033	2	1.000	1.75				
B1	B1	SAE	75*75*6	275.0	74.08	49.55	B1XY	58.511	b012-1RMN	188.305
120.000	118.080	0.000	3.391	2	1.000	1.75				
B2	B2	SAE	70*70*6	275.0	77.42	51.50	B2XY	60.808	b014-2R MN	173.498
120.000	118.080	0.000	3.176	2	1.000	1.75				
B3	B3	SAE	60*60*6	355.0	83.26	48.85	B3XY	58.617	b036-3RRSM	185.112
120.000	146.880	0.000	3.169	2	1.000	1.75				
T1	T1	SAE	50*50*5	275.0	44.73	43.22	T1Y	41.869	b005-1LMX	96.864
120.000	98.400	0.000	3.571	2	1.000	1.75				
T2	T2	SAE	45*45*5	275.0	57.74	49.82	T2Y	41.937	b007-2LMX	84.182
120.000	98.400	0.000	3.350	2	1.000	1.75				
T3	T3	SAE	45*45*5	275.0	59.34	59.34	T3Y	49.951	b009-3LMX	84.182
120.000	98.400	0.000	3.367	2	1.000	1.75				
P1	P1	SAE	50*50*6	275.0	42.38	35.03	P1XY	34.470	b020-PKLSM	98.414
120.000	118.080	0.000	3.324	2	2.000	1.75				
M8	M8	SAE	100*100*7	355.0	81.75	67.21	M8X	264.473	b002-NCMN	393.528
720.000	514.080	0.000	3.050	6	2.000	1.75				
M10	M10	SAE	100*100*7	355.0	86.85	68.15	M10X	268.176	b002-NCMN	393.528
720.000	514.080	0.000	6.099	6	2.000	1.75				
M12	M12	SAE	100*100*8	355.0	83.01	63.57	M12X	284.010	b002-NCMN	446.778
720.000	587.520	0.000	6.099	6	2.000	1.75				
DUMM	DUMM	SAE	DUMMY	275.0	0.00	0.00	DUM1Y	0.107	b001-NCMX	1.176
120.000	5.904	0.000	4.607	2	1.000	1.75				

*** Maximum Stress Summary for Each Load Case

Summary of Maximum Usages by Load Case:

Load Case	Maximum Usage %	Element Label	Element Type
b001-NCMX	89.45	M2P	Angle
b002-NCMN	83.96	M2Y	Angle
b003-PKMX	88.83	M6P	Angle
b004PKMN	80.70	M6P	Angle
b005-1LMX	85.90	D11X	Angle
b006-1LMN	85.84	D11X	Angle
b007-2LMX	84.71	D19Y	Angle
b008-2LMN	84.81	D19Y	Angle
b009-3LMX	93.48	H10Y	Angle
b010-3LMN	86.66	M61P	Angle
b011-1RMX	78.85	D13P	Angle
b012-1RMN	78.90	D13P	Angle
b013-2RMX	85.47	D19P	Angle
b014-2R MN	85.32	D19P	Angle
b015-3RMX	56.83	M2P	Angle
b016-3RMN	53.17	M2P	Angle
b017-NCLSMX	80.59	D42XY	Angle
b018-NCLSMN	74.43	D42XY	Angle
b019-PKLSMX	52.75	M61P	Angle
b020-PKLSMN	60.53	M61P	Angle
b021-1LLSMX	51.74	D42X	Angle
b022-1LLSMN	48.23	D42X	Angle

b023-2LLSMX	72.85	D42X	Angle
b024-2LLSMN	69.31	D42X	Angle
b025-3LLSMX	79.50	D23X	Angle
b026-3LLSMN	78.62	D23X	Angle
b027-NCRSMX	81.01	M6Y	Angle
b028-NCRSMN	66.48	D42XY	Angle
b029-PKRSMX	81.02	M6P	Angle
b030-PKRSMN	69.33	M6P	Angle
b031-1RRSMX	50.15	M6Y	Angle
b032-1RRSMN	43.49	D42XY	Angle
b033-2RRSMX	73.02	D171P	Angle
b034-2RRSMN	67.46	D19P	Angle
b035-3RRSMX	80.60	M6P	Angle
b036-3RRSMN	77.35	D23P	Angle

Summary of Insulator Usages:

Insulator Label	Insulator Type	Maximum Usage %	Load Case	Weight (N)
JA0	Clamp	2.78	b003-PKMX	0.0
CA0	Clamp	5.06	b005-1LMX	0.0
CB0	Clamp	5.06	b011-1RMX	0.0
CC0	Clamp	4.96	b007-2LMX	0.0
CD0	Clamp	4.96	b013-2RMX	0.0
CE0	Clamp	4.94	b009-3LMX	0.0
CF0	Clamp	4.56	b035-3RRSMX	0.0
AA0	Clamp	0.91	b002-NCMN	0.0
AA1	Clamp	0.91	b002-NCMN	0.0
AA2	Clamp	0.91	b002-NCMN	0.0
AA3	Clamp	0.91	b002-NCMN	0.0
XC0	Clamp	0.70	b002-NCMN	0.0
XC1	Clamp	0.70	b002-NCMN	0.0
XC2	Clamp	0.70	b002-NCMN	0.0
XC3	Clamp	0.70	b002-NCMN	0.0

*** Weight of structure (N):
Weight of Angles*Section DLF: 52794.0
Total: 52794.0

*** End of Report

Appendix H

Tower analys with New conductor loads

Serial No.	Tower Type	Body Extension	Modification if any	Serial No.	Tower Type	Body Extension	Modification if any
1	TDT	3		61	TDL	3	
2	TD3	6		62	TDL	0	
3	TDL	6		63	TDL	3	
4	TDL	9		64	TDL	0	
5	TDL	3		65	TDL	0	
6	TDL	6		66	TDL	0	
7	TDL	6		67	TD1	3	
8	TDL	9		68	TDL	3	
9	TDL	3		69	TDL	0	
10	TD1spe	6	2 members to be changed	70	TDL	0	
11	TDL	6		71	TDL	0	
12	TDL	6		72	TDL	0	
13	TDL	0		73	TDL	0	
14	TDL	3		74	TDL	3	
15	TDL	6		75	TD3	0	2 members to be changed
16	TDL	0		76	TDL	0	
17	TDL	0		77	TDL	0	
18	TDL	0		78	TDL	6	
19	TDL	0		79	TD1sus	9	
20	TD6	0	4 members to be changed	80	TD1sus	9	
21	TDL	3		81	TDL	3	
22	TDL	0		82	TDL	0	
23	TDL	6		83	TDL	3	
24	TDL	9	1 member to be changed	84	TDL	3	
25	TDL	0		85	TDL	3	
26	TDL	3		86	TD1	3	
27	TDL	0		87	TDL	3	
28	TDL	6		88	TDL	0	
29	TD1	6		89	TDL	0	
30	TDL	3		90	TDL	0	
31	TDL	6		91	TDL	0	
32	TDL	0		92	TDL	0	
33	TDL	3		93	TDL	3	
34	TDL	6		94	TDL	6	3 members to be changed
35	TDL	3		95	TD1sus	9	
36	TDL	3		96	TD1	6	
37	TD1	0		97	TDL	3	
38	TDL	9		98	TDL	6	
39	TDL	6		99	TDL	0	
40	TDL	3		100	TDL	0	
41	TDL	0		101	TDL	0	
42	TDL	3		102	TDL	3	

43	TDL	3		103	TDL	3	
44	TDL	3		104	TDL	3	
45	TDL	0		105	TD6	0	
46	TDL	3		106	TDL	3	
47	TD1	0		107	TDL	3	
48	TDL	3		108	TDL	0	
49	TDL	0		109	TDL	3	
50	TDL	0		110	TDL	0	
51	TDL	3		111	TDL	0	
52	TDL	3		112	TDL	3	
53	TDL	0		113	TDL	0	
54	TDL	3		114	TDL	0	
55	TDL	0		115	TDL	3	
56	TDL	0		116	TDL	0	
57	TDL	0		117	TD1	0	
58	TDL	3		118	TDL	0	
59	TDL	3		119	TDL	0	
60	TD1	3		120	TDL	3	

Serial No.	Tower Type	Body Extension	Modification if any	Serial No.	Tower Type	Body Extension	Modification if any
121	TDL	0		181	TDL	0	
122	TDL	0		182	TDL	0	
123	TDL	0		183	TDL	0	
124	TDL	3		184	TDL	3	
125	TDL	3		185	TDL	0	
126	TDL	3		186	TDL	0	
127	TDL	3		187	TD1	0	
128	TDL	3		188	TDL	3	
129	TD3	0	4 members to be changed	189	TDL	0	
130	TDL	3		190	TDL	0	
131	TDL	3		191	TDL	0	
132	TDL	0		192	TDL	0	
133	TDL	0		193	TDL	0	
134	TDL	0		194	TDL	3	
135	TDL	0		195	TDL	0	
136	TDL	0		196	TDL	0	
137	TDL	3		197	TD1	0	
138	TD1	0		198	TDL	0	
139	TDL	0		199	TDL	0	
140	TDL	0		200	TDL	0	
141	TDL	3		201	TDL	3	
142	TDL	3		202	TDL	0	
143	TDL	3		203	TDL	0	
144	TDL	3		204	TDL	0	
145	TDL	3		205	TDL	0	
146	TDL	0		206	TD1	0	2 members to be changed
147	TDL	0		207	TDL	3	
148	TDL	0		208	TDL	0	
149	TD1	0		209	TDL	3	

150	TDL	3		210	TDL	0	
151	TDL	0		211	TDL	0	
152	TDL	0		212	TDL	3	
153	TDL	3		213	TDL	0	
154	TDL	0		214	TDL	0	
155	TDL	3		215	TDL	0	
156	TDL	3		216	TDL	0	
157	TDL	0		217	TD1	0	
158	TDL	0		218	TDL	0	
159	TD1	0		219	TDL	3	
160	TDL	0		220	TDL	3	
161	TDL	3		221	TDL	3	
162	TDL	3		222	TDL	0	
163	TDL	0		223	TDL	0	
164	TDL	0		224	TDL	3	
165	TDL	0		225	TDL	6	
166	TDL	0		226	TDL	3	
167	TD3	0	1 member to be changed	227	TDL	0	
168	TDL	0		228	TD3	0	
169	TDL	0		229	TD1	0	
170	TDL	3		230	TDL	3	
171	TDL	0		231	TD1spe	0	
172	TDL	0		232	TD3	0	
173	TDL	0		233	TDL	6	
174	TDL	3		234	TDL	3	
175	TDL	0		235	TDL	3	
176	TDL	0		236	TD6	3	
177	TD1	0	1 member to be changed	237	TDL	6	3 members to be changed
178	TDL	0		238	TDT	0	
179	TDL	0					
180	TDL	3					

Appendix I

i. Angle Tower (TD3)

Angle of Deviation (Degree)	Wind Span (m)	
	Conductor	Earthwire
11	958.8	1003.3
12	926.9	969.0
13	895.0	934.8
14	863.2	900.6
15	831.4	866.4
16	799.6	832.3
17	767.9	798.2
18	736.2	764.2
19	704.5	730.2
20	672.9	696.2
21	641.4	662.3
22	609.9	628.5
23	578.4	594.7
24	547.0	561.0
25	515.7	527.3
26	484.4	493.7
27	453.2	460.2
28	422.1	426.7
29	391.0	393.3
30	***360.0***	***360.0***
31	329.1	326.8
32	298.2	293.6
33	267.4	260.5
34	236.7	227.6
35	206.1	194.7

36	175.6	161.8
37	145.1	129.1
38	114.8	96.5
39	84.5	64.0
40	54.3	31.6

iv. Angle Tower (TD6)

Angle of Deviation Degree	Wind Span (m)	
	Conductor	Earthwire
40	940.4	983.6
41	910.4	951.3
42	880.4	919.1
43	850.5	887.0
44	820.7	855.0
45	791.0	823.1
46	761.5	791.3
47	732.0	759.7
48	702.7	728.1
49	673.4	696.7
50	644.3	665.5
51	615.3	634.3
52	586.4	603.3
53	557.7	572.4
54	529.0	541.6
55	500.5	511.0
56	472.2	480.5
57	443.9	450.2
58	415.8	420.0

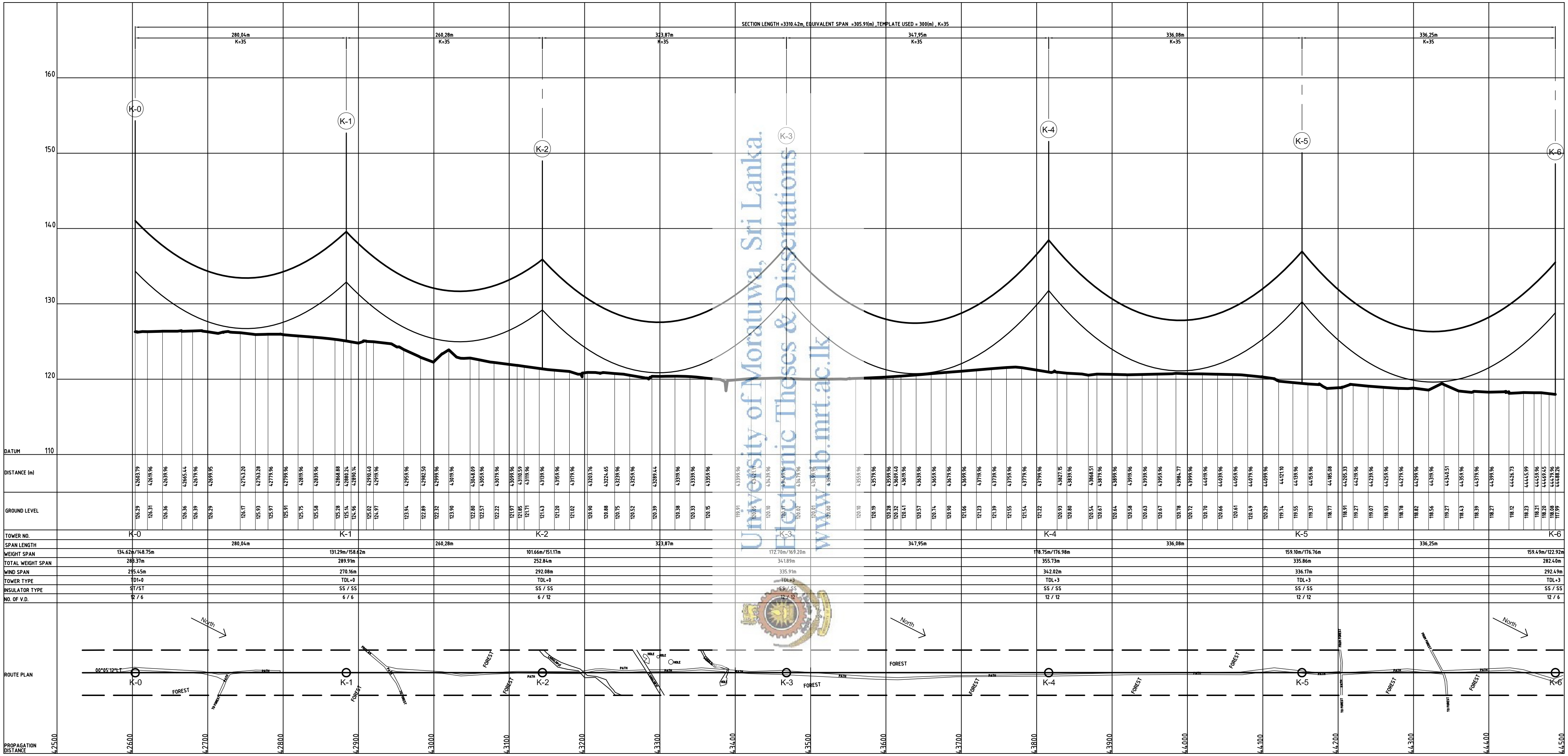
59	387.8	389.9
60	***360.0***	***360.0***
61	332.3	330.2
62	304.7	300.6
63	277.3	271.2
64	250.1	241.9
65	223.0	212.8
66	196.0	183.8
67	169.2	155.0
68	142.5	126.3
69	116.0	97.9
70	89.7	69.6

v. Angle Tower (TDT)

Angle of Deviation (Degree)	Wind Span (m)	
	Conductor	Earthwire
75	721.3	748.2
76	696.0	721.0
77	670.8	693.9
78	645.8	667.1
79	621.0	640.4
80	596.3	613.9
81	571.8	587.6
82	547.6	561.5
83	523.5	535.6
84	499.5	509.9
85	475.8	484.4
86	452.3	459.1
87	428.9	434.0

88	405.7	409.1
89	382.8	384.5
90	***360.0***	***360.0***
91	337.4	335.7
92	315.1	311.7
93	292.9	287.9
94	270.9	264.3
95	249.1	240.9
96	227.6	217.7
97	206.2	194.8
98	185.1	172.1
99	164.2	149.6
100	143.5	127.3

Appendix J



SECTION LENGTH =3310.42m, EQUIVALENT SPAN =305.91(m) ,TEMPLATE USED = 300(m) , K=35
280,04m K=35
260,28m K=35
323,87m K=35
347,95m K=35
336,08m K=35
336,25m K=35
K-0
K-1
K-2
K-3
K-4
K-5
K-6
DATUM
DISTANCE (m)
GROUND LEVEL
TOWER NO.
SPAN LENGTH
WEIGHT SPAN
TOTAL WEIGHT SPAN
WIND SPAN
TOWER TYPE
INSULATOR TYPE
NO. OF V.D.
ROUTE PLAN
PROPAGATION DISTANCE
134.62m/148.75m
283.37m
295.45m
TDI+0
ST/ST
12 / 6
131.29m/158.62m
289.91m
270.16m
TDL+0
SS / SS
6 / 6
101.66m/151.17m
252.84m
292.08m
TDL+0
SS / SS
6 / 12
172.70m/169.20m
341.89m
335.91m
TDL+3
SS / SS
12 / 12
178.75m/176.98m
355.73m
342.02m
TDL+3
SS / SS
12 / 12
159.10m/176.76m
335.86m
336.17m
TDL+3
SS / SS
12 / 12
159.49m/122.92m
282.40m
292.49m
TDL+3
SS / SS
12 / 6
North
FOREST
PATH
00°05'12"LT