

École polytechnique de Louvain

Optimization of steel lattice towers for the energy transition in Europe

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Contents

1	Introduction	5
1.1	Thesis introduction	5
1.2	State of the art	6
1.2.1	Transmission tower	6
1.2.2	Research project ANGELHY	9
1.2.3	Built-up angle	10
1.2.4	High strength steel S460 – one key for the energy transition	11
1.2.5	Current design norms for steel lattice towers	12
2	Norms	13
2.1	Comparison between EN 50341 & EN 1993	13
2.2	Comparison of standards in ANGELHY	14
2.2.1	Angle sections in compression – Cross-section resistance . . .	14
2.2.2	Member buckling resistance	15
2.2.2.1	Angle sections in compression – Buckling of diagonals	16
2.2.2.2	Buckling of leg members	18
2.3	Show case - Equal leg angle in compression	21
2.3.1	Method according to EN50341	21
2.3.1.1	Verification of the cross-section in compression . . .	21
2.3.1.2	Buckling verification	23
2.3.1.3	Flexural-torsion verification	25
2.3.2	Method according to the EN1993-3-1	25
2.3.2.1	Verification of the cross-section in compression . . .	26
2.3.2.2	Buckling verification	26
2.3.2.3	Flexural-torsion verification	28
2.3.3	Observations	30
3	Optimization	32
3.1	TOWER software	32
3.2	First model steel lattice tower – Suspension Tower	33
3.2.1	Typology of the model steel lattice tower	33

3.2.1.1	Geometry and dimensions	33
3.2.1.2	Conductors	36
3.2.1.3	Insulators	37
3.2.1.4	Transmission Line	37
3.2.2	Modelling in TOWER software	37
3.2.3	Analysis according to EN50341	38
3.2.3.1	General design assumptions	38
3.2.3.2	Load cases	39
3.2.3.3	Loads in the TOWER software	40
3.2.3.3.1	Permanent loads	40
3.2.3.3.2	Wind loads	41
3.2.3.3.3	Ice loads	42
3.2.3.4	Results of the linear elastic global design	43
3.2.3.4.1	Bottom section	44
3.2.3.4.2	Section 1	45
3.2.3.4.3	Section 2	46
3.2.3.4.4	Section 3	47
3.2.3.4.5	Section 4	48
3.2.3.4.6	Section 5	49
3.2.3.4.7	Top section	51
3.2.3.4.8	Three first big cross arms	52
3.2.3.4.9	Three first small cross arms	54
3.2.3.4.10	Big top cross arm	54
3.2.3.4.11	Small top cross arm	55
3.2.3.5	Analysis of results	56
3.3	Second model steel lattice tower – Dead end Tower	58
3.3.1	Typology of the steel lattice tower	58
3.3.1.1	Geometry and dimensions	58
3.3.1.2	Conductors	58
3.3.1.3	Insulators	59
3.3.1.4	Transmission Line	59
3.3.2	Analysis according to EN50341	59
3.3.2.1	General design assumptions	59
3.3.2.2	Load cases	60
3.3.2.3	Loads in the TOWER software	62
3.3.2.3.1	Permanent loads	62
3.3.2.3.2	Wind loads	62
3.3.2.3.3	Ice loads	64
3.3.2.3.4	Tension in the cables	64
3.3.2.4	Results of the linear elastic global design	65

	3.3.2.4.1	Bottom section	66
	3.3.2.4.2	Section 1	67
	3.3.2.4.3	Section 2	68
	3.3.2.4.4	Section 3	69
	3.3.2.4.5	Section 4	70
	3.3.2.4.6	Section 5	71
	3.3.2.4.7	Top section	73
	3.3.2.4.8	Three first big cross arms	74
	3.3.2.4.9	Three first small cross arms	75
	3.3.2.4.10	Big top cross arm	76
	3.3.2.4.11	Small top cross arm	77
	3.3.2.5	Analysis of results	78
3.4		Combination of steel grades for the dead-end tower	81
	3.4.1	Combination of steel S460 and S235	81
		3.4.1.1 Methodology	81
		3.4.1.2 Results of the linear analysis	82
	3.4.2	Combination of steel S460 and S355	86
		3.4.2.1 Methodology	86
		3.4.2.2 Results of the linear analysis	86
	3.4.3	Combination of steel S460, S355 and S235	90
		3.4.3.1 Methodology	90
		3.4.3.2 Results of the linear analysis	91
	3.4.4	Analysis of the results	95
3.5		Embedded tower	95
	3.5.1	Results of the linear analysis in TOWER software	95
	3.5.2	Analysis of the results	101
	3.5.3	Calculation of a connection	102
		3.5.3.1 Bolts resistance	102
		3.5.3.2 Force that the bolts must support	104
	3.5.4	Conclusion following the various results	105
3.6		Optimization of the tower geometry	105
	3.6.1	Optimization of the tower geometry according to tower bracing	106
		3.6.1.1 Typology of the steel lattice tower	106
		3.6.1.2 Analysis of the results of the linear analysis	107
	3.6.2	Optimization of the tower geometry according to the inclination of the tower legs	108
3.7		Combination of steel grades in the tower with optimised geometry .	110
	3.7.1	Combination of steel S460 and S235	111
	3.7.2	Combination of steel S460 and S355	115
	3.7.3	Combination of steel S460, S355 and S235	119

3.7.4 Analysis of the results	123
4 Conclusion	124
List of Figures	125
Bibliography	131
A Comparative table of norms	135
B Internal forces in embedded nodes	148
C Angles size - staggered bracing tower	173
C.1 Bottom section	173
C.2 Section 1	174
C.3 Section 2	176
C.4 Section 3	177
C.5 Section 4	179
C.6 Section 5	181
C.7 Top section	183
C.8 Cross arms	185
D Angles size according to leg inclination	187
D.1 7 metres between legs	187
D.2 8 metres between legs	191
D.3 9 metres between legs	195
D.4 10 metres between legs	198
D.5 10,2 metres between legs	202
D.6 11 metres between legs	206
D.7 12 metres between legs	210

Chapter 1

Introduction

1.1 Thesis introduction

“Renewables to overtake coal as world’s top energy source by 2025”
International Energy Agency^[11].

The increasing use of renewable energies to generate electricity is a growing trend in Europe. Indeed, Europe is actively engaged in this energy transition to reduce greenhouse gas emissions and promote a greener, more sustainable economy. As renewable energies such as solar, wind, hydro, and biomass are produced on a decentralized basis, this transition requires the electricity grid to be adapted to meet growing demand and guarantee a secure electricity supply. Extending and reinforcing the power grid is essential to effectively integrate these renewable energy sources, ensure reliable distribution and optimize the use of available energy resources.

As the ecological and sustainability aspects were not covered in my studies, I wanted to be able to take part in this movement as an engineer. I also liked the idea of promoting energy independence by reducing dependence on fuels.

A favourable solution for supporting these electrical transmission lines are steel lattice towers. These towers consist of an assembly of hot-rolled angle sections bolted together to form a lattice.

With increasing voltage of the electric grid, higher loads from the conductors are expected and in consequence new types of standardized steel lattice towers are required. The aim of this thesis is therefore to find a solution to optimize these towers and, in particular, to reduce their weight.

In a first step, the state-of-the-art of the transmission towers is assessed. In a second step, the different design standards for steel lattice towers are analysed and compared. Finally, a new typology for steel lattice towers is modelled with a structural engineer software and optimized with regard to its structural weight.

1.2 State of the art

1.2.1 Transmission tower

A transmission tower is a vertical support that carries the conductors of a high-voltage line at a safe height above the ground. These high-voltage transmission lines carry bulk electrical power from power stations to substations. Mostly made of steel, it is designed to support one or more overhead cables over long distances.

There are different types of transmission towers such as lattice towers, monopoles and guyed towers^[1]. The pylons studied in this thesis are the steel lattice towers.

Lattice towers (see Figure 1.1) are steel towers, consisting of an assembly of mostly hot-dipped galvanized and bolted steel angle sections (especially used as bracing) forming a lattice. Bolted connections make the erection of the tower simple and modular, unlike welded connections. The use of galvanized steel protects the tower from corrosion for the life of the tower, which can vary from 80 to 100 years.



Figure 1.1: Steel lattice tower^[40]

A steel lattice tower consists of three distinct parts: the tower body, the cross arms and the earth cable support.

1. The body of the tower:



Figure 1.2: Body of a steel lattice tower

This part of the tower is the main part and plays an essential role in maintaining the required distance from the ground for the lower driver and in supporting the cross arms. It consists, in general, of the 4 leg members, running from the top of the tower to ground level, and the primary and secondary bracing systems.

- Primary bracing is used to interconnect the legs of the transmission tower, which reduces their buckling length and increases the stability of the tower due to the triangularization effect. This bracing system is used to take up the horizontal loads that arrive on the tower, such as wind.
- Secondary bracing is used to reduce the unsupported length and thus increase their buckling resistance. The main legs and primary bracing members are laterally supported at intervals between their end nodes. This bracing system is also known as redundant bracing.

To ensure simple delivery and modular assembly, the tower body is cut into individual modules which are attached to each other by the leg members using bolts, either directly or via gussets.

2. The cross arms:

The crossbars of transmission towers hold the transmission conductors and insulators and transfer their loads to the tower body. The size of the cross

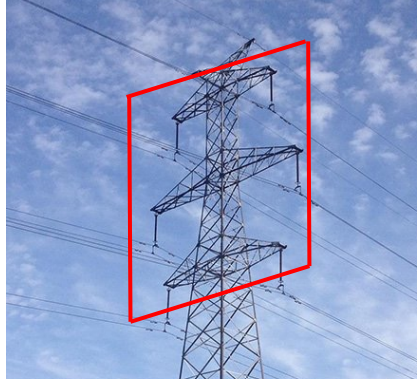


Figure 1.3: Cross arms of a steel lattice tower

arm depends on the transmission tension level, configuration, and minimum formation angle for stress distribution. One or more right or left arms may be required, depending on the type of tower.

The cross arm consists of an upper and a lower element which are connected by a vertical and horizontal system of angle braces required to brace them and therefore to take up the horizontal loads.

3. The earth wire support :



Figure 1.4: Body of a steel lattice tower

The earth wire support, also called the peak of the tower, is the upper module of a transmission tower, above the upper cross arm. Its role is to carry the earth wire that protects the tower from lightning and sometimes transmits information.

The electricity network covers a considerable distance across varied terrain. Lattice towers are installed at intervals of 300 to 500 meters. To overcome obstacles along the route, different lattice tower structures are used such as the Anchor portal tower, the Delta tower, the Fir tree tower, the Single plane tower, the Danube tower or the Barrel tower as described in the ANGELHY research project^[1].

1.2.2 Research project ANGELHY

Currently, transmission lattice towers are made from steel angles in steel grades S355 or S235. However, with the development of renewable energies and advances in telecommunication technology such as 5G, these towers are no longer sufficient. Indeed, these changes lead to an increase in the size of the electrical cables and thus to an increase in the loads on the towers. Several solutions have been put forward, such as the reinforcement of existing electrical transmission lines and towers and the construction of new lines and thus new telecommunication towers.

According to ENTSO-E, the European Network of Transmission System Operators for Electricity, an association representing 42 transmission system operators from 35 countries across Europe, the construction of more than 46,000 km of additional cables and lines in Europe is expected by 2035^[8].

This tells us that the market for steel lattice towers has the potential to grow considerably, which requires the development of innovative design rules and construction methods. The ANGELHY research project has been launched to try to find solutions to this expansion^[1]. This project of 42 months studies the behaviour of towers and their elements using a combination of experimental, analytical and numerical methods. It focuses on the establishment of analysis methods for different lattice towers typologies and the development of design rules for steel and hybrid angle sections, as well as for built elements composed of these angles.

The ANGELHY project has significantly improved the analysis and design of new lattice towers, as well as the rehabilitation of existing towers, using steel angle sections. The project introduced a new type of reinforced hybrid elements, which consist of a steel corner section with FRP plates attached to the legs. Several structural elements, as well as complete towers, were experimentally tested to failure to validate the developments.

Numerical models were developed and validated by comparing the results with the experimental tests and other available models. These models were then used to study ranges of variation of important parameters. New design rules were proposed for equal steel members, hybrid members and assembled members. These rules have been extensively validated by numerical results and experimental analysis. Appropriate rules have also been suggested for the construction of hybrid members.

The ANGELHY project also studied the performance of power transmission lines, taking into account the uncertain characteristics of wind and ice loads.

1.2.3 Built-up angle

One aspect of the ANGELHY research project that has been extensively examined concerns built-up angles. These are currently used to reinforce the leg angles of steel lattice towers.

EN1993-1-1 defines different categories of built-up elements intended for members in compression (see Figure 1.5).

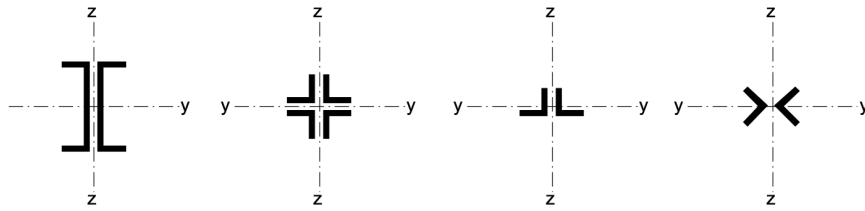


Figure 1.5: Different types of built-up members^[4]

In the context of steel lattice towers, the two types on the right are the most commonly used. On the other hand, the third type, from the left, is rarely used for legs, as it is difficult to attach to tower legs that have already been built, particularly where reinforcement is involved.

Standard EN1993-1-1 also provides guidance on how to determine the minimum distance between two connections for the construction of these built-up angles.

It stipulates that, for angles in “back-to-back” configuration (third type in Figure 1.5), the minimum distance between the interconnection points must be equal to 15 times the minimum radius of gyration of the angle section. For the “butterfly” type angle (Figures 1.6 and 1.7), this minimum distance must be at least 70 times the minimum radius of gyration of the section.

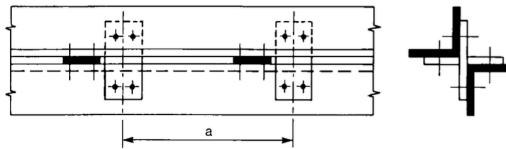


Figure 1.6: 2D view of butterfly connection^[4]

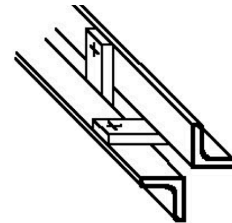


Figure 1.7: 3D view of butterfly connection^[41]

1.2.4 High strength steel S460 – one key for the energy transition

S460 structural steels are high strength, fine grain weldable structural steels and have a high strength-to-weight ratio. As the name indicates, steels in this class have a minimum yield strength of 460 MPa and offer high tensile strength, making them particularly suitable for heavily loaded structures such as transmission towers.

For a long time, non-alloyed steels according to EN 10025-2:2019^[7] are the standard steels for angles sections in steel lattice towers. Steel grade S460 is available in sub-grades JR, J0, J2 and K2.

Today, angles profiles are also available in thermomechanical rolled weldable fine grain structural steel S460M according to EN 10025-4:2019^[7]. Fine grain steels have an excellent weldability and increased toughness properties compared to non-alloyed steels. Thus, steel grade S460M is an excellent solution for steel lattice tower.

Finally, angle profiles are also available in weathering steel according to EN 10025-5:2019^[7]. The designations are S460J0W, S460J2W or S460K2W. This type of steel has a self-forming patina. There is no need to hot-dip galvanize or paint the angles, and no need to re-paint during the whole life of the structure. All this reduces the construction time of the structures and significantly reduces the maintenance efforts of the tower structure during its design lifetime.

The idea for the future of transmission lattice tower construction would be to use S460M in optimized tower structures, or possibly S460J2W+M steels.

Using S460M angles for the transmission towers would increase their strength without increasing their size and saving materials.

The use of S460M grade steels for structural sections has many advantages, such as reducing the size of the sections, which allows the structure to be lighter while maintaining its structural safety. Using S460 in constructions allows a weight reduction of 10 to 30%, of which 20 to 35% is for trusses^[19]. The reduction of the weight of the structure leads to lighter foundations, and all this reduces costs. It also allows for a reduction in embodied carbon that is proportional to the weight reduction and a reduction in carbon emissions due to the reduction in transport and raw material consumption.

S460 steel also has better weldability, which requires little or no preheating and less welding equipment. This leads to an optimal balance between cost and efficiency.

ArcelorMittal has a wide range of S460 steel sections such as fine-grained thermomechanical steels, weathering steels or steels under the XCarb(R) brand. XCarb(R) recycled and renewably produced steels are steel manufactured in an electric arc furnace using up to 100% recycled steel and 100% renewable energy. The carbon footprint of these sections is 333 kg CO₂eq per tonne of finished product, which is 7 times lower than the global average for the steel industry, which is approximately 2.3 tonnes of CO₂eq emissions per tonne of steel products^[7].

1.2.5 Current design norms for steel lattice towers

Currently, different standards can be used to design steel lattice towers. These standards are EN50341^[2], EN1993-3-1^[5] and EN1993-1-1^[4].

EN50341 is a specific standard for overhead power lines above 1 kV AC and has two parts. The first part deals specifically with general rules. This part, also known as the main body, includes clauses common to all countries. The second part includes national normative aspects that reflect national practices and varies from country to country.

EN1993 contains all the necessary information for the design of steel constructions. EN1993-3 specifically addresses the design of towers, masts, and chimneys and EN1993-1-1 addresses general rules and rules for buildings. Part 1-1 contains general design rules for the verification of cross-sections and stability verification for steel elements, while part 3-1 contains more specific rules for the verification of tower elements.

These three standards allow for the design of steel lattice towers for transmission towers, and all three can be applied for the design of steel lattice towers. The question is to know which one to use for the optimal design of steel lattice tower.

The present thesis will give an answer to this question. In a first step, a quantitative comparison between the standards will be carried out. In a second step, a given tower typology will be designed using steel grade S235, S355 and S460.

Chapter 2

Norms

2.1 Comparison between EN 50341 & EN 1993

As stated in subsection 1.2.4, several standards exist for the design of steel lattice towers. Therefore, in this section, the two standards will be compared based on a selected show-case to find similarities and differences.

A first simple observation can be made with regard to the scope of the standards. Indeed, EN50341, as stated in subsection 1.2.4, addresses the rules for the design of overhead power lines. This means that all parts of the line are taken into consideration, such as the tower itself, but also the conductors and insulators. EN1993-3-1, on the other hand, deals with the design rules for towers only, in addition to masts and chimneys. EN1993-1-1, as for her, addresses general design rules for steel structures and is complementary to EN1993-3-1.

The comparison of the design rules of the standards can be seen in the table of the Appendix A.

Only by looking at the differences between the two standards, it is difficult to know how this will affect the results. That is why, in Section 2.3, an example calculation of an equal leg angle in compression will be carried out using the two different standards to see the impact they have on the results and to decide which standard is more economic to use for the full analysis of a lattice tower. A look will also be taken at a part of the ANGELHY research project in Section 2.2, which is looking at the comparison of these standards in order to complete this research.

2.2 Comparison of standards in ANGELHY

The ANGELHY research project involved an in-depth comparison of standards EN 1993-1-1, EN 1993-3-1 and EN 50341-1 in the WORK PACKAGE 1 – DELIVERABLE 1.4^[6]. The aim of this report is to analyse the design methods proposed in the three standards mentioned. The aim is to measure the variations generated by these methods in the design of lattice towers and angular sections.

This section will therefore be devoted to summarizing the results obtained during this investigation into the design of angle sections in compression.

2.2.1 Angle sections in compression – Cross-section resistance

This part examines the strength of angular sections used for building elements. According to Eurocode 3 Part 1-1, the compressive strength capacity is classified as Class 3 if two conditions are met simultaneously: $\frac{h}{t} \leq 15\epsilon$ and $\frac{b+h}{2t} \leq 11,5\epsilon$. For angle sections with equal legs, the second condition is always relevant. This classification differs in EN 1993-3-1 and EN 50341-1, which offer more favourable limits (see Figure 2.1).

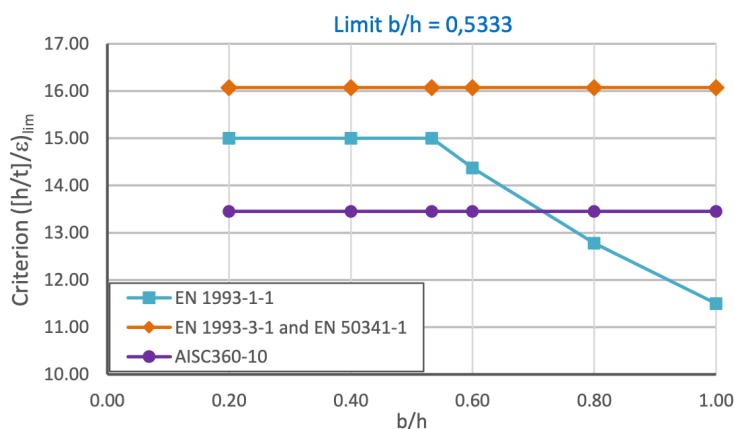


Figure 2.1: Limit between class 3 and class 4 for angle sections in compression^[6]

This is explained in the research by the inconsistency of the classification of corner sections in compression according to Part 1-1 of Eurocode 3 with the reduction curve taking into account the effect of local buckling given in EN 1993-1-5. In contrast, EN1993-3-1 and EN50341 base the classification of corner sections in compression on the reduction curve provided in EN 1993-1-5, thus creating a more uniform methodology (see Figure 2.2).

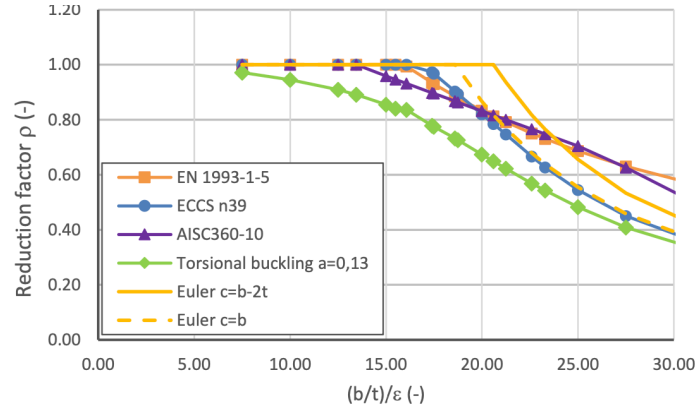


Figure 2.2: Comparison of reduction curves for equal leg angle sections in uniform compression^[6]

The Euler curve is defined by $1/\lambda^2$. In accordance with EN 1993-1-5 the relative slenderness, used as a base variable for strength reduction, can be determined by $\bar{\lambda} = \frac{c/t}{28,4\epsilon\sqrt{k_\sigma}}$. EN 1993-3-1 and EN 50341-1 define c as $b-2t$.

2.2.2 Member buckling resistance

The buckling behaviour of angular sections is complex due to the design of their joints. These sections in a lattice tower are generally connected to only one leg of the section, generate bending moments at their ends, in addition to the axial load they support. The complex interaction between these forces cannot be easily analysed using conventional analytical methods. To overcome this complexity, most design standards introduce a modification to the buckling index to take into account the effects of bending moments, without incorporating them directly into the design approach.

Resisting moments vary according to the design of the connections. Standards EN 1993-3-1 and EN 50341-1, developed for the design of towers, cover a variety of cases and equations for the modification factor “ k ”. Note that EN 50341-1 refers to Eurocode methods for this design. As a result, the resulting strength of the towers is similar in both standards. However, EN 50341-1 presents specific buckling rules in its Annex J, which only apply after full-scale tests. These rules can lead to significant variations in the calculated strength of pylons.

It is important to note that EN 1993-1-1 also provides specific rules for the buckling of angular sections. However, this standard only deals with three cases, which could lead to an excessively safe approach in certain situations.

2.2.2.1 Angle sections in compression – Buckling of diagonals

The different joint design solutions can be found in the Figure 2.3. Researchers from the ANGELHY research project carried out strength predictions for the different joint configurations presented and created diagrams.

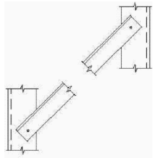
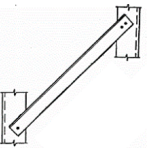
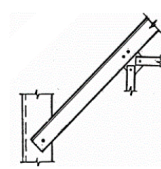
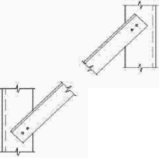
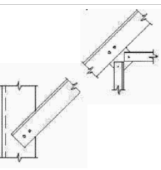
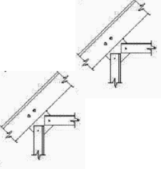
Case	Configuration	Description
1		Member without intermediate restraint connected with one bolt at its ends.
2a		Member without intermediate restraint connected with one bolt at one end and at least two bolts at the other end.
2b		Member with intermediate restraint connected with one bolt at its end and at least two bolts at the restraint.
3a		Member without intermediate restraint connected with at least two bolts at its ends.
3b		Member with intermediate restraint connected at least two bolts at its end and at the restraint.
3c		Intermediate segment of a continuous member connected with at least two bolts at the restraint.

Figure 2.3: Specific joint configurations for the buckling of diagonals^[6]

The predictions were made on a single angle members made of L70x70x7 section,

but it turns out that for the other sections, the results would be similar. Diagrams are shown in Figures 2.4 to 2.10.

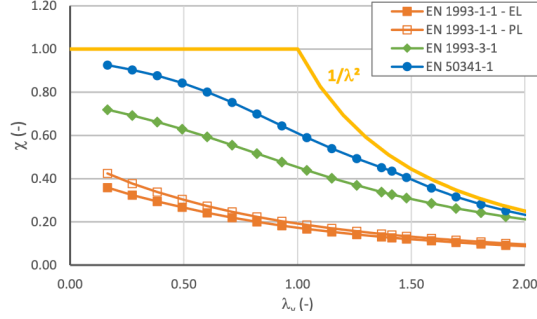


Figure 2.4: Strength prediction for minor-axis buckling – case 1^[6]

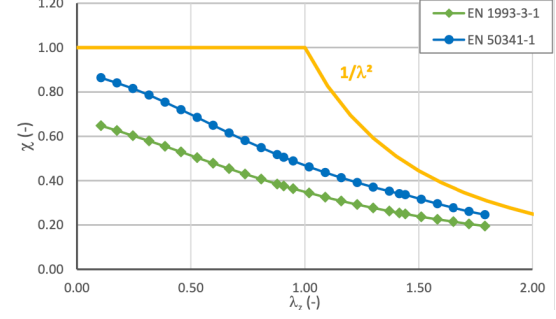


Figure 2.5: Strength prediction for z-z/y-y axis buckling – case 1^[6]

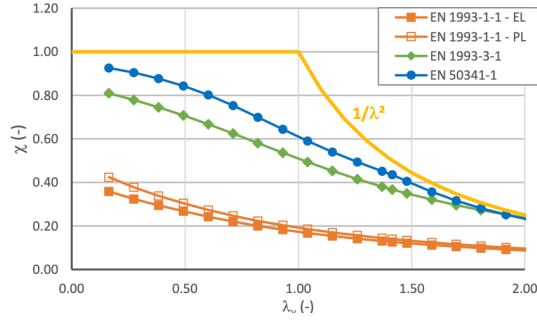


Figure 2.6: Strength prediction for minor-axis buckling – case 2a and 2b^[6]

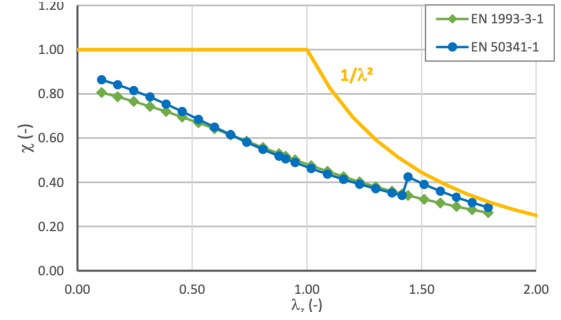


Figure 2.7: Strength prediction for z-z/y-y axis buckling – case 2a and 2b^[6]

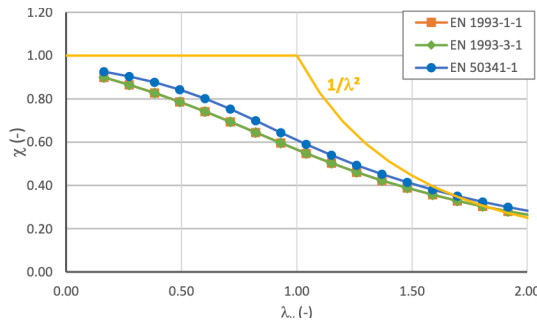


Figure 2.8: Strength prediction for minor-axis buckling – case 3a, 3b and 3c^[6]

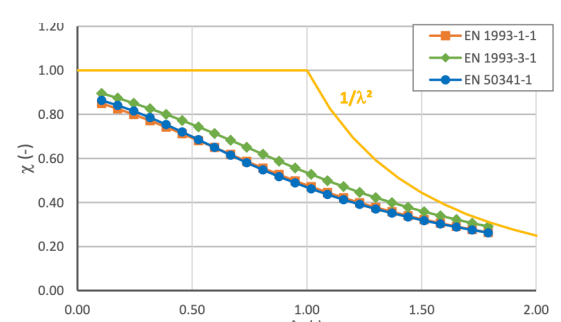


Figure 2.9: Strength prediction for z-z/y-y axis buckling – case 3a^[6]

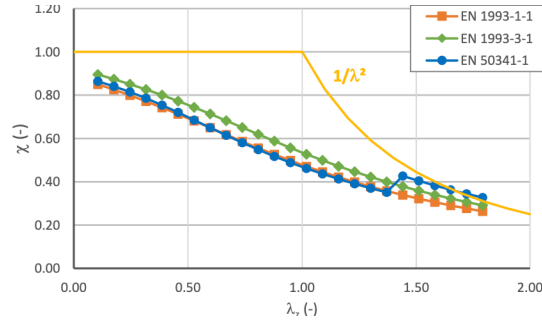


Figure 2.10: Strength prediction for z-z/y-y axis buckling – cases 3b and 3c^[6]

A number of conclusions have been drawn from these results.

Firstly, in cases 1, 2a and 2b, it has been observed that the predictions of standard EN1993-1-1 are extremely safe. By following the rules of EN 1993-3-1 and EN 50341, we arrive at resistances that are up to 3 times greater. This is due to systemic effects that are not taken into account in EN 1993-1-1.

Then, for the same cases, for simply bolted diagonal members, the rules of EN1993-3-1 and EN50341-1 lead to variations in resistance of between 15% and 30% which are mainly due to the reduction factor η to take into account the interaction between the tension moment and the axial force at the connection.

Next, for cases 3, elements connected by at least 2 bolts at their ends, the requirements of the three standards are closer, with a maximum variation of around 15% between them.

Finally, the buckling resistance curves along the z-z/y-y axes (cases 2a, 2b, 3b and 3c) carried out following the recommendation of standard EN50341-1 show a break in continuity of uncertain origin (see Figures 2.7 and 2.10), which is a disadvantage, especially for cases 2b, 3b and 3c, which are of practical importance.

2.2.2.2 Buckling of leg members

Standard EN1993-1-1 does not contain any specific rules on the buckling of leg members. However, standards EN1993-3-1 and EN50341-1, as for the buckling of diagonals, define slenderness modification factors for different cases. The different cases are as shown in Figure 2.11.

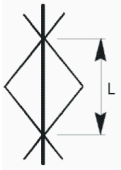
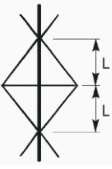
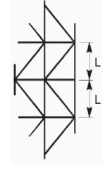
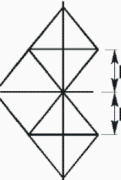
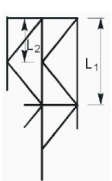
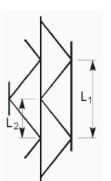
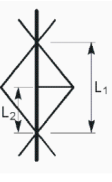
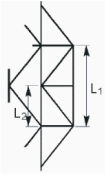
Case	Configuration		Description
1			Leg is connected to primary bracing at both ends (symmetrical case). <u>Minor-axis buckling</u> only has to be considered.
2	symmetric	asymmetric	Primary bracing at one end and secondary bracing at the second end of the leg. <u>Minor-axis buckling</u> only has to be considered.
			
3			Secondary bracing at both ends of the leg. <u>Minor-axis buckling</u> only has to be considered.
4	With horizontal members	Without horizontal members	Leg connected to primary bracing at both ends but in a single plane (unsymmetrical case). <u>Buckling about z-z/y-y axis</u> has to be considered over the length L_1 . <u>Only for unequal leg angles</u> , minor-axis buckling over the length L_2 should be considered.
			
5	With horizontal members	Without horizontal members	Leg connected to primary bracing at both ends but in a single plane (unsymmetrical case) and at an intermediate position it is connected to secondary bracing. <u>Buckling about z-z/y-y axis</u> has to be considered over the length L_1 . <u>Only for unequal leg angles</u> , minor-axis buckling over the length L_2 should be considered.
			

Figure 2.11: Slenderness modification factor for buckling of leg members^[6]

As for the previous verification, strength predictions obtained for leg elements were carried out by the project researchers and represented in diagrams (see Figures 2.12 to 2.16). These predictions were also made for a single corner section L70x70x7.

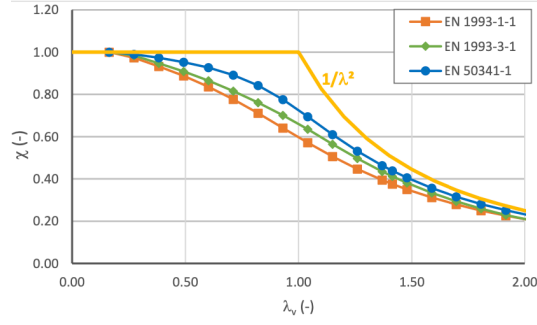


Figure 2.12: Strength prediction for minor-axis buckling – case 1^[6]

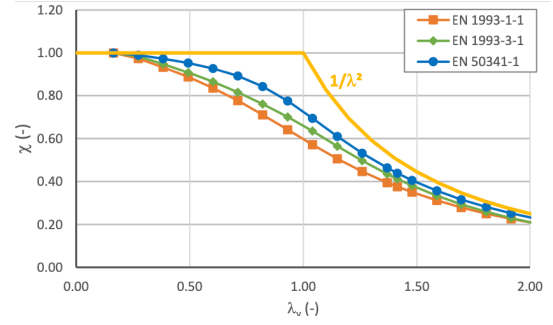


Figure 2.13: Strength prediction for minor-axis buckling – case 2^[6]

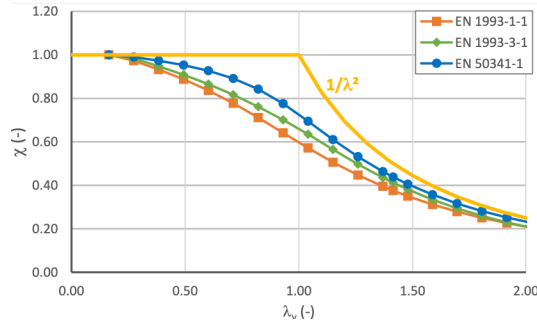


Figure 2.14: Strength prediction for minor-axis buckling – case 3^[6]

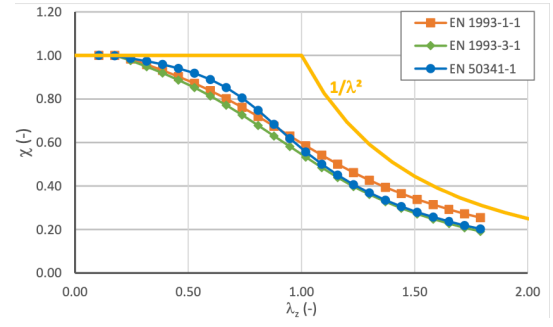


Figure 2.15: Strength prediction for y-y/z-z axis buckling – case 4^[6]

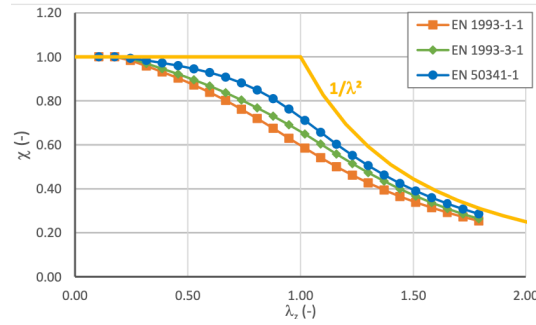


Figure 2.16: Strength prediction for y-y/z-z axis buckling – case 5^[6]

A number of observations have also been made based on these diagrams.

Firstly, it can be seen that in the majority of cases, the favourable standard is EN50341-1. This is due to the fact that this standard requires the use of the favourable buckling curve “ a_0 ” as opposed to the buckling curve “c” used in EN

1993-1-1 and EN 1993-3-1.

Secondly, because of the reduction factor on relative slenderness, EN1993-3-1 remains more favourable than EN 1993-1-1.

However, there is an exception to these trends in the fourth case, where the “k” factor causes a rise in relative slenderness. It should be observed that in this instance, the buckling constraint is only positioned in a single plane at the member ends. Therefore, the prevention of minor-axis buckling may not be as effective at the member ends as in the case of restraints in both perpendicular axis y-y and z-z. Therefore, the k factor might take into account the impact of an interaction buckling mode on the z-z/y-y and minor axes.

2.3 Show case - Equal leg angle in compression

A verification of a steel angle in compression will be carried out according to the norms EN50341 and EN 1993-3-1 and methods and results will be compared.

For this example, an angle in one of the four legs of a transmission tower in pure compression will be considered. The buckling length is assumed to be 3m. This is a biarticulated angle L250x250x20, fixed with a single bolt on each side. Results considering member in steel grade S355 and S460 will be compared.

Moment verification will not be performed as the member is biarticulated and there is no secondary moment induced by eccentricity in the extremities. The moments from the wind are neglected, as indicated in EN50341.

2.3.1 Method according to EN50341

According to EN50341, the following verifications must be carried out : verification of the cross-section in compression, buckling verification and flexural-torsional verification.

2.3.1.1 Verification of the cross-section in compression

For this part, EN50341 says that the cross-section in compression must be verified according to the Eurocode and more precisely according to the part 6.2.4 of EN1993-1-1:2005.

This part says that the design value of the compression force N_{Ed} on the cross-section must satisfy the following inequality:

$$\frac{N_{Ed}}{N_{c,Rd}} \leq 1 \quad (2.1)$$

Where $N_{c,Rd}$ is the design resistance of the cross-section for uniform compression, depend on the class of the cross-section.

To determine the class of our section, we will use table 5.2 of Eurocode 1993-1-1:2005. This says that for an L-section in compression, the cross-section is class 3 if it meets these two conditions:

$$\frac{h}{t} \leq 15\epsilon \quad (2.2)$$

$$\frac{h+b}{2t} \leq 11,5\epsilon \quad (2.3)$$

Where h and b are the lengths of the 2 bars of the L-section and are equal to 250 mm for both in this case, t is the thickness of the bars, 20 mm and ϵ is equal to 0,81 for an S355 steel grade and to 0,71 for an S460 steel grade.

With these values, the 2 conditions with the two different steel aren't fulfilled, and therefore it can be concluded that the cross-section is class 4. In fact,

$$12,5 > 12,15 \text{ and } 12,5 > 9,315 \text{ for S355 steel grade}$$

$$12,5 > 10,65 \text{ and } 12,5 > 8,165 \text{ for S460 steel grade}$$

For class 4 cross-section, the design resistance of the cross-section for uniform compression, according to 1993-1-1:2005 part 6.2.4, is defined as

$$N_{c,Rd} = \frac{A_{eff} f_y}{\gamma_{M0}} \quad (2.4)$$

Where γ_{M0} , a partial factor, is equal to 1, f_y , the yield strength of the steel, is equal to 355 MPa for the S355 steel grade and to 460 MPa for the S460 steel grade. The effective area for an equal angle can be calculated with this formula^[24]

$$A_{eff} = A - 2t(1 - \rho)h \quad (2.5)$$

Where the reduction factor ρ , according to EN1993-1-5 part 4.4, is determined as

$$\rho = 1 \quad \text{if } \bar{\lambda}_p \leq 0,748 \quad (2.6)$$

$$\rho = \frac{\bar{\lambda}_p - 0,188}{\bar{\lambda}_p^2} \leq 1 \quad \text{if } \bar{\lambda}_p > 0,748 \quad (2.7)$$

Where

$$\bar{\lambda}_p = \frac{(b - 2t)/t}{28,4\varepsilon\sqrt{k_\sigma}} \quad (2.8)$$

with k_σ equal to 0,43, ε equal to 0,81 for an S355 steel grade and to 0,71 for an S460 steel grade and, b and t are the dimensions of the section.

Therefore,

$$\begin{aligned} \bar{\lambda}_p &= 0,7 && \text{for S355 steel grade} \\ \bar{\lambda}_p &= 0,79 && \text{for S460 steel grade} \end{aligned}$$

In the case with the S355 steel grade, $\bar{\lambda}_p$ is less than 0.748, so the reduction factor is taken as 1 and the effective area is equal to the area of the cross-section which is equal to 96,3 cm².

But for the case with the S460 steel grade, $\bar{\lambda}_p$ is greater than 0,748, so according to the formulas (2.7) and (2.5), the reduction factor is equal to 0,96 and the effective area to 92,42 cm².

Finally, according to the formula (2.4), the design resistance of the cross-section for uniform compression for the two different steels can be determined,

$$\begin{aligned} N_{c,Rd} &= 34,19kN && \text{for S355 steel grade} \\ N_{c,Rd} &= 42,51kN && \text{for S460 steel grade} \end{aligned}$$

The angle in steel grade S460 has a design resistance of the cross-section in compression of 24,33% higher than the strength of the angle in steel grade S355.

2.3.1.2 Buckling verification

According to EN 50341, the buckling check of a compression element of lattice towers can only be carried out according to its annex J.4 if full-scale tests are performed, otherwise it has to be carried out according to the provisions of annex G and H of EN 1993-3-1:2005.

According to the Annex J.4.1 of EN50341, to be verified against buckling, the angle in compression must satisfy the following expression:

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1 \quad (2.9)$$

with $N_{b,Rd}$ the design buckling resistance which depends on the class of the cross-section. For class 4 cross-section, it is defined as

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}} \quad (2.10)$$

Where the effective area, A_{eff} and f_y has been detailed in the previous subsection for the two different steel, γ_{M1} is a partial factor equal to 1 as recommended in part 7.3.6.1 of EN50341 and χ is a reduction factor defined as

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}_{eff}^2}} \quad (2.11)$$

Where

$$\Phi = 0,5 \times [1 + \alpha \times (\bar{\lambda}_{eff} - 0,2) + \bar{\lambda}_{eff}^2] \quad (2.12)$$

With α the imperfection factor equal to 0,13 according to this norm and $\bar{\lambda}_{eff}$ the effective non-dimensional slenderness which is a linear transformation of $\bar{\lambda}$, the non-dimensional slenderness which depends on λ , the slenderness.

- (i) The slenderness for a leg member with symmetrical bracing, according to the annex J.4.3.2 of EN50341, is defined as

$$\lambda = \frac{L}{i_{vv}} \quad (2.13)$$

Where L is the buckling length and is equal to 3m.

And i_{vv} is the radius of gyration about v axis as defined in the Sales Program of ArcelorMittal^[7] :

$$i_{vv} = 4,93cm$$

Finally, $\lambda = 60,85$.

- (ii) The non-dimensional slenderness for a class 4 cross-section, according to the annex J.4.2.3, is defined as

$$\bar{\lambda} = \frac{\lambda}{\lambda_1} \times \sqrt{\frac{A_{eff}}{A}} \quad (2.14)$$

Where $\lambda_1 = \pi \sqrt{\frac{E}{f_y}}$.

And so,

$$\begin{aligned} \bar{\lambda} &= 0,80 && \text{for S355 steel grade} \\ \bar{\lambda} &= 0,89 && \text{for S460 steel grade} \end{aligned}$$

- (iii) The non-dimensional effective slenderness for a leg member, according to the annex J.4.2.4, is defined as

$$\bar{\lambda}_{eff} = \bar{\lambda} \quad (2.15)$$

$$\begin{aligned} \bar{\lambda}_{eff} &= 0,80 && \text{for S355 steel grade} \\ \bar{\lambda}_{eff} &= 0,89 && \text{for S460 steel grade} \end{aligned}$$

Finally, with all this information the design buckling resistance of the compression member according to the formula (2.10) can be determined,

$$\begin{aligned} N_{b,Rd} &= 29,23 \text{ kN} && \text{for S355 steel grade} \\ N_{b,Rd} &= 34,16 \text{ kN} && \text{for S460 steel grade} \end{aligned}$$

The angle in steel grade S460 has a design buckling resistance in compression of 16,87% higher than the strength of the angle in steel grade S355.

2.3.1.3 Flexural-torsion verification

According to EN50341, in order to perform the flexural-torsional verification of the angle, the same verification as for compression but using the effective area has to be performed.

In the present case, for a class 4 section, the effective area has already been used in the compression verification and therefore the two verifications are identical.

Therefore, the maximum forces, depending on the grade of steel, that can be applied to the angle can be determined while respecting the three verifications.

For both grades of steel, the buckling and flexural-torsion verifications have the lowest resistance forces and are therefore the ones to be retained to ensure the stability of the angle.

$$\begin{aligned} N_{Ed} &= 29,23 \text{ kN} && \text{for S355 steel angle} \\ N_{Ed} &= 34,16 \text{ kN} && \text{for S460 steel angle} \end{aligned}$$

The angle in steel grade S460 has a design resistance of 16,87% higher than the buckling resistance of the angle in steel grade S355.

2.3.2 Method according to the EN1993-3-1

According to EN1993-3-1, the following verifications must be carried out : verification of the cross-section in compression, buckling verification and flexural-torsional verification.

2.3.2.1 Verification of the cross-section in compression

As the method used in EN50341 is derived from EN1993-3-1, the verification of the compression cross-section is the same as in Subsection 2.3.1.1.

The resistance values are therefore

$$\begin{aligned} N_{c,Rd} &= 34,19kN && \text{for S355 steel grade} \\ N_{c,Rd} &= 42,51kN && \text{for S460 steel grade} \end{aligned}$$

The angle in steel grade S460 has a design resistance of the cross-section of 24,33% higher than the resistance of the angle in steel grade S355.

2.3.2.2 Buckling verification

The method for checking the buckling resistance of an angle in compression is developed in the part 6.3.1.1. of EN1993-1-1:2005 and also in the annex G – Buckling of components of masts and towers of EN1993-3-1:2006.

As in EN50341, to be verified against buckling, the angle in compression must satisfy, according to the part 6.3.1.1. of EN1993-1-1:2005, the following expression :

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1 \quad (2.16)$$

where the design buckling resistance is determined as

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}} \text{ for a cross-section of class} \quad (2.17)$$

Where the partial factor γ_{M1} is equal to 1,1 and χ is defined as

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \quad (2.18)$$

With

$$\Phi = 0,5 \times \left[1 + \alpha \times (\bar{\lambda}_{eff} - 0,2) + \bar{\lambda}^2 \right] \quad (2.19)$$

The imperfection factor α depends on the buckling curve. Knowing that for an L-section, the buckling curve is b according to EN1993-1-1:2005, the value of the imperfection factor is 0,34.

According to the annex G.1 of the EN1993-3-1:2006 : “For constant axial compression in members of constant cross-section, the reduction factor χ and the

factor φ to determine χ should both be determined with the effective slenderness ratio $\bar{\lambda}_{eff}$ instead of $\bar{\lambda}$ ".

The non-dimensional effective slenderness $\bar{\lambda}_{eff}$ depends on the non-dimensional slenderness, $\bar{\lambda}$ which itself depends on the slenderness λ .

- (i) The slenderness for leg members, according to annex H.2 of EN1993-3-1:2006, is defined as

$$\lambda = \frac{L}{i_{vv}} \quad (2.20)$$

Where L is the buckling length and is equal to 3m.

And i_{vv} is the radius of gyration about v axis as defined in the Sales Program of ArcelorMittal^[7] :

$$i_{vv} = 4,93 \text{ cm}$$

Finally, $\lambda = 60,85$.

- (ii) The non-dimensional slenderness for all classes cross-section, according to the annex G.1 of EN1993-3-1:2006, is defined as

$$\bar{\lambda} = \frac{\lambda}{\lambda_1} \quad (2.21)$$

Where $\lambda_1 = \pi \sqrt{\frac{E}{f_y}}$.

And so,

$$\begin{aligned} \bar{\lambda} &= 0,80 && \text{for S355 steel grade} \\ \bar{\lambda} &= 0,91 && \text{for S460 steel grade} \end{aligned}$$

- (iii) The non-dimensional effective slenderness, according to annex G.1 of EN1993-3-1:2006, is defined as

$$\bar{\lambda}_{eff} = k \times \bar{\lambda} \quad (2.22)$$

where k is the effective slenderness factor, which is deduced from Table G.1 of EN1993-3-1:2006 for a leg member. For a symmetrical bracing, k about v axis is defined as

$$k = 0,8 + \frac{\bar{\lambda}}{10} \text{ must be between } 0,9 \text{ and } 1. \quad (2.23)$$

For both grades of steel, a value of k less than 0,9 is obtained. k will therefore be set at 0,9.

So $\bar{\lambda}_{eff}$ can be determined,

$$\begin{aligned}\bar{\lambda}_{eff} &= 0,72 && \text{for S355 steel grade} \\ \bar{\lambda}_{eff} &= 0,82 && \text{for S460 steel grade}\end{aligned}$$

Now, all information is available to determine the design buckling resistances which are equal to

$$\begin{aligned}N_{b,Rd} &= 24,05 \text{ kN} && \text{for S355 steel grade} \\ N_{b,Rd} &= 27,61 \text{ kN} && \text{for S460 steel grade}\end{aligned}$$

But according to the annex G.1 of EN1993-3-1:2006, for a single angle member which are articulated at both end, the design buckling resistance has to be reduced by a reduction factor

$$\eta = 0,8 \text{ for a connection by one bolt at each end}$$

Finally, the design buckling resistances are

$$\begin{aligned}N_{b,Rd} &= 19,24 \text{ kN} && \text{for S355 steel grade} \\ N_{b,Rd} &= 22,09 \text{ kN} && \text{for S460 steel grade}\end{aligned}$$

The angle in steel grade S460 has a design buckling resistance in compression of 14,92% higher than the resistance of the angle in steel grade S355.

2.3.2.3 Flexural-torsion verification

According to the part 6.3.1.4 of EN1993-1-1, in order to perform the flexural-torsional verification of the angle, the same verification as for compression must be carried out but using the non-dimensional slenderness $\bar{\lambda}_T$ for torsional-flexural buckling which is defined, for a cross-section of class 4, as

$$\bar{\lambda}_T = \sqrt{\frac{A_{eff} f_y}{N_{cr,TF}}} \quad (2.24)$$

Where $N_{cr,TF}$ is the elastic torsional-flexural buckling force. As the Eurocode does not give a formula, a formula that comes from a document of the CTICM^[13] will be used. For an equal flange angle,

$$N_{cr,TF} = \frac{I_0}{I_v + I_u} \left(N_{cr,u} + N_{cr,T} - \sqrt{(N_{cr,u} + N_{cr,T})^2 - 4N_{cr,u}N_{cr,T} \frac{I_v + I_u}{I_0}} \right) \quad (2.25)$$

Where

- I_0 is the polar inertia and is defined as $I_0 = I_y + I_z$.
- I_y, I_z, I_v, I_u , are the inertia about the z, y, v and u axis and can be found in the ArcelorMittal profiles catalogue.
- $N_{cr,u}$, the critical buckling force about the u-axis is determined by the formula

$$N_{cr,u} = \frac{\pi^2 EI_u}{L_{cr}^2} \quad (2.26)$$

With the modulus of young, E equal to 210 GPa and buckling length, L_{cr} equal to 3m.

- $N_{cr,T}$ is the critical normal force for torsional buckling and is calculated as follows

$$N_{cr,T} = \frac{1}{i_0^2} \left(GI_t + \frac{\pi^2 EI_w}{L_{cr,T}^2} \right) \quad (2.27)$$

With the polar radius of gyration, i_0 which is calculated as $\sqrt{\frac{I_0}{A}}$, the shear modulus G which is equal to $\frac{E}{2(1+\nu)}$ ($\nu = 0,3$ for steel) and I_w , the secondary torsional inertia which is a measure of resistance to warping. In an angle, there is no warping and the inertia is therefore zero, and we can eliminate this part of the formula.

With all this information, we can determine the elastic torsional-flexural buckling force :

$$N_{cr,TF} = 13402495,26 \text{ N}$$

The non-dimensional slenderness for torsional-flexural buckling is therefore equal to

$$\bar{\lambda}_T = 0,51$$

which can be replaced in the buckling verification and obtain the design buckling resistance:

$$\begin{aligned} N_{b,Rd} &= 22,47 \text{ kN} && \text{for S355 steel grade} \\ N_{b,Rd} &= 27,24 \text{ kN} && \text{for S460 steel grade} \end{aligned}$$

The angle in steel grade S460 has a design flexural-torsion buckling resistance in compression of 21,23% higher than the resistance of the angle in steel grade S355.

For both steel grades, the buckling verification has the lowest resistance forces and is therefore the one to choose for the stability of the angle.

$$\begin{aligned} N_{Ed} &= 19,24 \text{ kN} && \text{for S355 steel grade} \\ N_{Ed} &= 22,09 \text{ kN} && \text{for S460 steel grade} \end{aligned}$$

The angle in steel grade S460 has a design resistance in compression of 14,92% higher than the resistance of the angle in steel grade S355.

2.3.3 Observations

It is clear that the two methods of compression buckling verification of the two different norms do not lead to the same results, as it can be seen in Table 2.1.

	Design resistance of the cross-section in compression [kN]		Design buckling resistance in compression [kN]		Design flexural-torsional buckling resistance in compression [kN]	
	S355	S460	S355	S460	S355	S460
EN50341	34,19	42,51	29,23	34,16	29,23	34,16
EN1993-3-1	34,19	42,51	19,24	22,09	22,47	27,24

Table 2.1: Results of the verifications

The first difference is the value of the partial factor used in the buckling resistance formula. In EN50341 it is considered that the partial factor γ_1 is equal to 1, whereas in EN1993-3-1 it is equal to 1,1. The difference of the safety factors contributes to a first difference of 10% in the design buckling resistance.

The following difference is the imperfection factor, α which depends on the buckling curve. EN50341 considers that the buckling curve to be used is the a_0 which gives a α value of 0,13 whereas in EN 1993-3-1 considers that for an L-section, the buckling curve to be used is the b which gives a α value of 0,34.

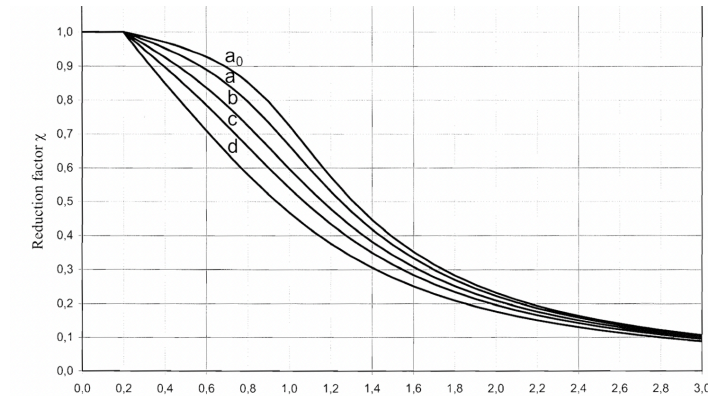


Figure 2.17: Buckling curves^[4]

One more difference comes from the definition of non-dimensional effective slenderness and non-dimensional slenderness.

Indeed, the EN50341 norm proposes a different formula, which involves the ratio between the effective area and the normal air of the section, for the dimensional slenderness if the section is of class 4 whereas the Eurocode proposes the same formula for sections of all classes. Secondly, EN50341 says that the effective non-dimensional slenderness of a leg member is the same as the non-dimensional slenderness, whereas EN1993-3-1 imposes a factor k which multiplies the non-dimensional slenderness. This k -factor is also a linear transformation of the non-dimensional slenderness and depends on the type of bracing system and the buckling axis.

In addition, it can be seen that the method used for flexural-torsional verification in EN50341 is totally different from the method used in EN1993-3-1. In view of the results obtained, it can be concluded that for this verification, the method according to EN1993-3-1 is more conservative.

Finally, it can be seen that EN1993-3-1 is more conservative. Indeed, whereas according to its method, the limit for the load on the member in steel grade S355 is 19,24 kN and in steel grade S460 is 22,09 kN, the EN50341 allows us to increase this load to 29,23 kN and 34,16 respectively.

It can also be seen that the verification using S460 allows the angles to take higher loads than with S355.

It can therefore be imagined that by using the EN50341 method with S460 steel angles, a saving in materials can be made because less material will be required to achieve the same resistance loads. This reduction in materials could therefore result in budget savings. It is for this reason that the analysis of a lattice tower in the TOWER software will be carried out on the basis of this standard (see Section 3).

Chapter 3

Optimization

3.1 TOWER software

To carry out the structural analysis of transmission lattice towers, we will use the TSE TOWER Structural Engineering software^[35].

TOWER is a powerful, comprehensive and easy-to-use program for the analysis and design of steel lattice transmission and communication towers. The program can perform design checks on structures based on loads that are selected by the user.

In addition, the program automatically generates wind and ice loads according to the standard the user wishes to follow.

Different standards are automatically encoded in the software. These standards are :

- EN50341 and its National Annexes for Belgium, Germany, the United Kingdom, Portugal, and Poland.
- American standards: ASCE 74 (Guidelines for Electrical Transmission Line Structural Loading) and NESC (National Electrical Safety Code).
- The international standard IEC 60826 (International Electrotechnical Commission : loading and strength requirements of overhead lines derived from reliability-based design principles).
- The methodology used in Spain as provided by the Spanish electricity network REE.
- The Russian 7th/SNiP standard.

- The New Zealand AS/NZS standard on overhead line design or the TPNS (Transpower & Maunsell).
- the Australian standard ESAA C(b)1 2003 (Guidelines for design and maintenance of overhead distribution and transmission lines).
- The Indian standard IS802 (Code of practice for use of structural steel in overhead transmission line towers).
- The Israel standard ISEC-NCR-83.
- The general structural analysis program that runs under Microsoft Windows, SAPS (SAP Application Performance Standard).

It is also possible to manually modify the parameters in order to adapt the analysis as required.

The main advantage of this software is its automatic optimization process. This automatically adjusts the size and/or type of corner sections to keep the tower as light as possible, while aiming for the highest possible degree of utilization.

3.2 First model steel lattice tower – Suspension Tower

3.2.1 Typology of the model steel lattice tower

3.2.1.1 Geometry and dimensions



Figure 3.1: M3 transmission tower for a 400kV double track line^[39]

The first tower studied in this thesis will be an M3 type transmission tower for a 400kV double track line (see Figure 3.1).

The tower is a suspension tower and is made of hot-dip galvanized steel equal-leg angle. The suspension tower was chosen because of its common use. Indeed, more than 75% of the transmission towers are suspension towers.

The steel lattice tower studied has a height of approximately 50m. The exact geometry and dimensions of the tower are shown in Figures 3.2 to 3.6 below

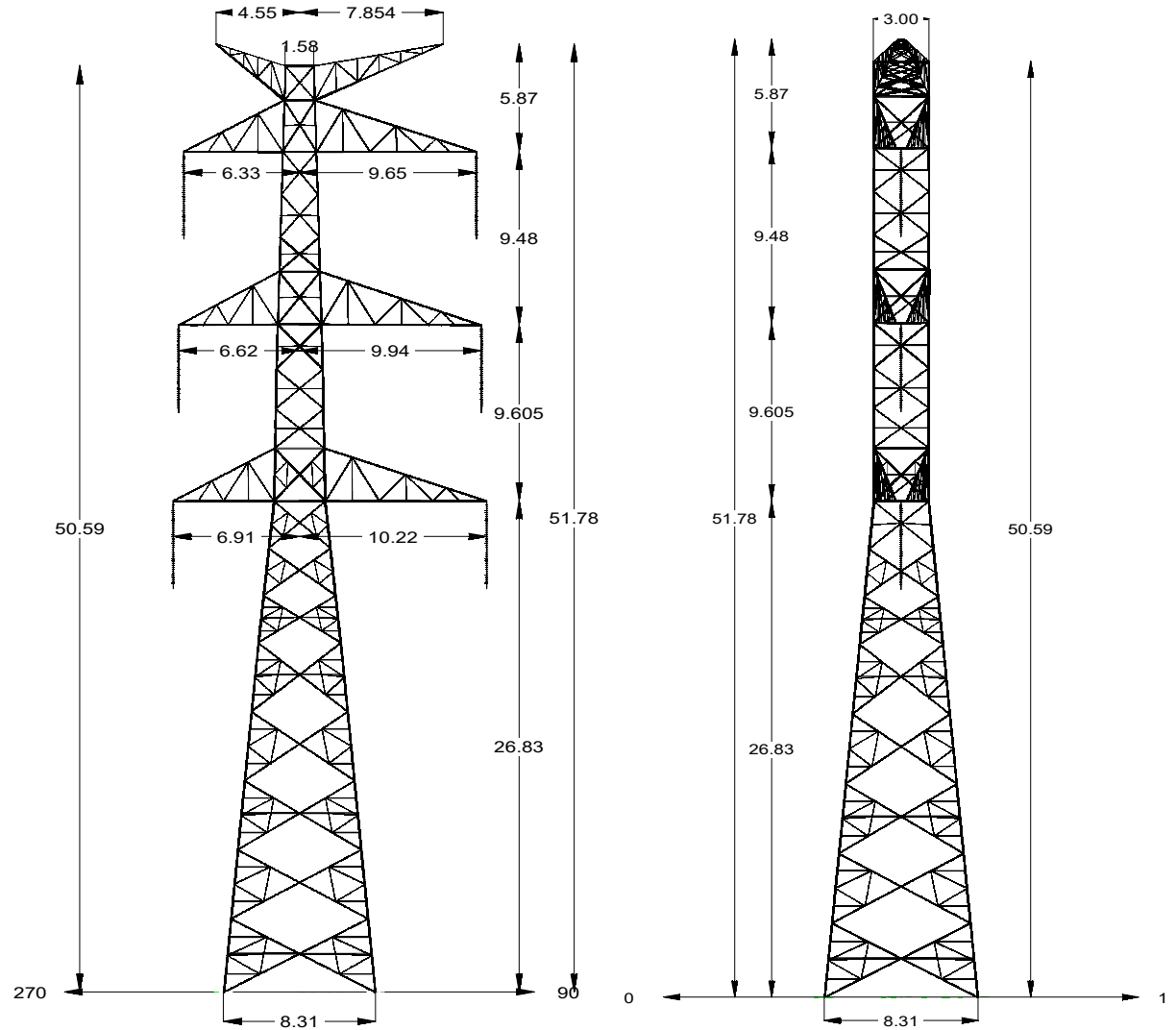


Figure 3.2: Dimensions of the suspension tower

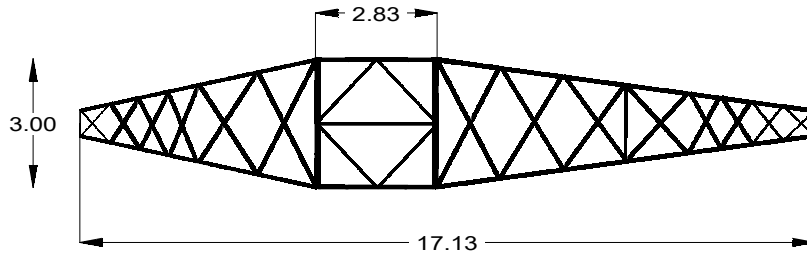


Figure 3.3: Base of lower cross arm

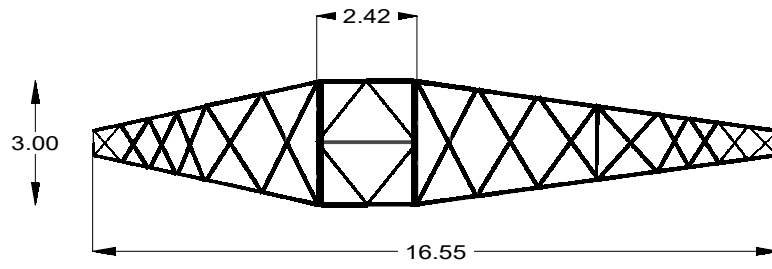


Figure 3.4: Base of first middle cross arm

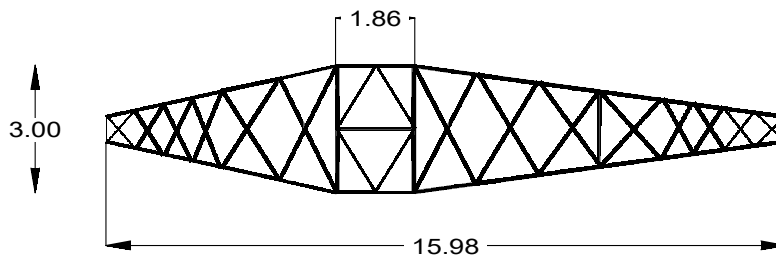


Figure 3.5: Base of second middle cross arm

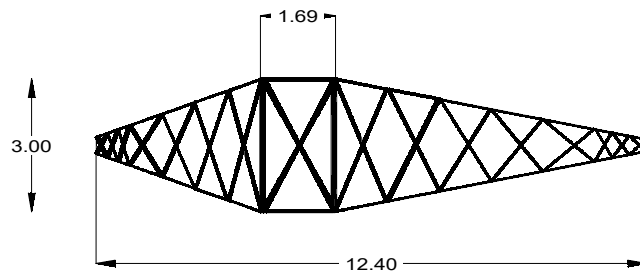


Figure 3.6: Base of top cross arm

3.2.1.2 Conductors

The tower in question supports two 400kV circuits, each consisting of three phases. Each phase consists of a bundle of four conductors, held together by an insulator. In addition, two earth wires to protect against the effects of lightning are attached to the top of the tower.

The conductors used are made of steel reinforced aluminium (see Figure 3.7). The aluminium core is designed to carry the electrical current, while the steel mesh provides strength and supports the weight of the conductor.



Figure 3.7: Aluminium-steel conductor^[37]

The conductors that were selected for the case study tower are the following:

- 434-AL1/56-ST1A for the conductors.
- 97-AL1/56-ST1A for the earth wires.

These conductors were chosen taking into account that the voltage of the electrical circuits is 400kV.

According to EN 50182:2001^[33], the first part of the notation refers to the area of the surface made of aluminium, while the second part refers to the area of the surface made of steel. The characteristic information of these cables is described in the Table 3.1

Code	Areas [mm ²]			No. of wires	Wire diameter [mm]		Diameter [mm]		Mass per unit length [kg/km]	Rated strength [kN]	E [N/mm ²]	α [1/K]	
	Al	Steel	Total		Al	Steel	Core	Cond.					
434-AL1/56-ST1A	434.3	55.6	490.6	54	7	3.2	3.2	9.6	28.8	1641.3	133.59	70000	1.93E-05
97-AL1/56-ST1A	96.5	56.3	152.8	12	7	3.2	3.2	9.6	16	706.8	77.85	107000	1.53E-05

Table 3.1: Mechanical data of the conductors

As the TOWER software only models the structure of the tower, this information will be useful in determining the load of the conductors on the tower (See section 3.2.3.3.1).

3.2.1.3 Insulators

In order to transfer the loads from the conductors to the tower's cross arms, they are connected to suspension insulators. The insulators are made of Hubbell silicone rubber and are type S025177S201^[34].

- S for suspension insulator.
- 025 defined the mechanical strength (25 kip = 111 kN).
- 177 defined the polymer length (185 inches = 4,5m).
- S for Standard Leakage Distance.
- 2 defined the top fitting (Y-Clevis).
- 01 defined the bottom fitting (ANSI Ball).

The total length of the insulator is approximately 4,8 m and ensures sufficient distance between the conductors and the tower structure.

3.2.1.4 Transmission Line

The distance between two transmission towers is usually 450m to 550m. In order to study the most general case possible, the distance between two towers will be taken as 500m. The towers will also be considered to be built at more or less the same altitude of 1100m, so that the lowest points of the cables are located halfway between two towers.

3.2.2 Modelling in TOWER software

With all this information, the tower could be modelled in the TOWER software (see Figure 3.8).

The colours of the members in this figure define the elements. The leg members have been modelled with beam elements, which are shown in green. The members shown in blue are truss elements and have been used to define the members that form the primary bracing of the tower. Finally, the secondary bracing is in orange, which means that the members are also truss elements but are redundant.

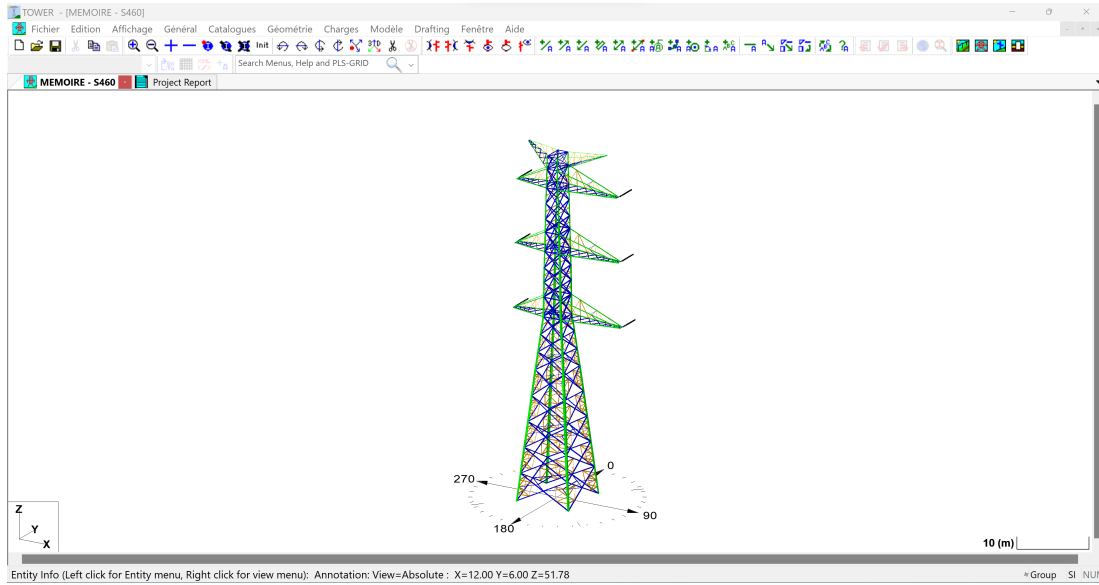


Figure 3.8: Tower modelled in TOWER software interface

3.2.3 Analysis according to EN50341

3.2.3.1 General design assumptions

The principal design assumptions are listed below. All these assumptions are based on the requirements from EN50341-1 standard^[2].

EN50341-1 refers to values defined in the National Annexes. Each time a value from the National Annex is required, reference to the German National Annex^[3] is made. The reason consists in the wide practical use of the values and methods from the German National Annex in practice, even in countries other than Germany.

- The internal forces shall be determined by means of a global elastic analysis and the first order theory, using the initial geometry of the structure.
- Lattice steel towers are considered as pin jointed truss structures.
- The partial material factors for lattice tower are : $\gamma_{M0} = 1$, $\gamma_{M1} = 1$ and $\gamma_{M2} = 1,25$.
- 12 different load cases are to be taken into account (see Subsection 3.2.3.2).
- Ice loads are not considered on the structure of the lattice tower.

- The wind forces on the tower itself shall be determined according to method 1 of EN50341-1 : “the tower is divided into sections and the wind force is acting at the centre of gravity of each tower section”.
- The eccentricities of the connections are taken into account by means of the non-dimensional effective slenderness λ_{eff} .
- The buckling verification of the angle profiles will be carried out using the buckling curve a_0 .

The assumption that the tower is located in wind zone 2 and ice zone E2 to calculate the wind and ice loads will be also made.

3.2.3.2 Load cases

The load cases to be considered are defined in the National Annexes to EN50341-1. German National Annex defines in part 4.12.2 twelve different standard load cases defined below that take into account meteorologically caused forces, construction, and maintenance loads as well as exceptional loads due to unbalanced ice accretion or ice shedding.

- **Load case A**
Permanent loads and wind forces in direction of the cross arms.
- **Load case B**
Permanent loads and wind forces in transversal direction of the cross arms.
- **Load case C**
Permanent loads and quartering wind forces at $\phi = 45^\circ$.
- **Load case D**
Permanent loads and wind forces in direction of the cross arms and ice loads.
- **Load case E**
Permanent loads and wind forces in transversal direction of the cross arms and ice loads.
- **Load case F**
Permanent loads and quartering wind forces at $\phi = 45^\circ$ and ice loads.
- **Load case G**
Permanent loads and ice loads in one of the adjacent spans, no ice loads in the other adjacent span, whereby 50% of the ice loads shall be assumed.

- **Load case I**

Permanent loads and construction loads.

- **Load case L**

Permanent loads and ice loads.

Failing of one insulator string of a multiple insulator set.

Load cases H, J and K are not to be taken into account as this is a suspension tower. This is because the suspension towers only take up the vertical load due to the cables' own weight. Load cases H, J and K vary according to the tension in the cables, and should not be taken into account in this analysis.

Each load case involves loads from different sources. The effects of these loads are determined by their characteristic values and require the application of appropriate partial factors.

The design value of the actions is given in the German National Annex EN50341-2-4 as follows :

$$Ed = \{\gamma_G G_K; \gamma_W Q_{WK}; \gamma_I Q_{IK}; \gamma_P Q_{PK}; \gamma_C Q_{CK}; \}$$

Where

E_d	Total load;
G_K	Dead load of conductors, insulators, and supports;
Q_{WK}	Wind force as specified in 4.4.1/DE.1 to 4.4.4/DE.1 in EN50341-2-4;
Q_{IK}	Ice forces on conductors as specified in 4.5.2/DE.1 in EN50341-2-4;
Q_{PK}	Construction loads as specified in 4.9.1/DE.1 and 4.9.2/DE.1 in EN50341-2-4;
Q_{CK}	Horizontal conductor tensile forces considering the temperature changes as well as wind and ice loads as specified in 4.12.2/DE.1. in EN50341-2-4.

The partial safety factors depend on the load case and are defined as :

$\gamma_G = \gamma_W = \gamma_I = \gamma_P = 1,35$	for load cases A to I in case of unfavourable action;
$\gamma_G = \gamma_I = 1$	for load cases A to F in case of favourable action;
$\gamma_G = \gamma_W = \gamma_I = \gamma_P = 1$	for load cases J to L;
$\gamma_P = 1,5$	for construction loads in load case I.

3.2.3.3 Loads in the TOWER software

3.2.3.3.1 Permanent loads

The TOWER software automatically calculates the self weight of the angles and the insulators used in the tower. In order to take into account any other structural elements used in the design of the tower, such as bolts or gusset plate, a factor of 1,2 on the self weight has been taken into account.

However, as the TOWER software does not model the conductors and earth wires, their self weight was calculated and inserted manually into the software. The self weights were calculated by multiplying the mass per unit length of the cables available in the Table 3.1 by the distance to the lowest points of the conductors.

For parts of the conductors, to get the point load per insulator, the value of the weight of the conductors is multiplied by four, knowing that a bundle is composed of four conductors.

The values obtained according to the type of cable are shown in the Table 3.2.

	Self weight [kN]
4*434-AL1/56-ST1A	32,2
1*97-AL1/56-ST1A	3,47

Table 3.2: Cable load values

These forces are to be multiplied by the partial factor corresponding to the load case and applied at the end point of the insulators.

3.2.3.3.2 Wind loads

Following the EN50341-1 standard, the basic wind parameters must be performed with reference to EN1991-1-4. This is done automatically by the TOWER software.

The rest of the wind parameters should follow the National Annexes. The reference National Annex selected is that of Germany (EN50341-2-4).

- Wind forces on the body of the tower :

The wind loads on the lattice tower body should be calculated according to part 4.4.3 of EN50341-1. Two methods can be used: dividing the tower into sections or considering each tower element individually. In order to choose which method to use, it is important to refer to the National Annex, which proscribes that the method to be followed is 1. Wind loads must be calculated on tower sections, and the force will therefore depend on the center of gravity

of the section.

The TOWER software automatically generates these calculations and determines the drag coefficient for the lattice tower based on the solidity ratio according to 4.4.3.2 of the German National Annex.

- Wind forces cross arms :

According to the German National Annex, the wind forces applied to the cross arms should be calculated in the same way as for the lattice tower body, which the software applies automatically.

- Wind forces on insulators :

The wind forces on the insulators must be determined according to part 4.4.2 of the German National Annex. The TOWER software also determines them automatically.

- Wind forces on conductors :

As the tower is a suspension tower, the conductors do not transfer any force to the tower apart from their own weight. The wind on the conductors should therefore not be considered.

Another parameter that need to be manually inserted into the program are the longitudinal and transverse wind pressures specific to a wind zone 2. As the towers are located at an altitude H greater than 1000m, according to part 4.3 DE1 of EN50341-2-4, this wind pressure must be multiplied by the factor $(0,25 + H/1000)$. The reference wind pressure q_0 for the wind zone 2 is 390 N/m².

3.2.3.3.3 Ice loads

According to the German National Annex : “For towers, no ice accretion needs to be assumed”.

However, ice loads on the conductors must be taken into account as additional dead weight applied to the cables. As TOWER software does not model the conductors, it does not determine the ice loads applied to them. They must therefore be calculated according to part 4.5.2 of the German National Annex, multiplied by the distance to the lowest points of the conductors, multiplied by four for the conductors and then entered manually into the software.

The values obtained according to the type of cable are shown in the Table 3.3.

	Ice loads [kN]
4*434-AL1/56-ST1A	31,52
1*97-AL1/56-ST1A	6,6

Table 3.3: Ice load values

These forces are to be multiplied by the partial factor by the partial factor corresponding to the load case and applied at the end point of the insulators.

3.2.3.4 Results of the linear elastic global design

The results of the global linear elastic analyses performed with TOWER software according to EN50341-1 are presented in the following table. Each table corresponds to a section of the tower (see Figure 3.9) and includes the angles that are to be used according to their steel grade.

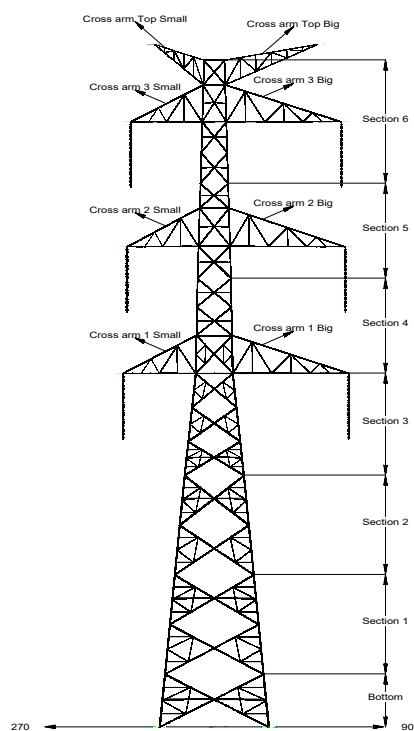


Figure 3.9: Annotations of the different sections of the tower

When the tower is made of S235 steel, the dominant load case is F, G unfavourable, I unfavourable. In other words, when the wind is at 45° to the cross-arms direction combined with the ice.

When the tower is made of S355 steel, the dominant load case is E, G unfavourable, I unfavourable. That is, the wind is in the direction perpendicular to the cross arms and is combined with ice.

When the tower is made of S460 steel, the dominant load case is also F, G unfavourable, I unfavourable.

The dominant loads are wind and ice combined.

3.2.3.4.1 Bottom section

This subsection contains annotations for the various members of the bottom section (see Figure 3.10 and 3.11), as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.4).

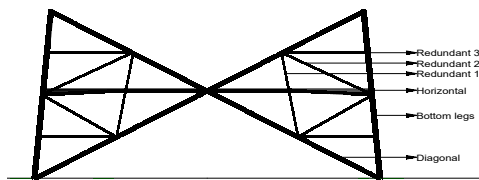


Figure 3.10: Annotations of the bottom section of the tower.

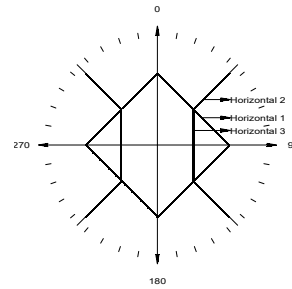


Figure 3.11: Annotations of the horizontal bracing in the bottom section

Group	Angle type	Angle size		
		S235	S355	S460
Bottom legs	SAE	AM 130x130x16	AM 140x140x10	AM 100x100x12*/-
Diagonal	SAE	AM 75x75x4	AM 75x75x4	AM 75x75x4
Redundant 1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 2	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
Redundant 3	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
Horizontal 1	SAE	AM 70x70x5	AM 70x70x5	AM 70x70x5
Horizontal 2	SAE	AM 70x70x5	AM 70x70x5	AM 70x70x5
Horizontal 3	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5

Table 3.4: Angle profiles for the different parts of the bottom section

The initials SAE is the type of angle used. SAE means that it is a single equal leg angle.

The initial AM means that they are sections of ArcelorMittal. The two first numbers are the lengths of the angle's legs, and the last numbers is the thickness of the angle's legs.

3.2.3.4.2 Section 1

This subsection contains annotations for the various members of the section 1 (see Figure 3.12 and 3.13), as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.5).

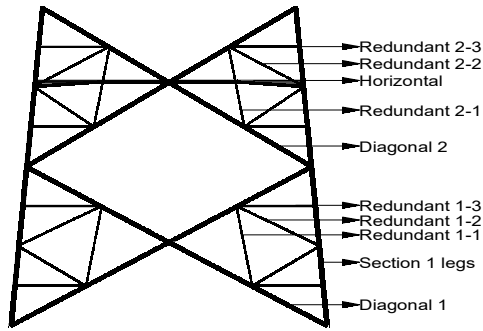


Figure 3.12: Annotations of the section 1 of the tower.

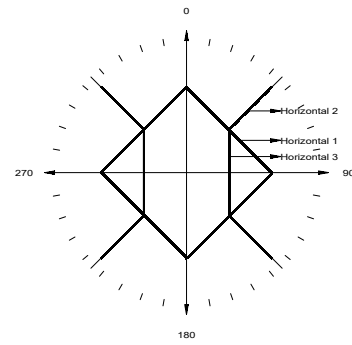


Figure 3.13: Annotations of the horizontal bracing in the section 1

Group	Angle type	Angle size		
		S235	S355	S460
Section 1 legs	SAE	AM 140x140x14	AM 130x130x10	AM 110x110x10*
Diagonal 1	SAE	AM 75x75x4	AM 75x75x4	AM 75x75x4
Diagonal 2	SAE	AM 75x75x4	AM 75x75x4	AM 120x120x9
Redundant 1-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 1-2	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
Redundant 1-3	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
Redundant 2-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 2-2	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 2-3	SAE	AM 45x45x4	AM 45x45x4	AM 45x45x4
Horizontal 1	SAE	AM 65x65x4	AM 65x65x4	AM 65x65x4
Horizontal 2	SAE	AM 65x65x4	AM 65x65x4	AM 65x65x4
Horizontal 3	SAE	AM 70x70x5	AM 70x70x5	AM 70x70x5

Table 3.5: Angle profiles for the different parts of the section 1

3.2.3.4.3 Section 2

This subsection contains annotations for the various members of the section 2 (see Figure 3.14 and 3.15), as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.6).

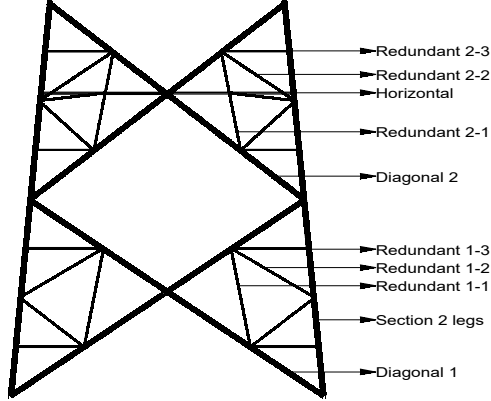


Figure 3.14: Annotations of the section 2 of the tower.

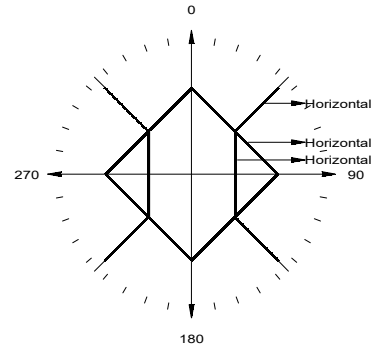


Figure 3.15: Annotations of the horizontal bracing in the section 2

Group	Angle type	Angle size		
		S235	S355	S460
Section 2 legs	SAE	AM 130x130x15	AM 110x110x12*	AM 100x100x11
Diagonal 1	SAE	AM 65x65x4	AM 65x65x4	AM 65x65x4
Diagonal 2	SAE	AM 65x65x4	AM 65x65x4	AM 65x65x4
Redundant 1-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 1-2	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 1-3	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 2-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 2-2	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 2-3	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Horizontal 1	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
Horizontal 2	SAE	AM 45x45x5	AM 45x45x5	AM 45x45x5
Horizontal 3	SAE	AM 60x60x4	AM 60x60x4	AM 60x60x4

Table 3.6: Angle profiles for the different parts of the section 2

3.2.3.4.4 Section 3

This subsection contains annotations for the various members of the section 3 (see Figure 3.16 and 3.17), as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.7).

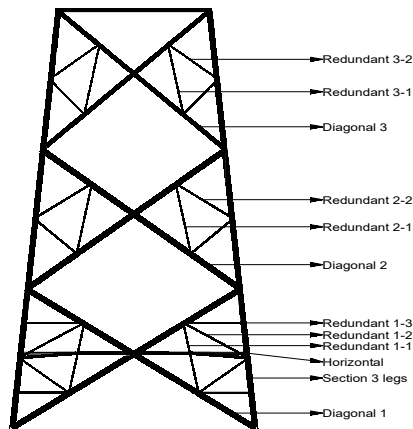


Figure 3.16: Annotations of the section 3 of the tower.

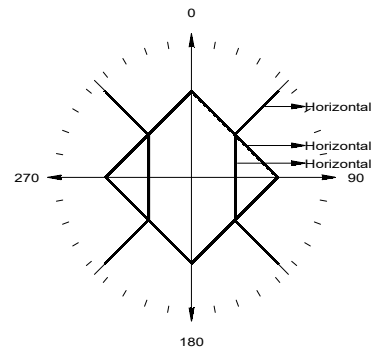


Figure 3.17: Annotations of the horizontal bracing in the section 3

Group	Angle type	Angle size		
		S235	S355	S460
Section 3 legs	SAE	AM 150x150x13-/+	AM 140x140x10	AM 120x120x10-
Diagonal 1	SAE	AM 65x65x4	AM 65x65x4	AM 65x65x4
Diagonal 2	SAE	AM 65x65x4	AM 65x65x4	AM 65x65x4
Diagonal 3	SAE	AM 75x75x4	AM 75x75x4	AM 60x60x5
Redundant 1-1	SAE	AM 30x30x3	AM 30x30x3	AM 30x30x3
Redundant 1-2	SAE	AM 30x30x4	AM 30x30x4	AM 30x30x4
Redundant 1-3	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 2-1	SAE	AM 30x30x4	AM 30x30x4	AM 30x30x3
Redundant 2-2	SAE	AM 30x30x4	AM 30x30x4	AM 30x30x3
Redundant 3-1	SAE	AM 30x30x3	AM 30x30x3	AM 30x30x3
Redundant 3-2	SAE	AM 30x30x3	AM 30x30x4	AM 30x30x3
Horizontal 1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Horizontal 2	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Horizontal 3	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4

Table 3.7: Angle profiles for the different parts of the section 3

3.2.3.4.5 Section 4

This subsection contains annotations (see Figure 3.18 to 3.20) for the various members of the section 4, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.8).

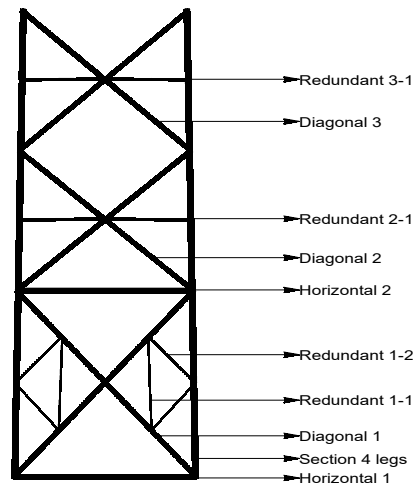


Figure 3.18: Annotations of the section 4 of the tower.

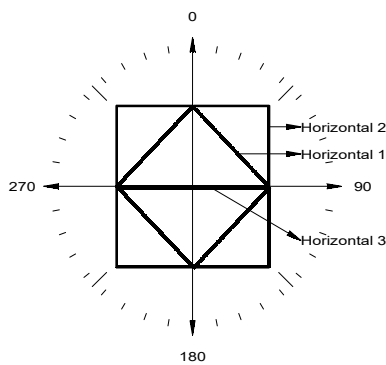


Figure 3.19: Annotations of the horizontal bracing in the section 4

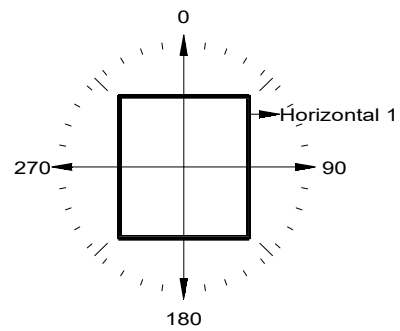


Figure 3.20: Annotations of the horizontal bracing in the section 4

Group	Angle type	Angle size		
		S235	S355	S460
Section 4 legs	SAE	AM 140x140x12	AM 120x120x10-	AM 120x120x9
Diagonal 1	SAE	AM 90x90x6	AM 90x90x5	AM 90x90x5
Diagonal 2	SAE	AM 65x65x4	AM 65x65x4	AM 60x60x4
Diagonal 3	SAE	AM 65x65x4	AM 65x65x4	AM 60x60x4
Redundant 1-1	SAE	AM 30x30x3	AM 30x30x3	AM 30x30x3
Redundant 1-2	SAE	AM 30x30x3	AM 30x30x3	AM 30x30x3
Redundant 2-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 3-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Horizontal 1-1	SAE	AM 60x60x4	AM 60x60x4	AM 60x60x4
Horizontal 1-2	SAE	AM 90x90x6	AM 80x80x5	AM 75x75x5
Horizontal 1-3	SAE	AM 75x75x5	AM 75x75x5	AM 75x75x5
Horizontal 2-1	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5

Table 3.8: Angle profiles for the different parts of the section 4

3.2.3.4.6 Section 5

This subsection contains annotations (see Figure 3.21 to 3.23) for the various members of the section 5, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.9).

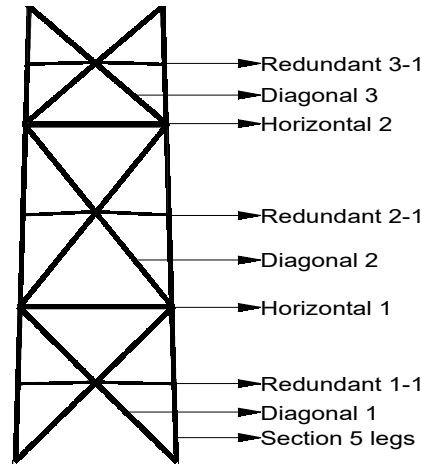


Figure 3.21: Annotations of the section 5 of the tower

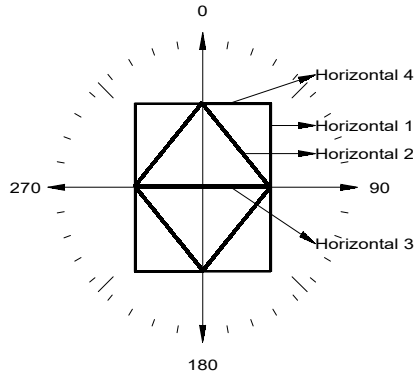


Figure 3.22: Annotations of the horizontal 1 bracing in the section 5

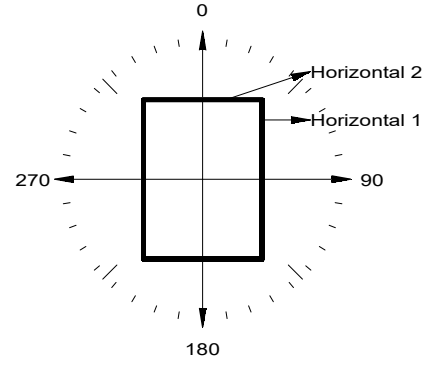


Figure 3.23: Annotations of the horizontal 2 bracing in the section 5

Group	Angle type	Angle size		
		S235	S355	S460
Section 5 legs	SAE	AM 130x130x9	AM 110x110x8	AM 100x100x8*/-
Diagonal 1	SAE	AM 90x90x5	AM 75x75x6-	AM 80x80x5
Diagonal 2	SAE	AM 90x90x5	AM 75x75x6-	AM 80x80x5
Diagonal 3	SAE	AM 90x90x5	AM 75x75x6-	AM 80x80x5
Redundant 1-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 2-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 3-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Horizontal 1-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Horizontal 1-2	SAE	AM 60x60x4	AM 60x60x4	AM 60x60x4
Horizontal 1-3	SAE	AM 75x75x5	AM 75x75x4	AM 60x60x4
Horizontal 1-4	SAE	AM 80x80x5	AM 70x70x5	AM 75x75x4
Horizontal 2-1	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Horizontal 2-2	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5

Table 3.9: Angle profiles for the different parts of the section 5

3.2.3.4.7 Top section

This subsection contains annotations (see Figure 3.24 to 3.27) for the various members of the top section, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.10).

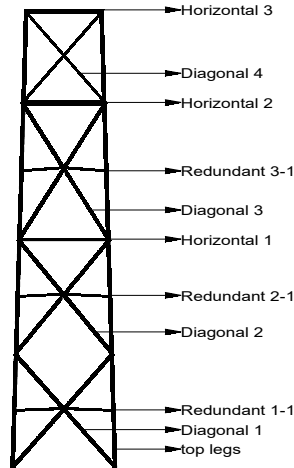


Figure 3.24: Annotations of the top of the tower

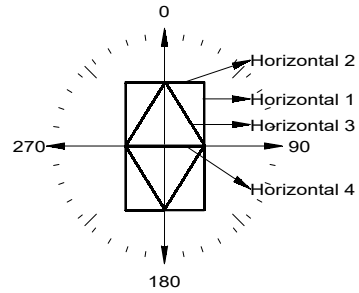


Figure 3.25: Annotations of the horizontal 1 bracing in the top section

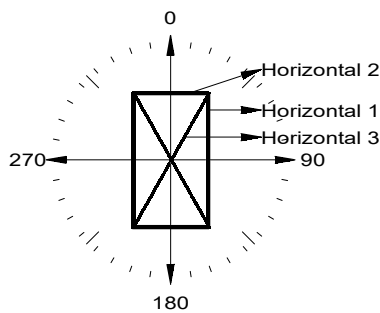


Figure 3.26: Annotations of the horizontal 2 bracing in the top section

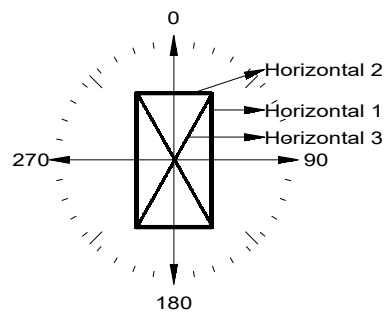


Figure 3.27: Annotations of the horizontal 3 bracing in the top section

Group	Angle type	Angle size		
		S235	S355	S460
Top legs	SAE	AM 100x100x7	AM 90x90x6	AM 80x80x6
Diagonal 1	SAE	AM 55x55x4	AM 55x55x4	AM 55x55x4
Diagonal 2	SAE	AM 55x55x4	AM 55x55x4	AM 55x55x4
Diagonal 3	SAE	AM 90x90x6	AM 90x90x5	AM 75x75x6-
Diagonal 4	SAE	AM 65x65x4	AM 65x65x4	AM 65x65x4
Redundant 1-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 2-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Redundant 3-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Horizontal 1-1	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Horizontal 1-2	SAE	AM 80x80x5	AM 63x63x5	AM 60x60x5
Horizontal 1-3	SAE	AM 55x55x4	AM 55x55x4	AM 55x55x4
Horizontal 1-4	SAE	AM 55x55x4	AM 55x55x4	AM 55x55x4
Horizontal 2-1	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Horizontal 2-2	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Horizontal 2-3	SAE	AM 100x100x6	AM 100x100x6	AM 100x100x6
Horizontal 3-1	SAE	AM 75x75x6-	AM 75x75x6-	AM 75x75x6-
Horizontal 3-2	SAE	AM 75x75x6-	AM 75x75x6-	AM 75x75x6-
Horizontal 3-3	SAE	AM 100x100x6	AM 100x100x6	AM 100x100x6

Table 3.10: Angle profiles for the different parts of the top section

3.2.3.4.8 Three first big cross arms

This subsection contains annotations (see Figure 3.28 and 3.29) for the various members of the three first big cross arms, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.11). These three first big cross arms are identical.

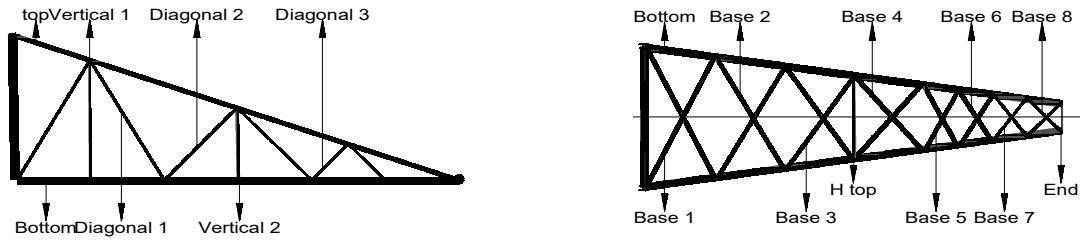


Figure 3.28: Annotations of the three first big cross arms (front and bottom view)

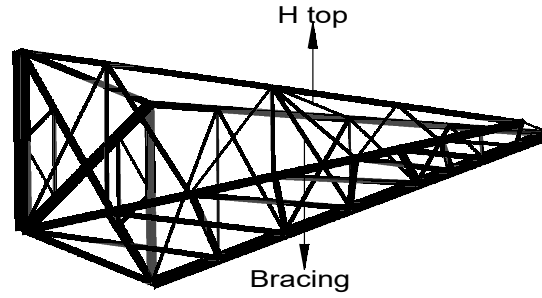


Figure 3.29: Annotations of the three first big cross arms (isometric view)

Group	Angle type	Angle size		
		S235	S355	S460
Bottom	SAE	AM 110x110x6	AM 90x90x6	AM 90x90x6
Top	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Diagonal 1	SAE	AM 60x60x4	AM 60x60x4	AM 60x60x4
Diagonal 2	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Diagonal 3	SAE	AM 30x30x3	AM 30x30x3	AM 30x30x3
Vertical 1	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
Vertical 2	SAE	AM 30x30x3	AM 30x30x3	AM 30x30x3
Base 1 to 6	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Base 7	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Base 8	SAE	AM 30x30x3	AM 30x30x3	AM 30x30x3
End	SAE	AM 20x20x3	AM 20x20x3	AM 20x20x3
H top	SAE	AM 40x40x4	AM 40x40x4	AM 40x40x4
Bracing	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4

Table 3.11: Angle profiles for the different parts of the three first big cross arms

3.2.3.4.9 Three first small cross arms

This subsection contains annotations (see Figure 3.30) for the various members of the three first small cross arms, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.12). These three first small cross arms are identical.

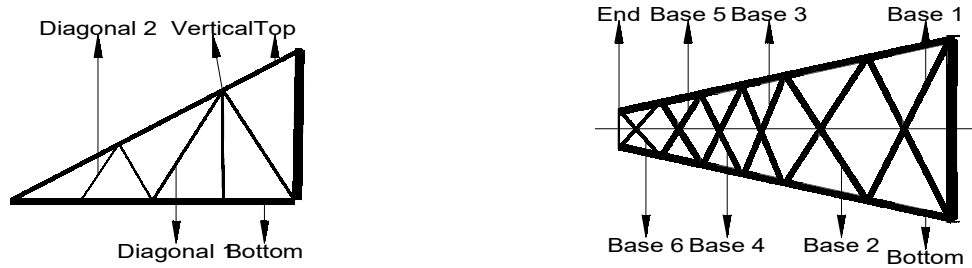


Figure 3.30: Annotations of the three first small cross arms (front and bottom view)

Group	Angle type	Angle size		
		S235	S355	S460
Bottom	SAE	AM 75x75x6-	AM 76x76x4,8	AM 70x70x5
Top	SAE	AM 75x75x4	AM 75x75x4	AM 75x75x4
Diagonal 1	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
Diagonal 2	SAE	AM 30x30x3	AM 30x30x3	AM 30x30x3
Vertical	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
Base 1 to 5	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Base 6	SAE	AM 30x30x3	AM 30x30x3	AM 30x30x3
End	SAE	AM 20x20x3	AM 20x20x3	AM 20x20x3

Table 3.12: Angle profiles for the different parts of the three first small cross arms

3.2.3.4.10 Big top cross arm

This subsection contains annotations (see Figure 3.31) for the various members of the big top cross arm, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.13).

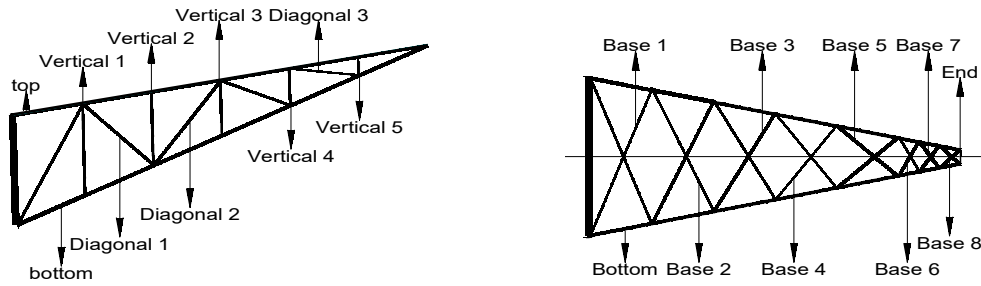


Figure 3.31: Annotations of the big top cross arm (front and bottom view)

Group	Angle type	Angle size		
		S235	S355	S460
Bottom	SAE	AM 60x60x4	AM 55x55x4	AM 50x50x4
Top	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Diagonal 1	SAE	AM 45x45x4	AM 45x45x4	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Diagonal 3	SAE	AM 30x30x3	AM 30x30x3	AM 30x30x3
Vertical 1 to 5	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Base 1	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Base 2	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Base 3	SAE	AM 65x65x4	AM 65x65x4	AM 65x65x4
Base 4	SAE	AM 55x55x4	AM 55x55x4	AM 55x55x4
Base 5 to 8	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
End	SAE	AM 20x20x3	AM 20x20x3	AM 20x20x3

Table 3.13: Angle profiles for the different parts of the big top cross arm

3.2.3.4.11 Small top cross arm

This subsection contains annotations (see Figure 3.32) for the various members of the small top cross arm, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.14).

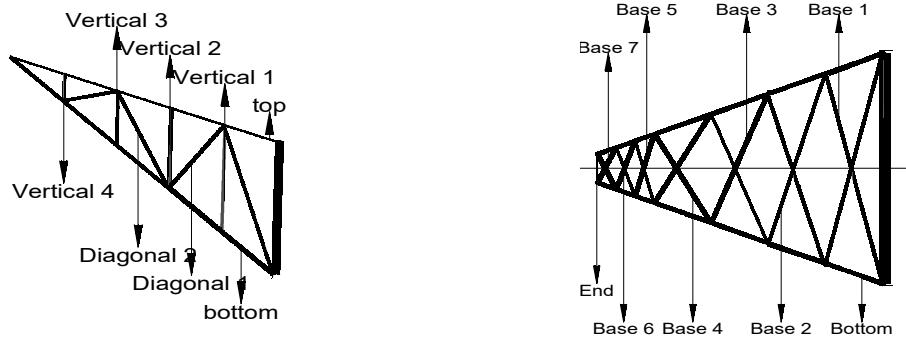


Figure 3.32: Annotations of the small top cross arm (front and bottom view)

Group	Angle type	Angle size		
		S235	S355	S460
Bottom	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Top	SAE	AM 25x25x3	AM 25x25x3	AM 25x25x3
Diagonal 1	SAE	AM 45x45x4	AM 45x45x4	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Vertical 1 to 4	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Base 1	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Base 2 to 7	SAE	AM 75x75x4	AM 75x75x4	AM 75x75x4
End	SAE	AM 20x20x3	AM 20x20x3	AM 20x20x3

Table 3.14: Angle profiles for the different parts of the small top cross arm

3.2.3.5 Analysis of results

Firstly, a reduction in the section sizes of some angles can be observed as the grade of steel increases (see angles size in bold). This reduction in size leads to a reduction in the weight of the tower and savings on materials.

In fact, it can be seen from Table 3.15 that the weight of the tower changes depending on the grade of steel used.

	Profiles weight [T]	Total weight of the tower [T]	Weight saved [T]	Weight saved [%]
S235	17,14	17,19	0	0
S355	15,08	15,13	2,06	11,9
S460	14,35	14,40	2,79	16,2

Table 3.15: Weight of the profiles,the tower and saved depending on the steel grade

By using S355 steel instead of S235 steel, 12,0% of the weight of the angles will be saved, leading to a saving of 11,9% on the total weight of the tower. From now on, if S460 steel is used, an additional 4,9% of the weight of the angles will be saved, leading to an additional 4,8% reduction in the total weight of the tower.

If a comparison is made with the use of S235 steel, a total saving of 16,3% on the weight of the angles and of 16,2% on the total weight of the tower can be made by using S460 steel.

Now, considering that S235 steel has a price of €900 per tonne, that S355 steel has a price of €950 per tonne and that S460 steel has a price of €1000 per tonne, a study of the steel costs per tower can be carried out (see Table 3.16).

Steel grade	Price per weight [€/T]	Tower steel weight [T]	Total price [€]
S235	900	17,14	15 426
S355	950	15,08	14 326
S460	1 000	14,35	14 350

Table 3.16: Costs per tower for steel

The use of S355 steel for suspension transmission towers, as it is currently the case, is a good alternative to S235 steel as it reduces the weight of the towers sufficiently to reduce their cost. However, the use of S460 steel for future suspended transmission towers does not allow for cost optimization. In fact, the weight reduction is not significant enough to compensate for the higher price of S460 steel compared with S355 steel.

What's more, whether the towers are built with S235 steel or S460 steel angles, there is no need for a butterfly angle. Using S460 steel also doesn't save on labour.

In conclusion, the use of S460 steel angles for the construction of future suspension transmission towers is not interesting. Although this would reduce the weight of the towers, the difference would not be great enough to achieve a cost saving.

3.3 Second model steel lattice tower – Dead end Tower

3.3.1 Typology of the steel lattice tower

3.3.1.1 Geometry and dimensions

The second tower studied in this thesis will also be an M3 type transmission tower for a 400kV double track line also made of hot-dip galvanized steel equal-leg angle. But this time, the tower is a dead end tower.

A dead end tower is a tower that is designed to be the first and last in the transmission line, and therefore to take the loads of the conductors on one side of the tower only. It means that the tower structure, in addition to supporting the conductor's own weight and ice loads, also supports the tensile forces exerted on the conductors by wind and ice. In a transmission line, dead-end towers represent only 25% of the total number of towers, whereas they concentrate over 75% of the total weight of the line. This is because dead-end towers are heavier structures compared to suspension towers since they bear, in addition to the self-weight of the conductors, the tension load of the latter. For reasons of redundancy, generally every fourth tower in a line is a dead-end tower.

The tower has exactly the same geometry and dimensions as in the previous case. The only things that will differ from the previous case are the forces exerted on the tower and the insulators.

The steel lattice tower studied still has an approximate height of 50 m and the exact geometry and dimensions are illustrated in the previous section in Figures 3.2 to 3.6.

3.3.1.2 Conductors

As mentioned above, the only structural elements that change are the insulators. The conductors therefore remain the same as in the previous case study.

The conductors that were selected for the case study tower are the following:

- 434-AL1/56-ST1A for the conductors.
- 97-AL1/56-ST1A for the earth wires.

3.3.1.3 Insulators

In order to transfer the loads from the conductors to the tower's cross arms, they are connected to modular suspension insulators. The insulators selected are type S148142FG01^[34].

- S1 defined the mechanical strength (S1 for 25 kip = 111 kN).
- 48 defined the terminal fitting type (4 for Y-Clevis type and 8 for Ball type).
- 142 defined the section length (142 inches = 3,61 m).
- F defined the profile of the skirt (F for Normal and fixed).
- G defined the crown ring (diameter of 12" = 30 cm and line of 17" = 43 cm). These rings are installed at one or both ends of the insulator to minimize corona effects and unwanted noise.
- 01 defined the internal use.

The total length of the insulator ensures sufficient distance between the conductors and the tower structure.

3.3.1.4 Transmission Line

The information on the transmission line also remains unchanged. In order to study the most general case possible, the distance between two towers will be taken as 500m. The towers will also be considered to be built at more or less the same altitude of 1100m, so that the lowest points of the cables are located halfway between two towers.

3.3.2 Analysis according to EN50341

3.3.2.1 General design assumptions

The main design assumptions remain identical to the previous case, based on the requirements of standard EN50341-1 and its German National Annex.

- The internal forces shall be determined by means of a global elastic analysis and the first order theory, using the initial geometry of the structure.
- Lattice steel towers are considered as pin jointed truss structures.
- The partial material factors for lattice tower are : $\gamma_{M0} = 1$, $\gamma_{M1} = 1$ and $\gamma_{M2} = 1,25$.

- 12 different load cases are to be taken into account (see subsection 3.3.2.2).
- Ice loads are not considered on the structure of the lattice tower.
- The wind forces on the tower itself shall be determined according to method 1 of EN50341-1 : “the tower is divided into sections and the wind force is acting at the centre of gravity of each tower section”.
- The eccentricities of the connections are taken into account by means of the non-dimensional effective slenderness λ_{eff} .
- The buckling verification of the angle profiles will be carried out using the buckling curve a_0 .

The assumption that the tower is located in wind zone 2 and ice zone E2 to calculate the wind and ice loads will be also made.

3.3.2.2 Load cases

The load cases to be considered remain identical to the previous case and are defined in the National Annexes to EN50341-1.

Unlike the previous case, since this is a dead-end tower, all load cases must be taken into account.

- **Load case A**
Permanent loads and wind forces in direction of the cross arms.
- **Load case B**
Permanent loads and wind forces in transversal direction of the cross arms.
- **Load case C**
Permanent loads and quartering wind forces at $\phi = 45^\circ$.
- **Load case D**
Permanent loads and wind forces in direction of the cross arms and ice loads.
- **Load case E**
Permanent loads and wind forces in transversal direction of the cross arms and ice loads.
- **Load case F**
Permanent loads and quartering wind forces at $\phi = 45^\circ$ and ice loads.

- **Load case G**

Permanent loads and ice loads in one of the adjacent spans, no ice loads in the other adjacent span, whereby 50% of the ice loads shall be assumed.

- **Load case H**

Permanent loads, whereby permanent loads on all conductors at $-20\text{ }^{\circ}\text{C}$, as well as permanent loads and ice loads on all conductors at $-5\text{ }^{\circ}\text{C}$.

One-sided horizontal design force of one conductor and two thirds of the conductor horizontal design forces at all other conductors acting in line direction.

- **Load case I**

Permanent loads and construction loads.

- **Load case J**

Permanent loads and ice loads.

The horizontal forces of a single or bundle conductor shall be assumed as reduced by 100% on one side.

- **Load case K**

Permanent loads and ice loads.

The horizontal tensile force of all conductors shall be assumed to be reduced by 40% on one side.

- **Load case L**

Permanent loads and ice loads.

Failing of one insulator string of a multiple insulator set.

Each load case involves loads from different sources. The effects of these loads are determined by their characteristic values and require the application of appropriate partial factors.

The design value of the actions is given in the German National Annex EN50341-2-4 as follows :

$$Ed = \{ \gamma_G G_K; \gamma_W Q_{WK}; \gamma_I Q_{IK}; \gamma_P Q_{PK}; \gamma_C Q_{CK}; \}$$

Where

E_d	Total load;
G_K	Dead load of conductors, insulators, and supports;
Q_{WK}	Wind force as specified in 4.4.1/DE.1 to 4.4.4/DE.1 in EN50341-2-4;
Q_{IK}	Ice forces on conductors as specified in 4.5.2/DE.1 in EN50341-2-4;
Q_{PK}	Construction loads as specified in 4.9.1/DE.1 and 4.9.2/DE.1 in EN50341-2-4;
Q_{CK}	Horizontal conductor tensile forces considering the temperature changes as well as wind and ice loads as specified in 4.12.2/DE.1. in EN50341-2-4.

The partial safety factors depend on the load case and are defined as :

$\gamma_G = \gamma_W = \gamma_I = \gamma_P = 1,35$	for load cases A to I in case of unfavourable action;
$\gamma_G = \gamma_I = 1$	for load cases A to F in case of favourable action;
$\gamma_G = \gamma_W = \gamma_I = \gamma_P = 1$	for load cases J to L;
$\gamma_P = 1,5$	for construction loads in load case I.

3.3.2.3 Loads in the TOWER software

3.3.2.3.1 Permanent loads

As with the suspension tower, the permanent loads include the self-weight of the tower and the conductors. The self-weight of the angle bars and insulators is automatically calculated by the TOWER software. The self-weight of all other structural elements that make up the tower is taken into account by a safety factor of 1,2 on the self-weight of the tower calculated by the TOWER software.

As the conductors are identical for both towers, their own weight also remains identical and is available in Table 3.17.

	Self weight [kN]
4*434-AL1/56-ST1A	32,2
1*97-AL1/56-ST1A	3,47

Table 3.17: Cable load values

These forces are to be multiplied by the partial factor by the partial factor corresponding to the load case and applied at the end point of the insulators.

3.3.2.3.2 Wind loads

As in the previous case, the wind loads are considered in accordance with the German National Annex EN50341-2-4.

The wind forces on the tower body, cross arms and insulators are determined in the same way as above. In this case, since it is a dead-end tower, an additional wind load on the conductors must be taken into account.

- Wind forces on the body of the tower :

The wind loads on the lattice tower body should be calculated according to the method 1 of part 4.4.3 of EN50341-1.

The TOWER software automatically generates these calculations.

- Wind forces cross arms :

The wind forces applied to the cross arms should be calculated in the same way as for the lattice tower body, which the software applies automatically.

- Wind forces on insulators :

The wind forces on the insulators must be determined according to part 4.4.2 of the German National Annex. The TOWER software also determines them automatically.

- Wind forces on conductors :

As the tower is a dead-end tower, the conductors transfer a force to the tower due to the wind pressure on them. This force must be calculated in accordance with section 4.4.1 DE1 of the German National Annex and then manually inserted into the various load cases.

Since the tower is part of a straight line, the following formulas can be used :

$$Q_{w_{cx}} = q_p(h) \times G_c \times C_c \times d \frac{L_1 + L_2}{2} \cos^2 \phi$$

$$Q_{w_{cy}} = 0$$

With $q_p(h)$, the wind pressure depending on the height of the tension point, G_c , the conductor response factor, C_c , the drag factor, d , the conductor diameter, L_1 and L_2 , the spans and ϕ , the angle of the wind action depending on the load case.

The longitudinal and transverse wind pressures specific to wind zone 2 must also be manually inserted into the program. As the towers are located at an altitude H greater than 1000m, according to part 4.3 DE1 of EN50341-2-4, this wind pressure must be multiplied by the factor $(0,25 + H/1000)$. The reference wind pressure q_0 for the wind zone 2 is 390 N/m^2 .

3.3.2.3.3 Ice loads

Ice loads should always be neglected on the tower itself. However, ice loads on the conductors must always be considered and calculated according to part 4.5.2 of the German National Annex and then entered manually into the software.

The values obtained according to the type of cable are shown in the Table 3.18 and are the same as in the previous case.

	Ice loads [kN]
4*434-AL1/56-ST1A	31,52
1*97-AL1/56-ST1A	6,6

Table 3.18: Ice load values

These forces are to be multiplied by the partial factor by the partial factor corresponding to the load case and applied at the end point of the insulators.

3.3.2.3.4 Tension in the cables

Since the tower is a dead-end tower, the cables transmit horizontal tension forces to the tower due to the wind, ice, and the cable's own weight. As the TOWER software does not model the conductors, it does not determine the tension. This horizontal tension can be calculated by solving this equation^[36] :

$$H_2^3 + AH_2^2 - B = 0$$

With H_2 , the final horizontal tension and

$$A = C_2(t_2 - t_1) + \left(\frac{W_1 SC_1}{H_1} \right)^2 - H_1$$

$$B = (W_2 SC_1)^2$$

$$C_1 = \sqrt{\frac{EA}{24}}$$

$$C_2 = \alpha EA$$

Where t_1 and t_2 are the initial and final conductor temperature, W_1 is the unit weight of the cable, S is the span between the two tower, H_1 is the initial horizontal tension or the rated strength available in the Table 3.1 as α , E and A.

W_2 is the resultant conductor weight which can be calculated using the formula :

$$W_2 = \sqrt{(W_1 + W_{ice})^2 + (W_{wind})^2}$$

Where W_{ice} is the additional conductor weight due to ice (see section 3.3.2.3.3) and W_{wind} is the additional conductor weight due to wind (see section 3.3.2.3.2). Depending on the load case, these loads must be multiplied by the corresponding partial factors.

3.3.2.4 Results of the linear elastic global design

The results of the global linear elastic analyses performed with TOWER software according to EN50341-1 are presented in the following table. Each table corresponds to a section of the tower (see Figure 3.33) and includes the angles that are to be used according to their steel grade.

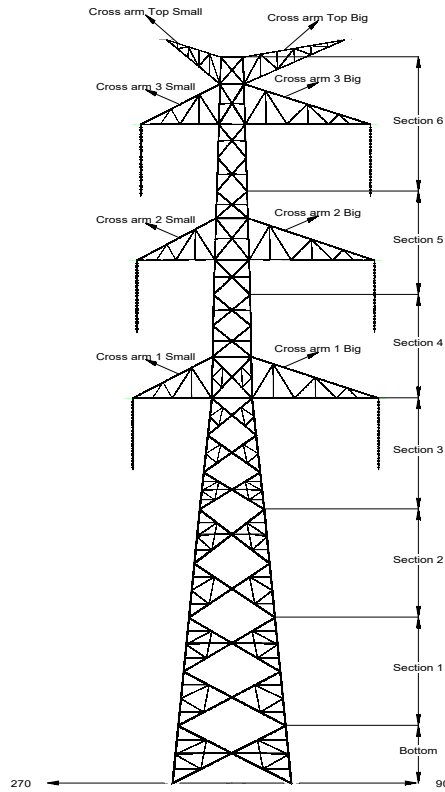


Figure 3.33: Annotations of the different sections of the tower

When the tower is made of S235 steel, the dominant load case is E, G favourable, I unfavourable. In other words, when the wind is in the direction perpendicular to the cross-arms direction combined with the ice.

When the tower is made of S355 steel, the dominant load case is F, G favourable, I unfavourable. That is, the wind is at 45° to the cross arms and is combined with ice.

When the tower is made of S460 steel, the dominant load case is D, G favourable, I unfavourable. That is, the wind is in the direction to the cross arms and is combined with ice

The dominant loads are wind and ice combined.

3.3.2.4.1 Bottom section

This subsection contains annotations for the various members of the bottom section (see Figure 3.34 and 3.35), as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.19).

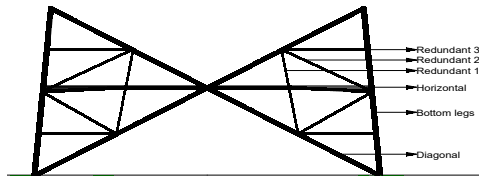


Figure 3.34: Annotations of the bottom section of the tower.

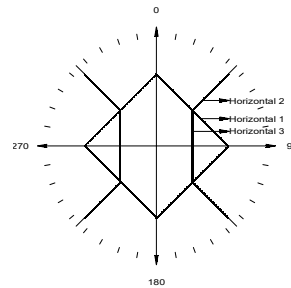


Figure 3.35: Annotations of the horizontal bracing in the bottom section

Group	Angle size					
	S235		S355		S460	
Bottom legs	DAE	AM 300x300x27	DAE	AM 250x250x21	SAE	AM 250x250x34
Diagonal	SAE	AM 130x130x8	SAE	AM 120x120x8	SAE	AM 120x120x8
Redundant 1	SAE	AM 76x76x4,8	SAE	AM 70x70x5	SAE	AM 70x70x5
Redundant 2	SAE	AM 90x90x6	SAE	AM 90x90x5	SAE	AM 90x90x5
Redundant 3	SAE	AM 110x110x7	SAE	AM 110x110x6	SAE	AM 100x100x6
Horizontal 1	SAE	AM 70x70x5	SAE	AM 70x70x5	SAE	AM 70x70x5
Horizontal 2	SAE	AM 70x70x5	SAE	AM 70x70x5	SAE	AM 70x70x5
Horizontal 3	SAE	AM 90x90x5	SAE	AM 90x90x5	SAE	AM 90x90x5

Table 3.19: Angle profiles for the different parts of the bottom section

SAE always means that it is a single equal leg angle, whereas DAE means that it is a section formed by a double equal leg angles fixed as a butterfly angle.

3.3.2.4.2 Section 1

This subsection contains annotations for the various members of the section 1 (see Figure 3.36 and 3.37), as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.20).

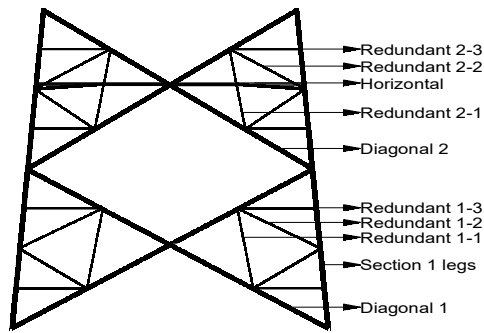


Figure 3.36: Annotations of the section 1 of the tower.

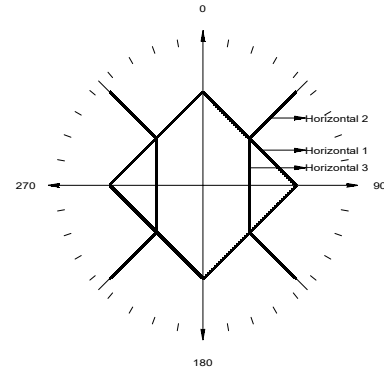


Figure 3.37: Annotations of the horizontal bracing in the section 1

Group	Angle size					
	S235		S355		S460	
Section 1 legs	DAE	AM 300x300x27	DAE	AM 200x200x26+	SAE	AM 300x300x27
Diagonal 1	SAE	AM 140x140x9	SAE	AM 120x120x9	SAE	AM 130x130x8
Diagonal 2	SAE	AM 140x140x9	SAE	AM 120x120x9	SAE	AM 130x130x8
Redundant 1-1	SAE	AM 76x76x4,8	SAE	AM 70x70x5	SAE	AM 70x70x5
Redundant 1-2	SAE	AM 90x90x6	SAE	AM 90x90x5	SAE	AM 90x90x5
Redundant 1-3	SAE	AM 110x110x7	SAE	AM 110x110x6	SAE	AM 100x100x6
Redundant 2-1	SAE	AM 70x70x5	SAE	AM 75x75x4	SAE	AM 76x76x4,8
Redundant 2-2	SAE	AM 90x90x5	SAE	AM 75x75x6-	SAE	AM 80x80x5
Redundant 2-3	SAE	AM 100x100x6	SAE	AM 100x100x6	SAE	AM 90x90x6
Horizontal 1	SAE	AM 65x65x4	SAE	AM 65x65x4	SAE	AM 65x65x4
Horizontal 2	SAE	AM 65x65x4	SAE	AM 65x65x4	SAE	AM 65x65x4
Horizontal 3	SAE	AM 70x70x5	SAE	AM 70x70x5	SAE	AM 70x70x5

Table 3.20: Angle profiles for the different parts of the section 1

3.3.2.4.3 Section 2

This subsection contains annotations for the various members of the section 2 (see Figure 3.38 and 3.39), as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.21).

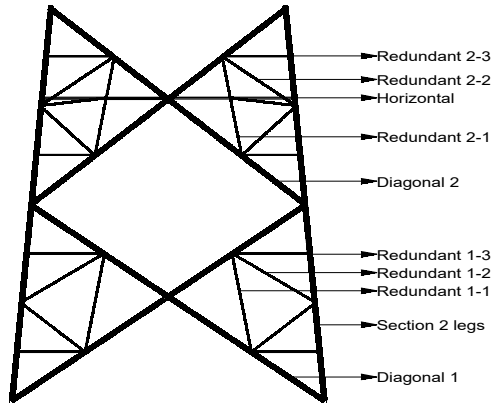


Figure 3.38: Annotations of the section 2 of the tower.

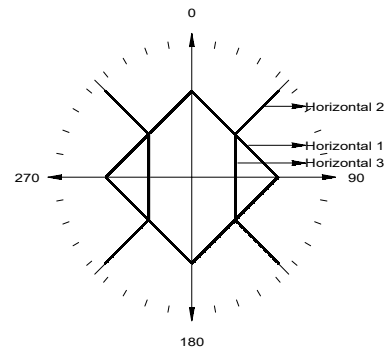


Figure 3.39: Annotations of the horizontal bracing in the section 2

Group	Angle size					
	S235		S355		S460	
Section 2 legs	DAE	AM 250x250x31	SAE	AM 300x300x33	SAE	AM 300x300x26
Diagonal 1	SAE	AM 150x150x10-/+	SAE	AM 130x130x9	SAE	AM 130x130x9
Diagonal 2	SAE	AM 150x150x10-/+	SAE	AM 130x130x9	SAE	AM 130x130x9
Redundant 1-1	SAE	AM 76x76x4,8	SAE	AM 80x80x5	SAE	AM 75x75x6-
Redundant 1-2	SAE	AM 90x90x5	SAE	AM 80x80x5	SAE	AM 75x75x5
Redundant 1-3	SAE	AM 100x100x6	SAE	AM 90x90x6	SAE	AM 80x80x6
Redundant 2-1	SAE	AM 90x90x5	SAE	AM 80x80x6	SAE	AM 90x90x6
Redundant 2-2	SAE	AM 75x75x6-	SAE	AM 75x75x5	SAE	AM 70x70x5
Redundant 2-3	SAE	AM 100x100x6	SAE	AM 90x90x6	SAE	AM 75x75x7
Horizontal 1	SAE	AM 50x50x4	SAE	AM 50x50x4	SAE	AM 50x50x4
Horizontal 2	SAE	AM 45x45x5	SAE	AM 45x45x5	SAE	AM 45x45x5
Horizontal 3	SAE	AM 60x60x4	SAE	AM 60x60x4	SAE	AM 60x60x4

Table 3.21: Angle profiles for the different parts of the section 2

3.3.2.4.4 Section 3

This subsection contains annotations for the various members of the section 3 (see Figure 3.40 and 3.41), as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.22).

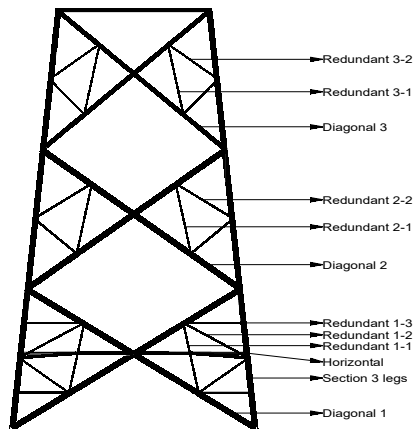


Figure 3.40: Annotations of the section 3 of the tower.

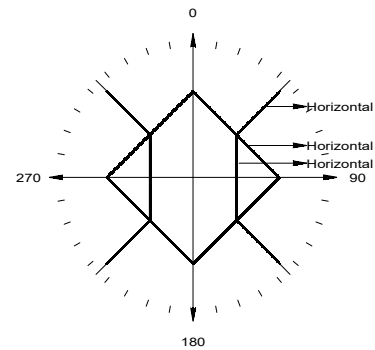


Figure 3.41: Annotations of the horizontal bracing in the section 3

Group	Angle size				
	S235		S355		S460
Section 3 legs	DAE	AM 250x250x29	SAE	AM 300x300x31	SAE AM 250x250x30
Diagonal 1	SAE	AM 130x130x14	SAE	AM 130x130x10	SAE AM 130x130x9
Diagonal 2	SAE	AM 130x130x14	SAE	AM 130x130x10	SAE AM 130x130x9
Diagonal 3	SAE	AM 150x150x15-/+	SAE	AM 150x150x12-/+	SAE AM 140x140x11
Redundant 1-1	SAE	AM 75x75x4	SAE	AM 75x75x4	SAE AM 75x75x4
Redundant 1-2	SAE	AM 76x76x4,8	SAE	AM 63x63x5	SAE AM 60x60x5
Redundant 1-3	SAE	AM 90x90x6	SAE	AM 75x75x6-	SAE AM 80x80x5
Redundant 2-1	SAE	AM 76x76x4,8	SAE	AM 75x75x5	SAE AM 70x70x5
Redundant 2-2	SAE	AM 76x76x4,8	SAE	AM 75x75x5	SAE AM 70x70x5
Redundant 3-1	SAE	AM 60x60x4	SAE	AM 65x65x5	SAE AM 75x75x4
Redundant 3-2	SAE	AM 70x70x5	SAE	AM 60x60x5	SAE AM 65x65x4
Horizontal 1	SAE	AM 45x45x3	SAE	AM 45x45x3	SAE AM 45x45x3
Horizontal 2	SAE	AM 45x45x3	SAE	AM 45x45x3	SAE AM 45x45x3
Horizontal 3	SAE	AM 50x50x4	SAE	AM 50x50x4	SAE AM 50x50x4

Table 3.22: Angle profiles for the different parts of the section 3

3.3.2.4.5 Section 4

This subsection contains annotations (see Figure 3.42 to 3.44) for the various members of the section 4, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.23).

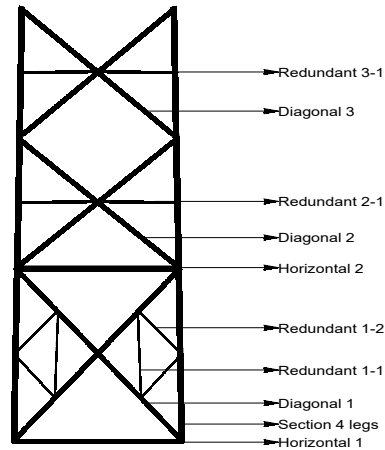


Figure 3.42: Annotations of the section 4 of the tower.

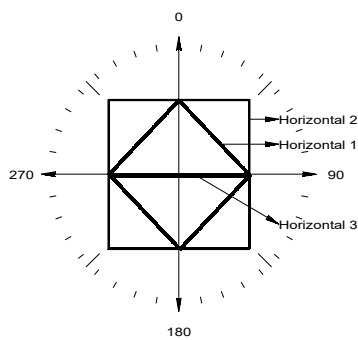


Figure 3.43: Annotations of the horizontal bracing in the section 4

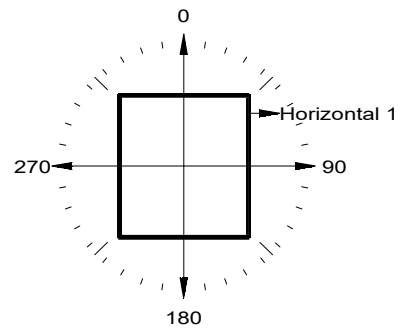


Figure 3.44: Annotations of the horizontal bracing in the section 4

Group	Angle size					
	S235		S355		S460	
Section 4 legs	DAE	AM 250x250x21	DAE	AM 200x200x17+	SAE	AM 250x250x22
Diagonal 1	DAE	AM 140x140x12	SAE	AM 160x160x16-/+	SAE	AM 160x160x16-/+
Diagonal 2	SAE	AM 200x200x13	SAE	AM 150x150x14+	SAE	AM 150x150x12-/+
Diagonal 3	SAE	AM 200x200x13	SAE	AM 150x150x14+	SAE	AM 150x150x12-/+
Redundant 1-1	SAE	AM 60x60x5	SAE	AM 60x60x5	SAE	AM 65x65x4
Redundant 1-2	SAE	AM 60x60x5	SAE	AM 60x60x5	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 80x80x5	SAE	AM 76x76x4,8	SAE	AM 75x75x5
Redundant 3-1	SAE	AM 80x80x5	SAE	AM 76x76x4,8	SAE	AM 75x75x5
Horizontal 1-1	SAE	AM 100x100x6	SAE	AM 100x100x6	SAE	AM 90x90x6
Horizontal 1-2	SAE	AM 140x140x16	SAE	AM 150x150x10-/+	SAE	AM 120x120x10-
Horizontal 1-3	SAE	AM 75x75x5	SAE	AM 75x75x5	SAE	AM 75x75x5
Horizontal 2-1	SAE	AM 150x150x10-/+	SAE	AM 140x140x12	SAE	AM 150x150x12-/+

Table 3.23: Angle profiles for the different parts of the section 4

3.3.2.4.6 Section 5

This subsection contains annotations (see Figure 3.45 to 3.47) for the various members of the section 5, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.24).

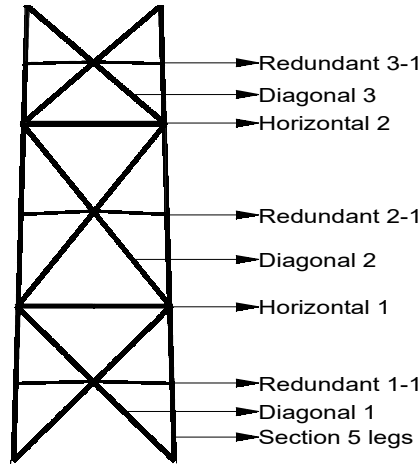


Figure 3.45: Annotations of the section 5 of the tower

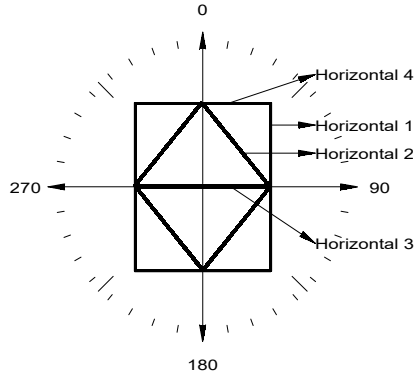


Figure 3.46: Annotations of the horizontal 1 bracing in the section 5

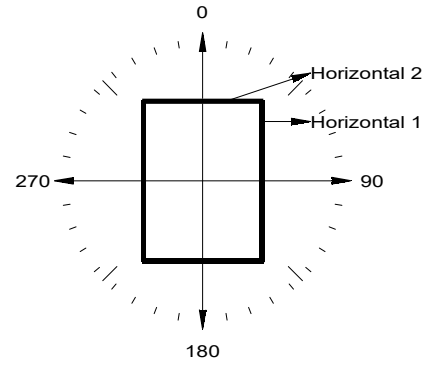


Figure 3.47: Annotations of the horizontal 2 bracing in the section 5

Group	Angle size					
	S235		S355		S460	
Section 5 legs	DAE	AM 200x200x14	DAE	AM 140x140x14	SAE	AM 200x200x16-/+
Diagonal 1	SAE	AM 200x200x14	SAE	AM 150x150x15-/+	SAE	AM 150x150x13-/+
Diagonal 2	SAE	AM 200x200x14	SAE	AM 150x150x15-/+	SAE	AM 150x150x13-/+
Diagonal 3	SAE	AM 200x200x14	SAE	AM 150x150x15-/+	SAE	AM 150x150x13-/+
Redundant 1-1	SAE	AM 75x75x4	SAE	AM 65x65x4	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 75x75x4	SAE	AM 65x65x4	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 75x75x4	SAE	AM 65x65x4	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 76x76x4,8	SAE	AM 76x76x4,8	SAE	AM 76x76x4,8
Horizontal 1-2	SAE	AM 90x90x6	SAE	AM 90x90x6	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x4	SAE	AM 75x75x4	SAE	AM 75x75x4
Horizontal 1-4	SAE	AM 150x150x10-/+	SAE	AM 130x130x9	SAE	AM 110x110x9
Horizontal 2-1	SAE	AM 110x110x6	SAE	AM 110x110x7	SAE	AM 110x110x7
Horizontal 2-2	SAE	AM 110x110x6	SAE	AM 110x110x7	SAE	AM 110x110x7

Table 3.24: Angle profiles for the different parts of the section 5

3.3.2.4.7 Top section

This subsection contains annotations (see Figure 3.48 to 3.51) for the various members of the top section, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.25).

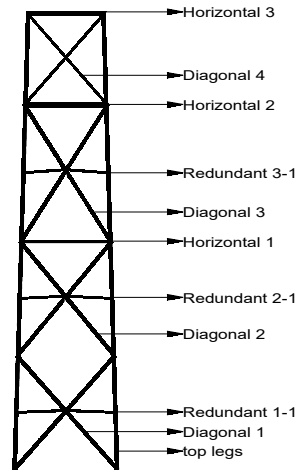


Figure 3.48: Annotations of the top of the tower

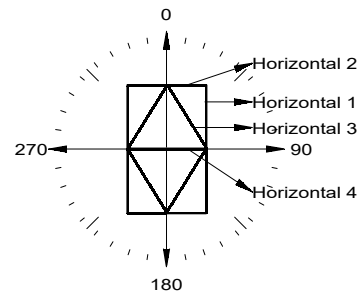


Figure 3.49: Annotations of the horizontal 1 bracing in the top section

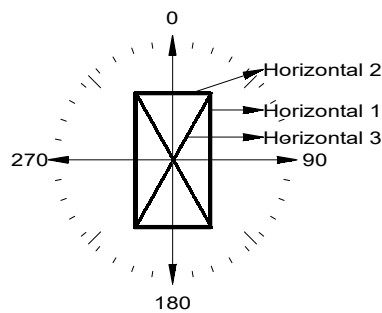


Figure 3.50: Annotations of the horizontal 2 bracing in the top section

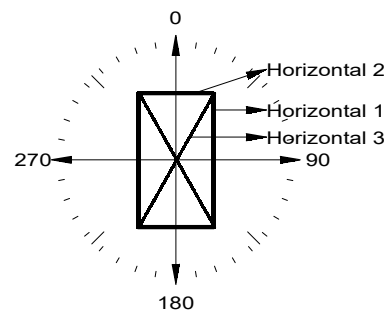


Figure 3.51: Annotations of the horizontal 3 bracing in the top section

Group	Angle size					
	S235		S355		S460	
Top legs	SAE	AM 180x180x13+	SAE	AM 140x140x12	SAE	AM 130x130x11
Diagonal 1	SAE	AM 150x150x12-/+	SAE	AM 140x140x10	SAE	AM 140x140x9
Diagonal 2	SAE	AM 150x150x12-/+	SAE	AM 140x140x10	SAE	AM 140x140x9
Diagonal 3	SAE	AM 110x110x7	SAE	AM 110x110x6	SAE	AM 100x100x6
Diagonal 4	SAE	AM 75x75x4	SAE	AM 65x65x4	SAE	AM 65x65x4
Redundant 1-1	SAE	AM 75x75x4	SAE	AM 65x65x4	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 75x75x4	SAE	AM 65x65x4	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 75x75x4	SAE	AM 65x65x4	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 75x75x6-	SAE	AM 80x80x5	SAE	AM 80x80x5
Horizontal 1-2	SAE	AM 140x140x9	SAE	AM 150x150x12-/+	SAE	AM 120x120x13
Horizontal 1-3	SAE	AM 90x90x6	SAE	AM 90x90x6	SAE	AM 90x90x6
Horizontal 1-4	SAE	AM 55x55x4	SAE	AM 55x55x4	SAE	AM 55x55x4
Horizontal 2-1	SAE	AM 90x90x5	SAE	AM 90x90x5	SAE	AM 90x90x5
Horizontal 2-2	SAE	AM 90x90x5	SAE	AM 90x90x5	SAE	AM 90x90x5
Horizontal 2-3	SAE	AM 100x100x6	SAE	AM 100x100x6	SAE	AM 100x100x6
Horizontal 3-1	SAE	AM 75x75x6-	SAE	AM 75x75x6-	SAE	AM 75x75x6-
Horizontal 3-2	SAE	AM 75x75x6-	SAE	AM 75x75x6-	SAE	AM 75x75x6-
Horizontal 3-3	SAE	AM 100x100x6	SAE	AM 100x100x6	SAE	AM 100x100x6

Table 3.25: Angle profiles for the different parts of the top section

3.3.2.4.8 Three first big cross arms

This subsection contains annotations (see Figure 3.52 and 3.53) for the various members of the three first big cross arms, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.26). These three first big cross arms are identical.

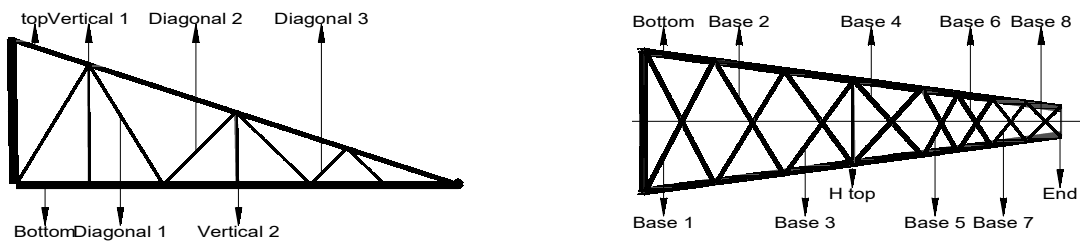


Figure 3.52: Annotations of the three first big cross arms (front and bottom view)

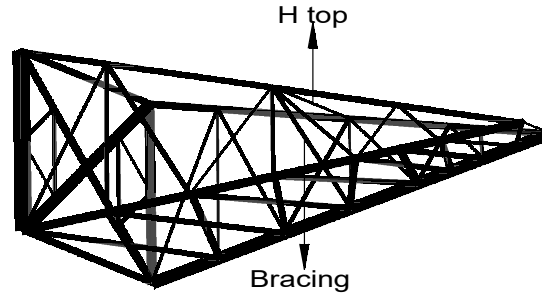


Figure 3.53: Annotations of the three first big cross arms (isometric view)

Group	Angle type	Angle size		
		S275	S355	S460
Bottom	SAE	AM 200x200x17+	AM 160x160x16-/+	AM 140x140x16
Top	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Diagonal 1	SAE	AM 60x60x4	AM 60x60x4	AM 60x60x4
Diagonal 2	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
Diagonal 3	SAE	AM 45x45x4	AM 45x45x4	AM 45x45x4
Vertical 1	SAE	AM 65x65x4	AM 65x65x4	AM 65x65x4
Vertical 2	SAE	AM 45x45x4	AM 45x45x4	AM 45x45x4
Base 1 to 6	SAE	AM 100x100x6	AM 90x90x6	AM 90x90x6
Base 7	SAE	AM 100x100x6	AM 80x80x6	AM 80x80x6
Base 8	SAE	AM 110x110x6	AM 80x80x6	AM 70x70x6-
End	SAE	AM 50x50x7	AM 45x45x5	AM 35x35x5
H top	SAE	AM 40x40x4	AM 40x40x4	AM 40x40x4
Bracing	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4

Table 3.26: Angle profiles for the different parts of the three first big cross arms

3.3.2.4.9 Three first small cross arms

This subsection contains annotations (see Figure 3.54) for the various members of the three first small cross arms, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.27). These three first small cross arms are identical.

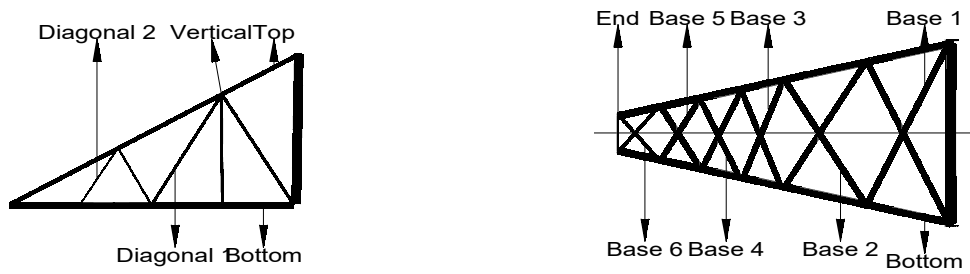


Figure 3.54: Annotations of the three first small cross arms (front and bottom view)

Group	Angle type	Angle size		
		S275	S355	S460
Bottom	SAE	AM 160x160x14+	AM 130x130x13	AM 130x130x11
Top	SAE	AM 75x75x4	AM 75x75x4	AM 75x75x4
Diagonal 1	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
Diagonal 2	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Vertical	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
Base 1 to 5	SAE	AM 100x100x6	AM 90x90x6	AM 90x90x6
Base 6	SAE	AM 70x70x9	AM 70x70x7-	AM 75x75x5
End	SAE	AM 45x45x4	AM 45x45x3	AM 35x35x4

Table 3.27: Angle profiles for the different parts of the three first small cross arms

3.3.2.4.10 Big top cross arm

This subsection contains annotations (see Figure 3.55) for the various members of the big top cross arm, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.28).

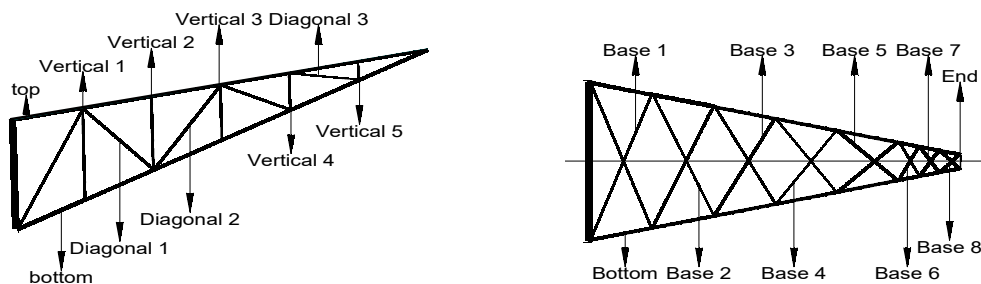


Figure 3.55: Annotations of the big top cross arm (front and bottom view)

Group	Angle type	Angle size		
		S275	S355	S460
Bottom	SAE	AM 110x110x6	AM 90x90x6	AM 75x75x7
Top	SAE	AM 60x60x4	AM 55x55x4	AM 50x50x4
Diagonal 1	SAE	AM 45x45x4	AM 45x45x4	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Diagonal 3	SAE	AM 30x30x3	AM 30x30x3	AM 30x30x3
Vertical 1 to 5	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Base 1	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Base 2	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Base 3	SAE	AM 65x65x4	AM 65x65x4	AM 65x65x4
Base 4	SAE	AM 55x55x4	AM 55x55x4	AM 55x55x4
Base 5 to 8	SAE	AM 50x50x4	AM 50x50x4	AM 50x50x4
End	SAE	AM 45x45x4	AM 45x45x3	AM 30x30x4

Table 3.28: Angle profiles for the different parts of the big top cross arm

3.3.2.4.11 Small top cross arm

This subsection contains annotations (see Figure 3.56) for the various members of the small top cross arm, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table 3.29).

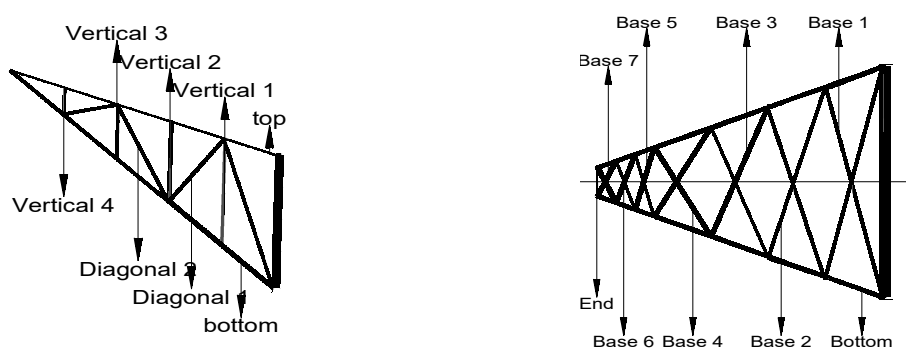


Figure 3.56: Annotations of the small top cross arm (front and bottom view)

Group	Angle type	Angle size		
		S275	S355	S460
Bottom	SAE	AM 75x75x6-	AM 70x70x5	AM 70x70x5
Top	SAE	AM 45x45x4	AM 45x45x3	AM 45x45x3
Diagonal 1	SAE	AM 45x45x4	AM 45x45x4	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Vertical 1 to 4	SAE	AM 45x45x3	AM 45x45x3	AM 45x45x3
Base 1	SAE	AM 90x90x5	AM 90x90x5	AM 90x90x5
Base 2 to 7	SAE	AM 75x75x4	AM 75x75x4	AM 75x75x4
End	SAE	AM 45x45x4	AM 45x45x3	AM 30x30x4

Table 3.29: Angle profiles for the different parts of the small top cross arm

3.3.2.5 Analysis of results

Firstly, despite the wide selection of simple equal legs angles available, some members of the S235 and S355 steel towers are used in compression at over 100%. This could indicate that there is some instability in the tower.

To avoid this instability, built-up angles as butterfly angles (type DAE angle) were used.

Contrary to this, none of the tower members made of S460 steel grade are used in compression at more than 100%, so simple angles will suffice. This is a first indication of the efficiency of S460 compared with other grades of steel. In addition, butterfly angles require more steel due to connection, labour, precision and time, which can lead to higher costs.

For example, a butterfly angle is required for the legs of section 3 of the tower, made from steel grade S235. By determining the connections required to make this butterfly angle, an initial idea of the work involved, and the costs can be observed.

As explained in section 1.2.3, in order to determine the number of connections required to ensure the correct operation of the double angle as a single section, the indications in part 6.4.4 of EN1993-1-1^[4] should be followed.

This states that for a butterfly angle, the distance between 2 connections “a” must be less than 70 times the minimum radius of gyration of the section of a single angle.

Given that the angle is L250x250x29, its minimum radius of gyration i_{min} is equal to 4.87 cm. The minimum distance between 2 connections must therefore be

340.9 cm. As the length of the leg is 7,822m, three connections are required. They must be spaced 1955,5 mm apart.

The connection plan is shown below, in Figures 3.57 to 3.59. A connection consists of 2 cleats and 8 bolts.

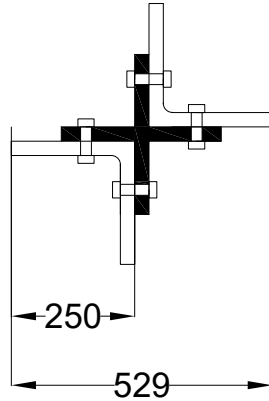


Figure 3.57: Section of the butterfly angle

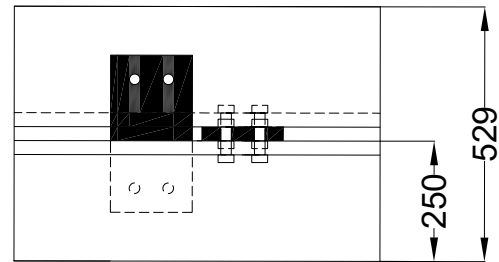


Figure 3.58: Connection of the butterfly angle

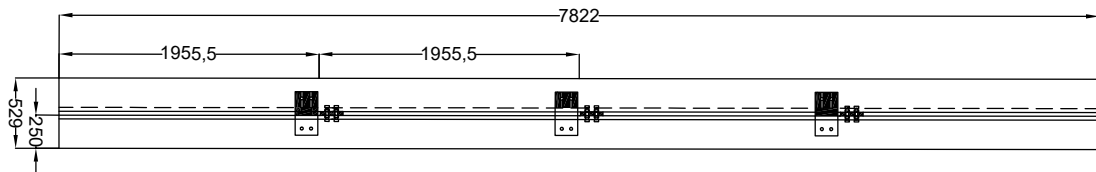


Figure 3.59: Plan view of the butterfly angle for the leg of section 3

This result is for only one leg of section 3. If we consider the 4 legs of the section, they would already need 12 connections. That's 24 cleats and 96 bolts. With this, only the butterfly angles of section 3 have been covered, whereas the tower, built with steel grade S235, requires double angles on 6 sections, from the bottom section to section 5.

It is therefore more attractive to build this tower with S460 angles only, in order to use only simple angles.

In addition to this, a reduction in the section sizes of the angles can be observed for most of them as the grade of steel increases (see angles size in bold). This reduction in size leads to a reduction in the weight of the tower and savings on

materials.

In fact, it can be seen from Table 3.30 that the weight of the tower changes considerably depending on the grade of steel used.

	Profiles weight [T]	Total weight of the tower [T]	Weight saved [T]	Weight saved [%]
S235	79,77	79,86	0	0
S355	58,75	58,84	21,02	26,3
S460	51,38	51,47	28,39	35,6

Table 3.30: Weight of the profiles, the tower and saved depending on the steel grade

By using S355 steel instead of S235 steel, 26,4% of the weight of the angles will be saved, leading to a saving of 26,3% on the total weight of the tower. Now, if S460 steel is used, 12,6% of the angle weight will be saved compared to the tower built with S355 steel angle, resulting in a further reduction of 12,5% in the total weight of the tower.

If a comparison is made with the use of S235 steel, a total saving of 35,6% on the weight of the angles and of 35,5% on the total weight of the tower can be made by using S460 steel.

The fact that the big angle profiles are not available in S235 shows the need to use higher steel grades, preferably S460, for the new tower typologies to bear the high voltage lines.

However, some angles, such as most of those used for horizontal bracing, retain the same dimensions whether they are made from one steel grade or another. This shows us that using S460 angles is not always necessary.

It can also be seen noticed that by increasing the steel grade from S355 to S460, some horizontal bracing profile increase in size. At a first glance this seems contradictory, but it should be considered that by decreasing for instance the sections of the leg profiles lead to higher secondary forces to be taken by the secondary bracing elements. In consequence, the size of the horizontal bracing could increase with increasing steel grades. However, the total weight of the tower structure using S460 is significantly reduced compared to a tower in S355.

This significant reduction in material, as well as the avoidance of built-up angles, leads us to conclude that the use of S460 steel grade angles would result in considerable budget savings.

As with the suspension tower, an initial cost study can be carried out, taking into account the price of different grades of steel per tonne.

Steel grade	Price per weight [€/T]	Steel tower weight [T]	Total price [€]
S235	900	79,77	71 793
S355	950	58,75	55 812,5
S460	1 000	51,38	51 380

Table 3.31: Costs per tower for steel

These costs only represent the cost of the angle steel. If the cost of labour and the price of connections were taken into account, there would be a substantial additional saving on costs by doing away with the butterfly connectors.

However, the fact that some angles do not change dimensions despite being made of S460 steel shows that it may still be more economical to use S460 steel for the main load-bearing elements (e.g. leg profiles) and S355 or S235 steel for the horizontal or cross-arm elements.

3.4 Combination of steel grades for the dead-end tower

As demonstrated in the previous study, there is considerable interest in exploring different grades of steel for tower angles. An analysis of various combinations will be undertaken in this section. Initially, modelling involving S460 and S235 alloy steel will be carried out. This will be followed by modelling using S460 steel in conjunction with S355. Finally, modelling will be carried out using a combination of the three steel grades. Following these stages, a comparative assessment of the different scenarios will be carried out, paving the way for constructive discussions to determine the optimum solution.

3.4.1 Combination of steel S460 and S235

3.4.1.1 Methodology

The architectural configuration and cross-sectional dimensions of the angles will remain unchanged from the previous study of the dead-end tower optimised using S460 steel. Subsequently, we plan to change the grade of all the angles to S235 steel and then run an EN50341 compliant analysis similar to the previous case.

Once the software has completed its analysis of the tower, it will provide data on the maximum percentage of use in compression or tension for each angle. All angles with a utilisation rate of less than 100% could be made of S235 steel. However,

those with a percentage of use above this threshold will have to be designed using S460 steel, as this choice is necessary to guarantee the optimum structural stability of the tower.

3.4.1.2 Results of the linear analysis

Following this, a determination of the steel grade for each angle was carried out. The results are shown in Tables 3.32 to 3.42 below. The groups refer to the annotations in the previous section (see Figures 3.34 to 3.55).

Group	Steel grade
Bottom legs	S460
Diagonal	S460
Redundant 1	S460
Redundant 2	S460
Redundant 3	S460
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.32: Steel grade of bottom section angles

Group	Steel grade
Section 1 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Redundant 1-1	S460
Redundant 1-2	S460
Redundant 1-3	S460
Redundant 2-1	S460
Redundant 2-2	S460
Redundant 2-3	S460
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.33: Steel grade of section 1 angles

Group	Steel grade
Section 2 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Redundant 1-1	S460
Redundant 1-2	S460
Redundant 1-3	S460
Redundant 2-1	S460
Redundant 2-2	S460
Redundant 2-3	S460
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.34: Steel grade of section 2 angles

Group	Steel grade
Section 3 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S460
Redundant 1-2	S460
Redundant 1-3	S460
Redundant 2-1	S460
Redundant 3-1	S460
Redundant 3-2	S460
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.35: Steel grade of section 3 angles

Group	Steel grade
Section 4 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S460
Redundant 1-2	S460
Redundant 2-1	S460
Redundant 3-1	S460
Horizontal 1-1	S460
Horizontal 1-2	S460
Horizontal 1-3	S235
Horizontal 2-1	S460

Table 3.36: Steel grade of section 4 angles

Group	Steel grade
Section 5 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S235
Redundant 2-1	S235
Redundant 3-1	S235
Horizontal 1-1	S460
Horizontal 1-2	S460
Horizontal 1-3	S235
Horizontal 1-4	S460
Horizontal 2-1	S460
Horizontal 2-2	S460

Table 3.37: Steel grade of section 5 angles

Group	Steel grade
Top legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Diagonal 4	S460
Redundant 1-1	S235
Redundant 2-1	S235
Redundant 3-1	S235
Horizontal 1-1	S460
Horizontal 1-2	S460
Horizontal 1-3	S460
Horizontal 1-4	S235
Horizontal 2-1	S235
Horizontal 2-2	S235
Horizontal 2-3	S235
Horizontal 3-1	S235
Horizontal 3-2	S235
Horizontal 3-3	S235

Table 3.38: Steel grade of top section angles

Group	Steel grade
Bottom	S460
Top	S235
Diagonal 1	S235
Diagonal 2	S235
Diagonal 3	S235
Vertical 1	S235
Vertical 2	S235
Base 1 to 6	S460
Base 7	S460
Base 8	S460
End	S460
H top	S235
Bracing	S235

Table 3.39: Steel grade of the three first big cross arms angles

Group	Steel grade
Bottom	S460
Top	S460
Diagonal 1	S235
Diagonal 2	S235
Diagonal 3	S235
Vertical 1 to 5	S235
Base 1	S235
Base 2	S235
Base 3	S235
Base 4	S235
Base 5 to 8	S235
End	S460

Table 3.41: Steel grade of the big top cross arm angles

Group	Steel grade
Bottom	S460
Top	S235
Diagonal 1	S235
Diagonal 2	S235
Vertical	S235
Base 1 to 5	S460
Base 6	S460
End	S460

Table 3.40: Steel grade of the three first small cross arms angles

Group	Steel grade
Bottom	S460
Top	S235
Diagonal 1	S235
Diagonal 2	S235
Vertical 1 to 4	S235
Base 1	S235
Base 2 to 7	S235
End	S460

Table 3.42: Steel grade of the small top cross arm angles

When the tower is made of S460 and S235 steel, the dominant load case is D, G favourable, I unfavourable. That is, the wind is in the direction of the cross arms and is combined with ice. The dominant loads are therefore wind and ice combined.

The distribution of S460 and S235 angle steels in the tower can be seen in Figure 3.60. S460 grade angles are shown in green, while S235 grade angles are shown in pink.

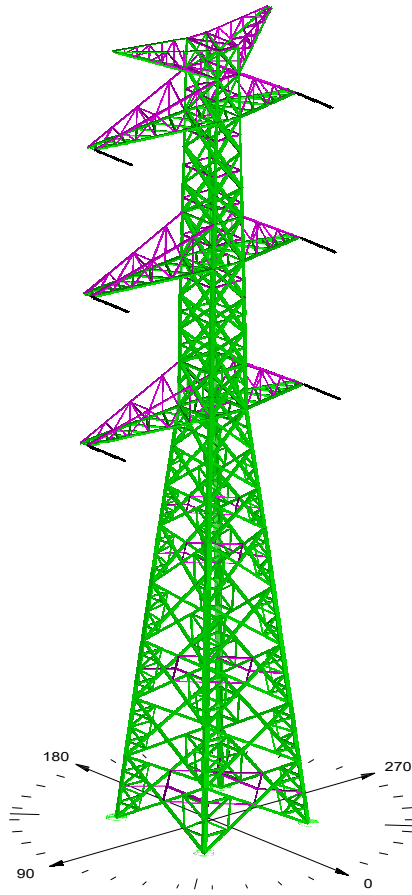


Figure 3.60: Distribution of steel grade S460 and S235 in the tower

Thanks to the TOWER software, the weight of the S235 and S460 angles can be extracted. As for the 2 previous cases, a cost study can therefore be carried out. The results obtained are shown in Table 3.43.

Steel grade	Price per weight [€/T]	Steel weight in the tower [T]	Price [€]
S235	900	3,05	2 745
S460	1 000	48,33	48 330
S235 + S460		51,38	51 075

Table 3.43: Cost of steel for the tower

The total cost of steel for the tower angles, using steel grades S460 and S235, is therefore €51 075.

3.4.2 Combination of steel S460 and S355

3.4.2.1 Methodology

As before, the architectural configuration and cross-sectional dimensions of the angles will remain unchanged from the previous study of the dead-end tower optimised using S460 steel. This time, the grade of all the angle bars will be replaced by the S355 steel grade, and then the analysis for a dead-end tower will be carried out in accordance with standard EN50341.

Again as before, once the software has completed its analysis of the tower, it will provide data on the maximum percentage of use in compression or tension for each angle. This will tell us what grade of steel is needed for each angle to maintain the tower's stability.

3.4.2.2 Results of the linear analysis

Following this, a determination of the steel grade for each angle was carried out. The results are shown in Tables 3.44 to 3.54 below.

When the tower is made of S460 and S355 steel, the dominant load case is D, G favourable, I unfavourable. That is, the wind is in the direction of the cross arms and is combined with ice. The dominant loads are therefore wind and ice combined.

Group	Steel grade
Bottom legs	S460
Diagonal	S355
Redundant 1	S355
Redundant 2	S355
Redundant 3	S355
Horizontal 1	S355
Horizontal 2	S355
Horizontal 3	S355

Table 3.44: Steel grade of bottom section angles

Group	Steel grade
Section 1 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Redundant 1-1	S355
Redundant 1-2	S355
Redundant 1-3	S355
Redundant 2-1	S460
Redundant 2-2	S355
Redundant 2-3	S355
Horizontal 1	S355
Horizontal 2	S355
Horizontal 3	S355

Table 3.45: Steel grade of section 1 angles

Group	Steel grade
Section 2 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Redundant 1-1	S460
Redundant 1-2	S355
Redundant 1-3	S460
Redundant 2-1	S355
Redundant 2-2	S355
Redundant 2-3	S460
Horizontal 1	S355
Horizontal 2	S355
Horizontal 3	S355

Table 3.46: Steel grade of section 2 angles

Group	Steel grade
Section 3 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S460
Redundant 1-2	S355
Redundant 1-3	S460
Redundant 2-1	S460
Redundant 3-1	S460
Redundant 3-2	S355
Horizontal 1	S355
Horizontal 2	S355
Horizontal 3	S355

Table 3.47: Steel grade of section 3 angles

Group	Steel grade
Section 4 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S460
Redundant 1-2	S460
Redundant 2-1	S460
Redundant 3-1	S460
Horizontal 1-1	S460
Horizontal 1-2	S460
Horizontal 1-3	S355
Horizontal 2-1	S460

Table 3.48: Steel grade of section 4 angles

Group	Steel grade
Section 5 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S355
Redundant 2-1	S355
Redundant 3-1	S355
Horizontal 1-1	S460
Horizontal 1-2	S355
Horizontal 1-3	S355
Horizontal 1-4	S460
Horizontal 2-1	S355
Horizontal 2-2	S355

Table 3.49: Steel grade of section 5 angles

Group	Steel grade
Top legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S355
Diagonal 4	S355
Redundant 1-1	S355
Redundant 2-1	S355
Redundant 3-1	S355
Horizontal 1-1	S355
Horizontal 1-2	S460
Horizontal 1-3	S355
Horizontal 1-4	S355
Horizontal 2-1	S355
Horizontal 2-2	S355
Horizontal 2-3	S355
Horizontal 3-1	S355
Horizontal 3-2	S355
Horizontal 3-3	S355

Table 3.50: Steel grade of top section angles

Group	Steel grade
Bottom	S460
Top	S355
Diagonal 1	S355
Diagonal 2	S355
Diagonal 3	S355
Vertical 1	S355
Vertical 2	S355
Base 1 to 6	S355
Base 7	S460
Base 8	S460
End	S460
H top	S355
Bracing	S355

Table 3.51: Steel grade of the three first big cross arms angles

Group	Steel grade
Bottom	S460
Top	S355
Diagonal 1	S355
Diagonal 2	S355
Vertical	S355
Base 1 to 5	S355
Base 6	S460
End	S460

Table 3.52: Steel grade of the three first small cross arms angles

Group	Steel grade
Bottom	S460
Top	S355
Diagonal 1	S355
Diagonal 2	S355
Diagonal 3	S355
Vertical 1 to 5	S355
Base 1	S355
Base 2	S355
Base 3	S355
Base 4	S355
Base 5 to 8	S355
End	S460

Table 3.53: Steel grade of the big top cross arm angles

Group	Steel grade
Bottom	S355
Top	S355
Diagonal 1	S355
Diagonal 2	S355
Vertical 1 to 4	S355
Base 1	S355
Base 2 to 7	S355
End	S460

Table 3.54: Steel grade of the small top cross arm angles

The distribution of S460 and S355 angle steels in the tower can be seen in Figure 3.61 where S460 grade angles are shown in green and S355 grade angles are shown in blue.

Thanks to the TOWER software, the weight of the S355 and S460 angles can be extracted, and a cost study can therefore be carried out. The results obtained are shown in Table 3.55.

Steel grade	Price per weight [€/T]	Steel weight in the tower [T]	Price [€]
S355	950	9,35	8 882,5
S460	1 000	42,03	42 030
S355 + S460		51,38	50 912,5

Table 3.55: Cost of steel for the tower

The total cost of steel for the tower angles, using steel grades S460 and S355, is therefore €50 912,5.

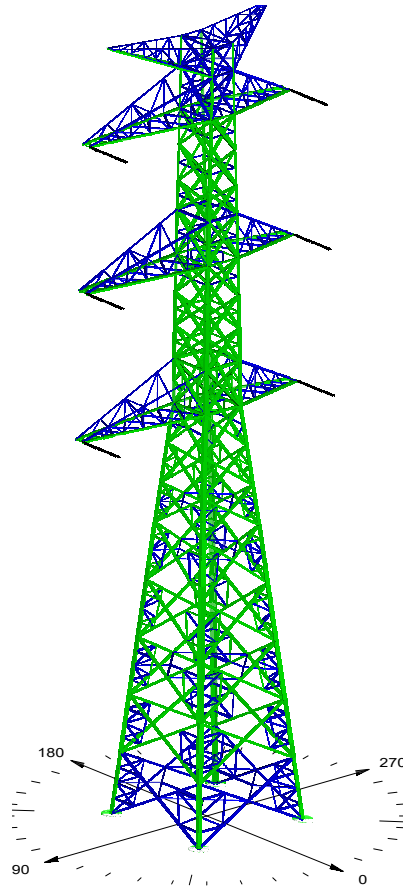


Figure 3.61: Distribution of steel grade S460 and S355 in the tower

3.4.3 Combination of steel S460, S355 and S235

3.4.3.1 Methodology

the architectural configuration and cross-sectional dimensions of the angles will remain unchanged compared to the study of the dead-end tower optimised using S460 steel. This time, we will start from the tower made using steel grades S460 and S235, and we will replace the steel grade of all the angles in S460 with steel grade S355. With this distribution, the analysis for the dead-end tower in accordance with standard EN50341, still identical to the previous one, will be launched.

Again as before, once the software has completed its analysis of the tower, it will provide data on the maximum percentage of use in compression or tension for each angle. This will tell us what grade of steel is needed for each angle to maintain the tower's stability.

3.4.3.2 Results of the linear analysis

Following this, a determination of the steel grade for each angle was carried out. The results are shown in Tables 3.56 to 3.66 below.

When the tower is made of S460, S355 and S235 steel, the dominant load case is always D, G favourable, I unfavourable. That is, the wind is in the direction of the cross arms and is combined with ice. The dominant loads are therefore wind and ice combined.

Group	Steel grade
Bottom legs	S460
Diagonal	S355
Redundant 1	S355
Redundant 2	S355
Redundant 3	S355
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.56: Steel grade of bottom section angles

Group	Steel grade
Section 1 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Redundant 1-1	S355
Redundant 1-2	S355
Redundant 1-3	S355
Redundant 2-1	S460
Redundant 2-2	S355
Redundant 2-3	S355
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.57: Steel grade of section 1 angles

Group	Steel grade
Section 2 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Redundant 1-1	S460
Redundant 1-2	S355
Redundant 1-3	S460
Redundant 2-1	S355
Redundant 2-2	S355
Redundant 2-3	S460
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.58: Steel grade of section 2 angles

Group	Steel grade
Section 3 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S460
Redundant 1-2	S355
Redundant 1-3	S460
Redundant 2-1	S460
Redundant 3-1	S460
Redundant 3-2	S355
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.59: Steel grade of section 3 angles

Group	Steel grade
Section 4 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S460
Redundant 1-2	S460
Redundant 2-1	S460
Redundant 3-1	S460
Horizontal 1-1	S460
Horizontal 1-2	S460
Horizontal 1-3	S235
Horizontal 2-1	S460

Table 3.60: Steel grade of section 4 angles

Group	Steel grade
Section 5 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S235
Redundant 2-1	S235
Redundant 3-1	S235
Horizontal 1-1	S460
Horizontal 1-2	S355
Horizontal 1-3	S235
Horizontal 1-4	S460
Horizontal 2-1	S355
Horizontal 2-2	S355

Table 3.61: Steel grade of section 5 angles

Group	Steel grade
Top legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S355
Diagonal 4	S355
Redundant 1-1	S235
Redundant 2-1	S235
Redundant 3-1	S235
Horizontal 1-1	S355
Horizontal 1-2	S460
Horizontal 1-3	S355
Horizontal 1-4	S235
Horizontal 2-1	S235
Horizontal 2-2	S235
Horizontal 2-3	S235
Horizontal 3-1	S235
Horizontal 3-2	S235
Horizontal 3-3	S235

Table 3.62: Steel grade of top section angles

Group	Steel grade
Bottom	S460
Top	S235
Diagonal 1	S235
Diagonal 2	S235
Diagonal 3	S235
Vertical 1	S235
Vertical 2	S235
Base 1 to 6	S355
Base 7	S460
Base 8	S460
End	S460
H top	S235
Bracing	S235

Table 3.63: Steel grade of the three first big cross arms angles

Group	Steel grade
Bottom	S460
Top	S235
Diagonal 1	S235
Diagonal 2	S235
Vertical	S235
Base 1 to 5	S355
Base 6	S460
End	S460

Table 3.64: Steel grade of the three first small cross arms angles

Group	Steel grade
Bottom	S460
Top	S355
Diagonal 1	S235
Diagonal 2	S235
Diagonal 3	S235
Vertical 1 to 5	S235
Base 1	S235
Base 2	S235
Base 3	S235
Base 4	S235
Base 5 to 8	S235
End	S460

Table 3.65: Steel grade of the big top cross arm angles

Group	Steel grade
Bottom	S355
Top	S235
Diagonal 1	S235
Diagonal 2	S235
Vertical 1 to 4	S355
Base 1	S235
Base 2 to 7	S235
End	S460

Table 3.66: Steel grade of the small top cross arm angles

The distribution of the 3 steel grades in the tower is shown in Figure 3.62 where grade S460 angles are shown in green, grade S355 angles are shown in blue and grade S235 angles are shown in pink.

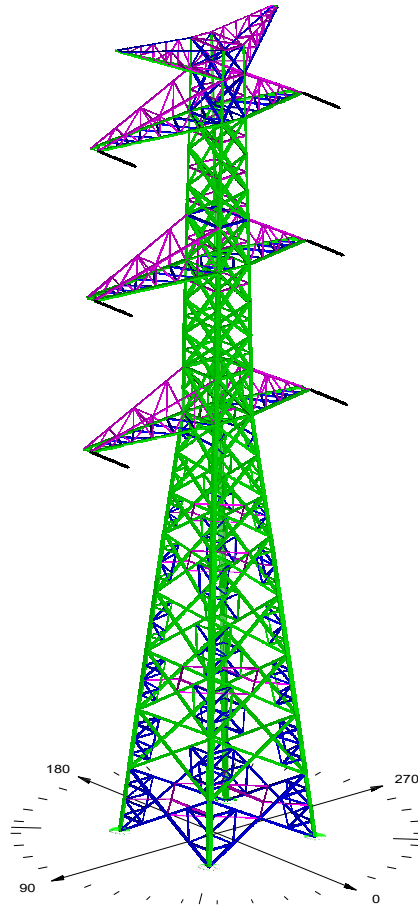


Figure 3.62: Distribution of steel grade S460, S355 and S235 in the tower

Thanks to the TOWER software, the weight of the S235, S355 and S460 angles can be extracted, and a cost study can therefore be carried out. The results obtained are shown in Table 3.67.

Steel grade	Price per weight [€/T]	Steel weight in the tower [T]	Price [€]
S235	900	3,05	2 745
S355	950	6,30	5 985
S460	1 000	42,03	42 030
S235 + S355 + S460		51,38	50 760

Table 3.67: Cost of steel for the tower

The total cost of steel for the tower angles, using steel grades S460, S355 and S235, is therefore €50 760.

3.4.4 Analysis of the results

The different price results per round can be seen in the Table 3.68 below.

Mixing type	Tower steel price [€]	Cost saving [€]
S460	51 380	0
S460 + S235	51 075	305
S460 + S355	50 912,5	467,5
S460 + S355 + S235	50 760	620

Table 3.68: Tower steel prices depending on the mix of steel grades

In all cases, by mixing different grades of steel, cost savings can be achieved. In fact, by mixing S460 and S35 steel grades, a saving of €305 can be made. Now, if we mix the S460 and S355 steel grades, we save €467,5. Finally, if we mix the three different steel grades, a saving of €620 can be made. These savings represent the savings per tower. Bear in mind that a transmission line is made up of a hundred or so towers, so the winnings should be multiplied accordingly.

In this sense, the most interesting case for optimising costs is to use the 3 different grades of steel in the towers. However, it is important to bear in mind the work on site. In fact, by using different types of steel, the work for the workers will become more complicated and errors may occur, with repair costs higher than the gains made on the steel mix.

From this perspective, it can be deduced that the use of various grades of steel is optimised from a numerical point of view. However, it should be noted that in practice, the implementation of this approach may not be of particular interest due to the complexities encountered on site.

3.5 Embedded tower

For the time being, throughout the analyses, it has been assumed that all the nodes of the tower are hinged and therefore the moment in the nodes is zero. In this section, the effect that the embedding of all the nodes could have, and therefore the effect of the appearance of moment in the nodes, will be observed.

3.5.1 Results of the linear analysis in TOWER software

After modifying the properties of the nodes and fixing them in an embedded position, we carried out a linear analysis in accordance with standard EN50341,

following the same protocol as that used for the study of the initial dead-end tower.

The results obtained using the TOWER software are compiled and presented in the Tables 3.69 to 3.79 below, classified by section of the tower. In these tables, it is also possible to find the results obtained during the analysis of the tower at the hinged joints, so that a comparison can be made.

When the tower has embedded nodes, the dominant load case is F, G favourable, I unfavourable. That is, the wind is at 45° to the cross arms and is combined with ice. The dominant loads are always therefore wind and ice combined.

Group	Angle type	Angle size	
		Hinged nodes	Embedded nodes
Bottom legs	SAE	AM 250x250x34	AM 200x200x20-/+
Diagonal	SAE	AM 120x120x8	AM 130x130x8
Redundant 1	SAE	AM 70x70x5	AM 60x60x4
Redundant 2	SAE	AM 90x90x5	AM 60x60x4
Redundant 3	SAE	AM 100x100x6	AM 70x70x5
Horizontal 1	SAE	AM 70x70x5	AM 70x70x5
Horizontal 2	SAE	AM 70x70x5	AM 70x70x5
Horizontal 3	SAE	AM 90x90x5	AM 90x90x5

Table 3.69: Angle profiles for the different parts of the bottom section

Group	Angle type	Angle size	
		Hinged nodes	Embedded nodes
Section 1 legs	SAE	AM 300x300x27	AM 180x180x20+
Diagonal 1	SAE	AM 130x130x8	AM 130x130x8
Diagonal 2	SAE	AM 130x130x8	AM 130x130x8
Redundant 1-1	SAE	AM 70x70x5	AM 60x60x4
Redundant 1-2	SAE	AM 90x90x5	AM 60x60x4
Redundant 1-3	SAE	AM 100x100x6	AM 70x70x5
Redundant 2-1	SAE	AM 76x76x4,8	AM 60x60x4
Redundant 2-2	SAE	AM 80x80x5	AM 50x50x4
Redundant 2-3	SAE	AM 90x90x6	AM 60x60x4
Horizontal 1	SAE	AM 65x65x4	AM 65x65x4
Horizontal 2	SAE	AM 65x65x4	AM 65x65x4
Horizontal 3	SAE	AM 70x70x5	AM 70x70x5

Table 3.70: Angle profiles for the different parts of the section 1

Group	Angle type	Angle size	
		Hinged nodes	Embedded nodes
Section 2 legs	SAE	AM 300x300x26	AM 180x180x16-/+
Diagonal 1	SAE	AM 130x130x9	AM 110x110x8
Diagonal 2	SAE	AM 130x130x9	AM 110x110x8
Redundant 1-1	SAE	AM 75x75x6-	AM 65x65x4
Redundant 1-2	SAE	AM 75x75x5	AM 50x50x4
Redundant 1-3	SAE	AM 80x80x6	AM 60x60x4
Redundant 2-1	SAE	AM 90x90x6	AM 65x65x4
Redundant 2-2	SAE	AM 70x70x5	AM 45x45x4
Redundant 2-3	SAE	AM 75x75x7	AM 55x55x4
Horizontal 1	SAE	AM 50x50x4	AM 50x50x4
Horizontal 2	SAE	AM 45x45x5	AM 45x45x5
Horizontal 3	SAE	AM 60x60x4	AM 60x60x4

Table 3.71: Angle profiles for the different parts of the section 2

Group	Angle type	Angle size	
		Hinged nodes	Embedded nodes
Section 3 legs	SAE	AM 250x250x30	AM 180x180x15+
Diagonal 1	SAE	AM 130x130x9	AM 100x100x7
Diagonal 2	SAE	AM 130x130x9	AM 100x100x7
Diagonal 3	SAE	AM 140x140x11	AM 110x110x7
Redundant 1-1	SAE	AM 75x75x4	AM 50x50x4
Redundant 1-2	SAE	AM 60x60x5	AM 45x45x3
Redundant 1-3	SAE	AM 80x80x5	AM 45x45x4
Redundant 2-1	SAE	AM 70x70x5	AM 45x45x4
Redundant 2-2	SAE	AM 70x70x5	AM 45x45x4
Redundant 3-1	SAE	AM 75x75x4	AM 45x45x3
Redundant 3-2	SAE	AM 65x65x4	AM 45x45x3
Horizontal 1	SAE	AM 45x45x3	AM 45x45x3
Horizontal 2	SAE	AM 45x45x3	AM 45x45x3
Horizontal 3	SAE	AM 50x50x4	AM 50x50x4

Table 3.72: Angle profiles for the different parts of the section 3

Group	Angle type	Angle size	
		Hinged nodes	Embedded nodes
Section 4 legs	SAE	AM 250x250x22	AM 140x140x13
Diagonal 1	SAE	AM 160x160x16-/+	AM 130x130x8
Diagonal 2	SAE	AM 150x150x12-/+	AM 110x110x7
Diagonal 3	SAE	AM 150x150x12-/+	AM 110x110x7
Redundant 1-1	SAE	AM 65x65x4	AM 60x60x5
Redundant 1-2	SAE	AM 65x65x4	AM 60x60x5
Redundant 2-1	SAE	AM 75x75x5	AM 45x45x3
Redundant 3-1	SAE	AM 75x75x5	AM 45x45x3
Horizontal 1-1	SAE	AM 90x90x6	AM 110x110x7
Horizontal 1-2	SAE	AM 120x120x10-	AM 65x65x4
Horizontal 1-3	SAE	AM 75x75x5	AM 75x75x5
Horizontal 2-1	SAE	AM 150x150x12-/+	AM 90x90x5

Table 3.73: Angle profiles for the different parts of the section 4

Group	Angle type	Angle size	
		Hinged nodes	Embedded nodes
Section 5 legs	SAE	AM 200x200x16-/+	AM 100x100x8*/-
Diagonal 1	SAE	AM 150x150x13-/+	AM 120x120x10-
Diagonal 2	SAE	AM 150x150x13-/+	AM 120x120x10-
Diagonal 3	SAE	AM 150x150x13-/+	AM 120x120x10-
Redundant 1-1	SAE	AM 65x65x4	AM 45x45x3
Redundant 2-1	SAE	AM 65x65x4	AM 45x45x3
Redundant 3-1	SAE	AM 65x65x4	AM 45x45x3
Horizontal 1-1	SAE	AM 76x76x4,8	AM 45x45x3
Horizontal 1-2	SAE	AM 90x90x6	AM 60x60x4
Horizontal 1-3	SAE	AM 75x75x4	AM 75x75x4
Horizontal 1-4	SAE	AM 110x110x9	AM 100x100x7
Horizontal 2-1	SAE	AM 110x110x7	AM 90x90x5
Horizontal 2-2	SAE	AM 110x110x7	AM 90x90x5

Table 3.74: Angle profiles for the different parts of the section 5

Group	Angle type	Angle size	
		Hinged nodes	Embedded nodes
Top legs	SAE	AM 130x130x11	AM 90x90x5
Diagonal 1	SAE	AM 140x140x9	AM 110x110x7
Diagonal 2	SAE	AM 140x140x9	AM 110x110x7
Diagonal 3	SAE	AM 100x100x6	AM 90x90x5
Diagonal 4	SAE	AM 65x65x4	AM 65x65x4
Redundant 1-1	SAE	AM 65x65x4	AM 45x45x3
Redundant 2-1	SAE	AM 65x65x4	AM 45x45x3
Redundant 3-1	SAE	AM 65x65x4	AM 45x45x3
Horizontal 1-1	SAE	AM 80x80x5	AM 45x45x3
Horizontal 1-2	SAE	AM 120x120x13	AM 100x100x9
Horizontal 1-3	SAE	AM 90x90x6	AM 60x60x4
Horizontal 1-4	SAE	AM 55x55x4	AM 55x55x4
Horizontal 2-1	SAE	AM 90x90x5	AM 110x110x6
Horizontal 2-2	SAE	AM 90x90x5	AM 110x110x6
Horizontal 2-3	SAE	AM 100x100x6	AM 100x100x6
Horizontal 3-1	SAE	AM 75x75x6-	AM 75x75x6-
Horizontal 3-2	SAE	AM 75x75x6-	AM 75x75x6-
Horizontal 3-3	SAE	AM 100x100x6	AM 100x100x6

Table 3.75: Angle profiles for the different parts of the top section

Group	Angle type	Angle size	
		Hinged nodes	Embedded nodes
Bottom	SAE	AM 140x140x16	AM 120x120x10-
Top	SAE	AM 90x90x5	AM 130x130x8
Diagonal 1	SAE	AM 60x60x4	AM 100x100x6
Diagonal 2	SAE	AM 50x50x4	AM 90x90x6
Diagonal 3	SAE	AM 45x45x4	AM 50x50x4
Vertical 1	SAE	AM 65x65x4	AM 50x50x4
Vertical 2	SAE	AM 45x45x4	AM 50x50x4
Base 1 to 6	SAE	AM 90x90x6	AM 110x110x6
Base 7	SAE	AM 80x80x6	AM 65x65x4
Base 8	SAE	AM 70x70x6-	AM 50x50x4
End	SAE	AM 35x35x5	AM 45x45x4
H top	SAE	AM 40x40x4	AM 40x40x4
Bracing	SAE	AM 50x50x4	AM 50x50x4

Table 3.76: Angle profiles for the different parts of the three first big cross arms

Group	Angle type	Angle size	
		Hinged nodes	Embedded nodes
Bottom	SAE	AM 130x130x11	AM 120x120x10-
Top	SAE	AM 75x75x4	AM 110x110x6
Diagonal 1	SAE	AM 50x50x4	AM 110x110x6
Diagonal 2	SAE	AM 45x45x3	AM 60x60x5
Vertical	SAE	AM 50x50x4	AM 110x110x6
Base 1 to 5	SAE	AM 90x90x6	AM 100x100x6
Base 6	SAE	AM 75x75x5	AM 60x60x5
End	SAE	AM 35x35x4	AM 45x45x4

Table 3.77: Angle profiles for the different parts of the three first small cross arms

Group	Angle type	Angle size	
		Hinged nodes	Embedded nodes
Bottom	SAE	AM 75x75x7	AM 60x60x4
Top	SAE	AM 50x50x4	AM 65x65x4
Diagonal 1	SAE	AM 45x45x4	AM 60x60x4
Diagonal 2	SAE	AM 45x45x3	AM 50x50x4
Diagonal 3	SAE	AM 30x30x3	AM 50x50x4
Vertical 1 to 5	SAE	AM 45x45x3	AM 50x50x4
Base 1	SAE	AM 90x90x5	AM 90x90x5
Base 2	SAE	AM 90x90x5	AM 90x90x5
Base 3	SAE	AM 65x65x4	AM 65x65x4
Base 4	SAE	AM 55x55x4	AM 55x55x4
Base 5 to 8	SAE	AM 50x50x4	AM 60x60x4
End	SAE	AM 30x30x4	AM 25x25x3

Table 3.78: Angle profiles for the different parts of the big top cross arm

Group	Angle type	Angle size	
		Hinged nodes	Embedded nodes
Bottom	SAE	AM 70x70x5	AM 40x40x4
Top	SAE	AM 45x45x3	AM 50x50x4
Diagonal 1	SAE	AM 45x45x4	AM 75x75x4
Diagonal 2	SAE	AM 45x45x3	AM 65x65x4
Vertical 1 to 4	SAE	AM 45x45x3	AM 65x65x4
Base 1	SAE	AM 90x90x5	AM 90x90x5
Base 2 to 7	SAE	AM 75x75x4	AM 75x75x4
End	SAE	AM 30x30x4	AM 25x25x3

Table 3.79: Angle profiles for the different parts of the small top cross arm

In Appendix B, it is also possible to observe the internal moment at the nodes of all the elements and it is possible to see that the moments at the nodes are non-zero.

3.5.2 Analysis of the results

Firstly, it is remarkable to note that the majority of the tower's cross-sections are reduced when all the structure's nodes are embedded (see angles size in bold). This optimisation of the angle sections leads to a significant reduction in the materials used and, consequently, in costs. In fact, the total weight of the tower is considerably reduced. The variations in weight depending on the type of node can be seen in the Table 3.80 below.

	Profiles weight [T]	Total weight of the tower [T]	Weight saved [T]	Weight saved [%]
With hinged nodes	51,38	51,47	0	0
With embedded nodes	31,07	31,16	20,31	39,46

Table 3.80: Weight of the profiles, the tower and saved depending on the type of node

By completely embedding the tower, a weight reduction of 39,5% on the weight of the angles and a weight reduction of 39,4% on the total weight of the tower can be achieved.

Considering the price of S460 steel at €1000 per tonne, a cost study can also be carried out in order to realise the importance of this reduction in materials. The results can be seen in the Table 3.81 below.

Steel grade	Price per weight [€/tonne]	Tower steel weight [tonnes]	Total price [€]
With hinged nodes	1000	51,38	51 380
With embedded nodes	1000	31,07	31 070

Table 3.81: Costs per tower for steel

By embedding the nodes in the tower, we could save €20 310 on the price of the tower with ball-jointed nodes. Despite this impressive saving, it is essential to consider the costs of the connections and their feasibility. In fact, only 1 or even 2 bolts per connection are needed to install hinged connections, whereas for embedded connections, the connection has to withstand moments and must therefore be more complex and substantial.

3.5.3 Calculation of a connection

To better understand the extent of the connections, an example calculation should be carried out for a diagonal connection, to assess the feasibility of embedding the tower.

The calculation will be carried out on the connection of diagonal 3 of section 3 on the leg (see Figure 3.63). The cross-section of this angle is 110x110x7.

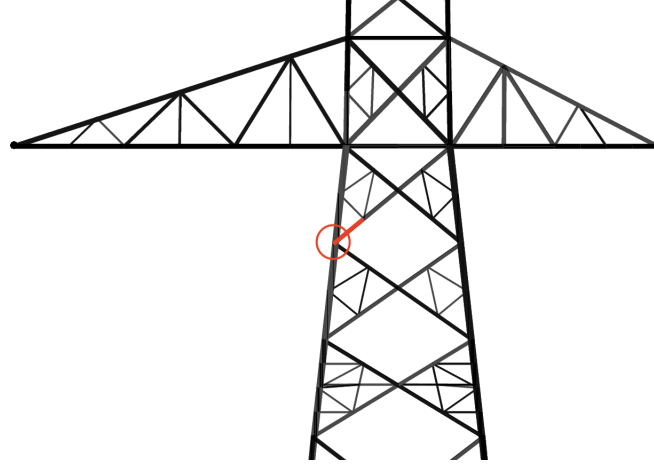


Figure 3.63: Position of the connection studied

3.5.3.1 Bolts resistance

The first step is to determine the maximum force that the bolts can withstand. This involves determining the shear and rolling resistance. These should be determined in accordance with Table 3.4 of EN 1993-1-8:2005^[9].

Shear resistance is determined using the formula (3.1)

$$F_{v,Rd} = \frac{\alpha_v f_{ub} A}{\gamma_{M2}} \quad (3.1)$$

Where α_v depends on the type of the bolt, f_{ub} is the tensile strength of the bolt, A is the shank section of the bolt and γ_{M2} is a partial factor.

Bearing resistance is determined using the formula (3.2)

$$F_{b,Rd} = \frac{k_1 \alpha_b f_u d t}{\gamma_{M2}} \quad (3.2)$$

Where α_b and k_1 depend on the disposition of the bolts and if it's an inner or an end bolt, f_u is the tensile strength of the steel plate, d is the diameter of the bolt, t is the thickness of the steel plate and γ_{M2} is a partial factor.

In order to determine these resistances, we therefore need to know the type of bolt and its arrangement for the connection. It will be assumed that the bolts are M20 5.6 and we're going to check the possible arrangements of the bolts depending on the angle and the space available.

Minimum distances between bolts must be respected depending on the type of bolt (see Figure 3.64).

Bolts	Usual values [mm]			Minimal values [mm]			
	p_1, p_2	e_1	e_2	p_1	p_2	e_1	e_2
M 12	40	25	20	29	39	16	20
M 16	55	35	30	40	54	22	27
M 20	70	40	35	48	66	26	33
M 24	80	50	40	57	78	31	39
M 27	90	55	45	66	90	36	45
				$2,2 d_0$	$3d_0$	$1,2d_0$	$1,5d_0$

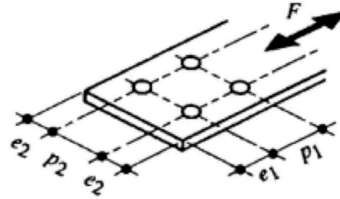


Figure 3.64: Dimensions to be respected when positioning the bolts^[42]

If we want to fit two rows of bolts, the space available must be greater than or equal to $2e_2 + p_2$. Knowing that the bolts are M20, the distance available must be greater than or equal to 132 mm. As the section has a wing length of 110 mm, it is not possible to fit two rows of bolts. Consequently, only one row of bolts will be considered at the centre of the section (see Figure 3.65).

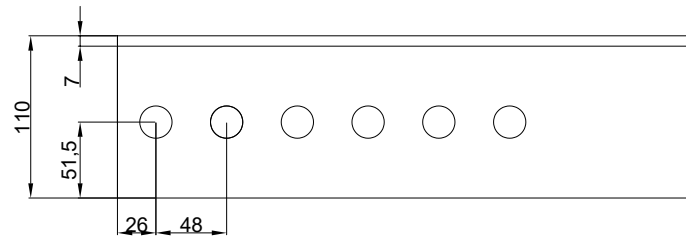


Figure 3.65: Position of bolts on the section angle

With all this information, we can determine the bearing and shear resistance of a bolt.

$$F_{v,Rd} = \frac{0,6 \times 500 \times 314}{1,25} = 75,36 \text{ kN}$$

$$F_{b,Rd,innerbolt} = \frac{2,5 \times 0,48 \times 540 \times 20 \times 10}{1,25} = 103,09 \text{ kN}$$

$$F_{b,Rd,endbolt} = \frac{2,5 \times 0,39 \times 540 \times 20 \times 10}{1,25} = 85,09 \text{ kN}$$

The maximum force a bolt can resist is therefore the minimum of all and is therefore 75,36 kN.

3.5.3.2 Force that the bolts must support

Now that the resistance force of the bolts has been determined, it is necessary to determine how many bolts are required to take up the loads in the connection.

To do this, the method described in the document “Work aid: Design of steel structures – Recessed fittings” of Bauforumstahl will be followed.

This method states that the maximum force that the bolts will have to take up is defined by the following formula.

$$\max V_{Schr} = \sqrt{\left(\frac{M_a z_i}{I_p} + \frac{N}{n}\right)^2 + \left(\frac{M_a y_i}{I_p} + \frac{V}{n}\right)^2}$$

With,

- M_a , the internal moment at the end of the angle which is equal to 8,398 kNm according to the TOWER software (element g459XY in the table of Appendix B).
- N , the internal normal force at the end of the angle, which is equal to 103,15 kN according to the TOWER software (element g459XY in the table of Appendix B).
- V , the internal cutting force at the end of the angle, which is equal to 16,57 kN according to the TOWER software (element g459XY in the table of Appendix B).
- z_i , the distance from the centre of the connection to the various bolts along the length of the angle. In order to obtain the maximum force, the distance to the furthest bolt will be taken.

- y_i , the distance from the centre of the connection to the various bolts in the direction perpendicular to the length of the angle. In this case, as there is only one row of bolts, this distance is always zero.
- $I_p = \Sigma y_i^2 + \Sigma z_i^2 = \Sigma z_i^2$
- n , the number of bolts.

For the connection to be verified, this force must be less than the resistance force of the bolt. An initial analysis will be carried out with 6 bolts. z_{max} is therefore equal to 0.12m and I_p to 0.010368 m^2 .

The force that the bolt must be able to take is therefore

$$V_{Schr} = 114,43\text{kN}$$

This value is much higher than the bolt's resistance value of 75.36kN.

If we now try with 10 bolts, we obtain a value of $V_{Schr} = 102,95$ kN, which is still much higher than the resistance of the bolt. Even if we try with 20 bolts, the value of the force remains higher than the resistance with $V_{Schr} = 95,01$ kN. With 20 bolts, the length of the connection would be almost 1m, which is unimaginable.

3.5.4 Conclusion following the various results

The embedding of all the nodes in the tower would result in a reduction in the weight of the transmission tower steel of 39.5%, corresponding to a saving of €20 310.

However, it is important to note that the installation of connections to embed a node can be complex, requiring a considerable number of holes for the installation of bolts. This approach would significantly increase costs and weight. Alternatively, in some cases, it may not be possible to provide such connections to take up the moments at the node as discussed above.

It can be concluded that embedding the tower nodes appears to be a promising solution on paper, but unfortunately it is proving impossible to achieve.

3.6 Optimization of the tower geometry

When it comes to optimising a steel transmission tower, one of the key approaches is to manipulate the tower geometry. Within this approach, two major elements are of particular interest: the configuration of the bracing bars and the angle of inclination of the tower legs.

3.6.1 Optimization of the tower geometry according to tower bracing

3.6.1.1 Typology of the steel lattice tower

One approach to adjusting the tower's bracing is to shift the bracing system. In practical terms, this means that the front and side bracing elements will be moved relative to each other. This modification to the bracing helps to reduce the buckling length of the tower legs.

Changing the arrangement of the bracing would mean the disappearance of the horizontal bracing, which would not be symmetrical and could cause the tower to flexing.

The rest of the structural elements, such as conductors and insulators, remain the same as in the first case of the dead-end tower.

The different faces of the initial tower can be seen in Figures 3.66 and 3.67, while those of the tower with staggered bracing can be seen in Figures 3.68 and 3.69.

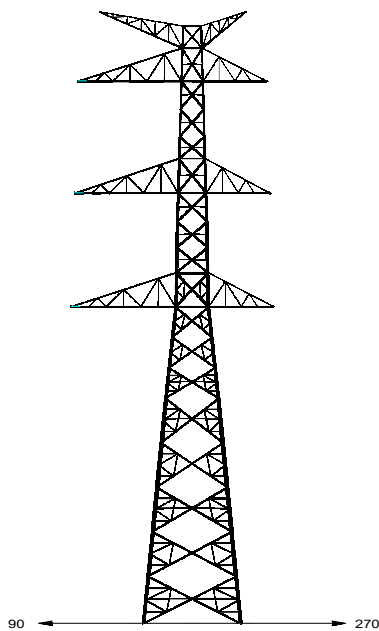


Figure 3.66: Front view of the tower with normal bracing

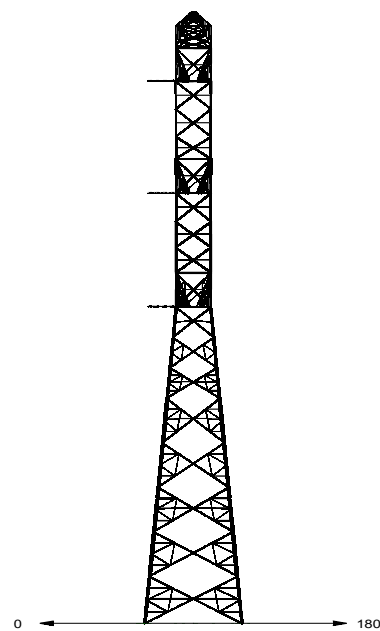


Figure 3.67: Side view of the tower with normal bracing

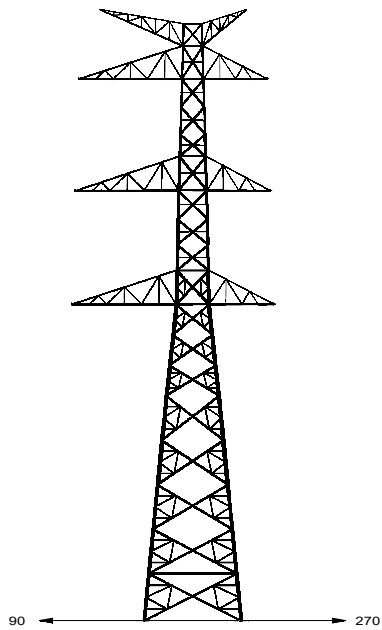


Figure 3.68: Front view of the tower with staggered bracing

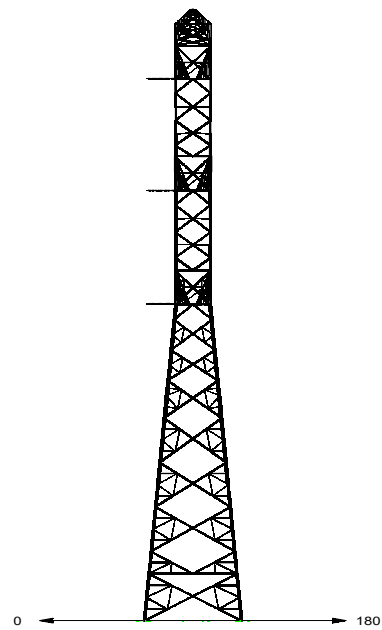


Figure 3.69: Side view of the tower with staggered bracing

After changing the geometry of the tower, the linear analysis according to standard EN50341, still identical to the previous cases, will be carried out by the TOWER software. All angles size for the new tower can be found in Appendix C.

3.6.1.2 Analysis of the results of the linear analysis

When the bracing is staggered, the dominant load case is D, G favourable, I unfavourable. That is, the wind is in the direction of the cross arms and is combined with ice. The dominant loads are always therefore wind and ice combined.

As can be seen from the tables in Appendix C, the size of some angles decreases while others increase. It is therefore difficult to assess the impact of the geometrical change. The variation in weight depending on the type of bracing can be seen in the Table 3.82 below.

By shifting the bracing on the sides of the tower, the weight of the tower increases by 3,5 tonnes, which represents 6,8% of the initial weight. The tower is therefore not optimised, which means that there is no point in modifying the tower bracing.

	Profiles weight [T]	Total weight of the tower [T]	Weight saved [T]	Weight saved [%]
With normal bracing	51,38	51,47	0	0
With staggered bracing	54,88	54,97	-3,5	-6,8

Table 3.82: Weight of the profiles,the tower and saved depending on the type of bracing

3.6.2 Optimization of the tower geometry according to the inclination of the tower legs

In order to assess the optimality of the basic inclination or to explore possible improvements, a range of configurations will be examined by varying the distances between the tower legs.

To begin with, a series of analyses will be undertaken by adjusting the distances between the legs from 7 to 12 metres (see Figures 3.70 and 3.71), in increments of 1 metre.

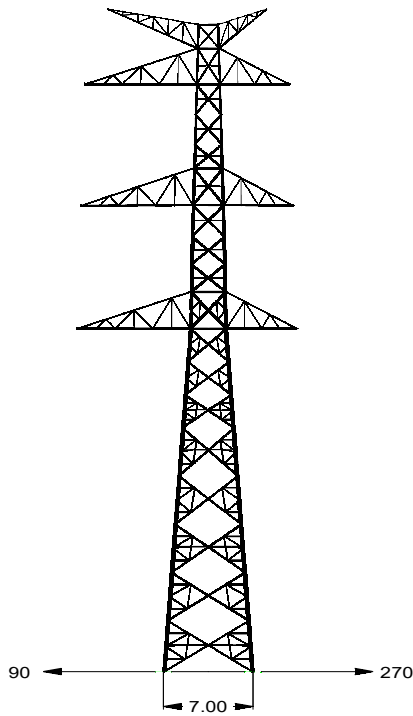


Figure 3.70: Tower with a distance of 7m between the legs

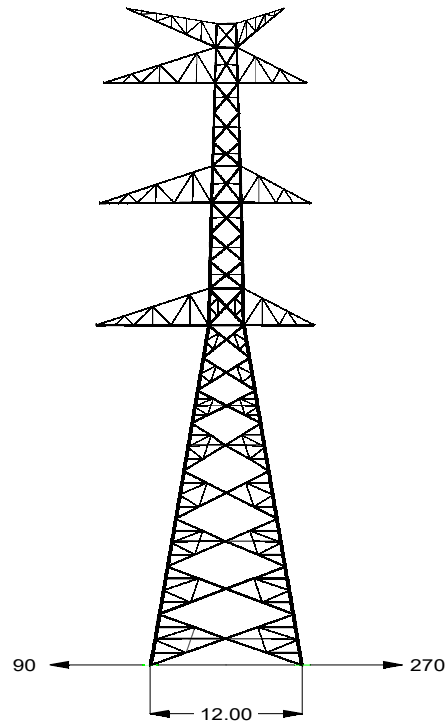


Figure 3.71: Tower with a distance of 12m between the legs

The section sizes of all angles for each turn can be seen in Appendix D.

The weight of the different towers following the linear analysis according to EN50341 can be seen in the Table 3.83. It is also possible to see the evolution of the weight in Figure 3.72.

Distance between legs [m]	7	8	9	10	11	12
Weight of the Tower [T]	53,11	51,62	50,68	49,89	50,18	51,28

Table 3.83: Tower weight as a function of distance between legs

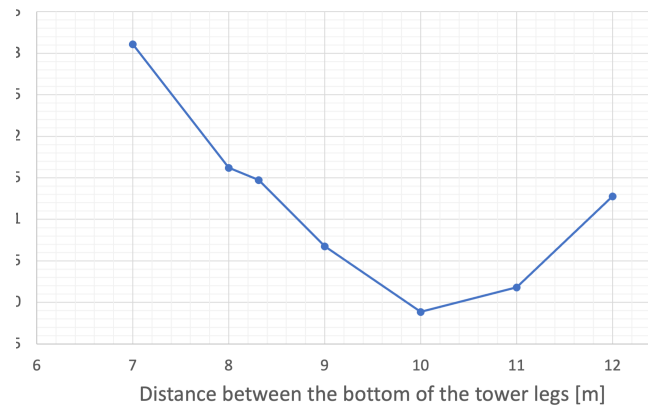


Figure 3.72: Evolution of tower weight as a function of distance between legs

As you can see, the minimum weight is reached when the distance between the lower legs is 10m.

In order to find the smallest possible weight, an increment of 0,1 m will be made from 10m. As the weight rises, the distance at which the weight will be the minimum can be determined to one decimal place.

The different weights as a function of the distance between the legs can be seen in Table 3.84 while the evolution of weight as a function of distance can be seen in Figure 3.73.

Distance between legs [m]	10	10,1	10,2	10,3	10,4	10,5
Weight of the Tower [T]	49,89	49,84	49,79	49,81	50,00	50,09

Table 3.84: Tower weight as a function of distance between legs

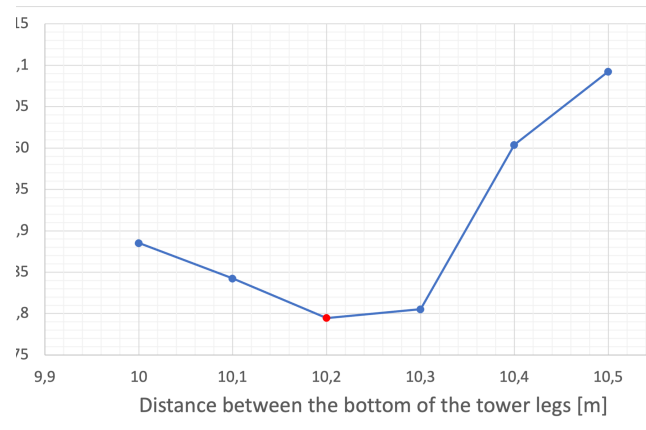


Figure 3.73: Evolution of weight as a function of distance between legs

The steel lattice tower would therefore have minimal weight if the distance between the lower legs were 10,2m. The initial weight of the tower with a distance of 8,145m between the lower legs was 51,47 tonnes. By modifying this distance by 10,2m, there is a saving of 1,69 tonnes on the total weight of the tower, which represents a cost saving of €1 680 per tower, considering that a tonne of S460 steel costs €1 000 (see Table 3.85).

Tower	Price per weight [€/T]	Weight of tower steel [T]	Total price [€]
Initial geometry	1 000	51,38	51 380
Optimized geometry	1 000	49,7	49 700

Table 3.85: Cost per tower for steel

3.7 Combination of steel grades in the tower with optimised geometry

As for the initial tower, in this section an analysis will be carried out to see if gains can be made by using different grades of steel in the same tower with an optimised geometry. Initially, modelling involving S460 and S235 alloy steel will be carried out. This will be followed by modelling using S460 steel in conjunction with S355. Finally, modelling will be carried out using a combination of the three steel grades. Following these stages, a comparative assessment of the different scenarios will be carried out, paving the way for constructive discussions to determine the optimum solution.

The methodology for each case will be the same as in the analysis of the initial tower, mixing the different grades of steel. The results can be found below in the next 3 subsections.

3.7.1 Combination of steel S460 and S235

The results are shown in Tables 3.86 to 3.96 below.

Group	Steel grade
Bottom legs	S460
Diagonal	S460
Redundant 1	S460
Redundant 2	S235
Redundant 3	S460
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.86: Steel grade of bottom section angles

Group	Steel grade
Section 1 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Redundant 1-1	S460
Redundant 1-2	S235
Redundant 1-3	S460
Redundant 2-1	S460
Redundant 2-2	S460
Redundant 2-3	S460
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.87: Steel grade of section 1 angles

Group	Steel grade
Section 2 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Redundant 1-1	S460
Redundant 1-2	S460
Redundant 1-3	S460
Redundant 2-1	S460
Redundant 2-2	S460
Redundant 2-3	S460
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.88: Steel grade of section 2 angles

Group	Steel grade
Section 3 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S460
Redundant 1-2	S460
Redundant 1-3	S460
Redundant 2-1	S460
Redundant 3-1	S460
Redundant 3-2	S460
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.89: Steel grade of section 3 angles

Group	Steel grade
Section 4 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S460
Redundant 1-2	S460
Redundant 2-1	S460
Redundant 3-1	S460
Horizontal 1-1	S460
Horizontal 1-2	S460
Horizontal 1-3	S235
Horizontal 2-1	S460

Table 3.90: Steel grade of section 4 angles

Group	Steel grade
Section 5 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S235
Redundant 2-1	S235
Redundant 3-1	S235
Horizontal 1-1	S460
Horizontal 1-2	S460
Horizontal 1-3	S235
Horizontal 1-4	S460
Horizontal 2-1	S460
Horizontal 2-2	S460

Table 3.91: Steel grade of section 5 angles

Group	Steel grade
Top legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Diagonal 4	S460
Redundant 1-1	S235
Redundant 2-1	S235
Redundant 3-1	S235
Horizontal 1-1	S460
Horizontal 1-2	S460
Horizontal 1-3	S460
Horizontal 1-4	S235
Horizontal 2-1	S235
Horizontal 2-2	S235
Horizontal 2-3	S235
Horizontal 3-1	S235
Horizontal 3-2	S235
Horizontal 3-3	S235

Table 3.92: Steel grade of top section angles

Group	Steel grade
Bottom	S460
Top	S235
Diagonal 1	S235
Diagonal 2	S235
Diagonal 3	S235
Vertical 1	S235
Vertical 2	S235
Base 1 to 6	S460
Base 7	S460
Base 8	S460
End	S460
H top	S235
Bracing	S235

Table 3.93: Steel grade of the three first big cross arms angles

Group	Steel grade
Bottom	S460
Top	S235
Diagonal 1	S235
Diagonal 2	S235
Vertical	S235
Base 1 to 5	S460
Base 6	S460
End	S460

Table 3.94: Steel grade of the three first small cross arms angles

Group	Steel grade
Bottom	S460
Top	S460
Diagonal 1	S235
Diagonal 2	S235
Diagonal 3	S235
Vertical 1 to 5	S235
Base 1	S235
Base 2	S235
Base 3	S235
Base 4	S235
Base 5 to 8	S235
End	S460

Table 3.95: Steel grade of the big top cross arm angles

Group	Steel grade
Bottom	S460
Top	S235
Diagonal 1	S235
Diagonal 2	S235
Vertical 1 to 4	S235
Base 1	S235
Base 2 to 7	S235
End	S460

Table 3.96: Steel grade of the small top cross arm angles

When the tower has a distance of 10,2m between legs and is in S460 and S235 steel, the dominant load case is E, G favourable, I unfavourable. That is, the wind is at perpendicular direction to the cross arms and is combined with ice. The dominant loads are always therefore wind and ice combined.

The distribution of S460 and S235 angle steels in the tower can be seen in

Figure 3.74. S460 grade angles are shown in green, while S235 grade angles are shown in pink.

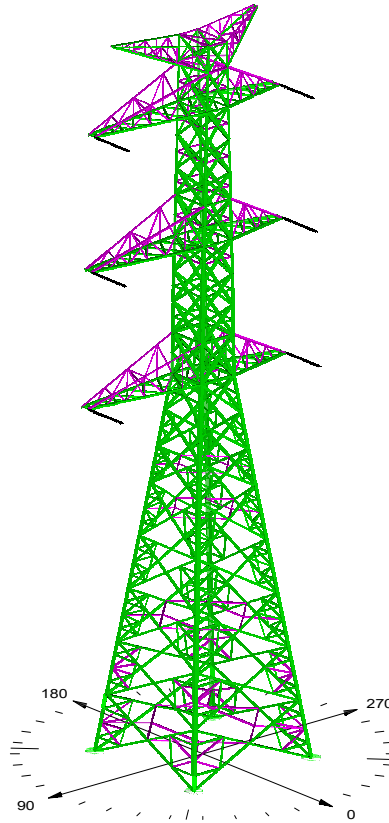


Figure 3.74: Distribution of steel grade S460 and S235 in the tower

Thanks to the TOWER software, the weight of the S235 and S460 angles can be extracted, and cost study can therefore be carried out. The results obtained are shown in Table 3.97.

Steel grade	Price per weight [€/T]	Steel weight [T]	Price [€]
S235	900	3,84	3 456
S460	1 000	45,86	45 860
S235 + S460		49,70	49 316

Table 3.97: Cost of steel for the tower

The total cost of steel for the tower angles, using steel grades S460 and S235, is therefore €49 316.

3.7.2 Combination of steel S460 and S355

When the tower has a distance of 10,2m between legs and is in S460 and S355 steel, the dominant load case is E, G favourable, I unfavourable. That is, the wind is at perpendicular direction to the cross arms and is combined with ice. The dominant loads are always therefore wind and ice combined.

The results are shown in Tables 3.98 to 3.108 below.

Group	Steel grade
Bottom legs	S460
Diagonal	S460
Redundant 1	S355
Redundant 2	S355
Redundant 3	S460
Horizontal 1	S355
Horizontal 2	S355
Horizontal 3	S355

Table 3.98: Steel grade of bottom section angles

Group	Steel grade
Section 1 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Redundant 1-1	S355
Redundant 1-2	S355
Redundant 1-3	S460
Redundant 2-1	S355
Redundant 2-2	S355
Redundant 2-3	S355
Horizontal 1	S355
Horizontal 2	S355
Horizontal 3	S355

Table 3.99: Steel grade of section 1 angles

Group	Steel grade
Section 2 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Redundant 1-1	S355
Redundant 1-2	S355
Redundant 1-3	S460
Redundant 2-1	S355
Redundant 2-2	S355
Redundant 2-3	S460
Horizontal 1	S355
Horizontal 2	S355
Horizontal 3	S355

Table 3.100: Steel grade of section 2 angles

Group	Steel grade
Section 3 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S460
Redundant 1-2	S355
Redundant 1-3	S460
Redundant 2-1	S460
Redundant 3-1	S460
Redundant 3-2	S355
Horizontal 1	S355
Horizontal 2	S355
Horizontal 3	S355

Table 3.101: Steel grade of section 3 angles

Group	Steel grade
Section 4 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S355
Redundant 1-2	S355
Redundant 2-1	S460
Redundant 3-1	S460
Horizontal 1-1	S460
Horizontal 1-2	S460
Horizontal 1-3	S355
Horizontal 2-1	S460

Table 3.102: Steel grade of section 4 angles

Group	Steel grade
Section 5 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S355
Redundant 2-1	S355
Redundant 3-1	S355
Horizontal 1-1	S460
Horizontal 1-2	S355
Horizontal 1-3	S355
Horizontal 1-4	S460
Horizontal 2-1	S355
Horizontal 2-2	S355

Table 3.103: Steel grade of section 5 angles

Group	Steel grade
Top legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S355
Diagonal 4	S355
Redundant 1-1	S355
Redundant 2-1	S355
Redundant 3-1	S355
Horizontal 1-1	S355
Horizontal 1-2	S460
Horizontal 1-3	S355
Horizontal 1-4	S355
Horizontal 2-1	S355
Horizontal 2-2	S355
Horizontal 2-3	S355
Horizontal 3-1	S355
Horizontal 3-2	S355
Horizontal 3-3	S355

Table 3.104: Steel grade of top section angles

Group	Steel grade
Bottom	S460
Top	S355
Diagonal 1	S355
Diagonal 2	S355
Diagonal 3	S355
Vertical 1	S355
Vertical 2	S355
Base 1 to 6	S355
Base 7	S460
Base 8	S460
End	S460
H top	S355
Bracing	S355

Table 3.105: Steel grade of the three first big cross arms angles

Group	Steel grade
Bottom	S460
Top	S355
Diagonal 1	S355
Diagonal 2	S355
Diagonal 3	S355
Vertical 1 to 5	S355
Base 1	S355
Base 2	S355
Base 3	S355
Base 4	S355
Base 5 to 8	S355
End	S460

Table 3.107: Steel grade of the big top cross arm angles

Group	Steel grade
Bottom	S460
Top	S355
Diagonal 1	S355
Diagonal 2	S355
Vertical	S355
Base 1 to 5	S355
Base 6	S460
End	S460

Table 3.106: Steel grade of the three first small cross arms angles

Group	Steel grade
Bottom	S355
Top	S355
Diagonal 1	S355
Diagonal 2	S355
Vertical 1 to 4	S355
Base 1	S355
Base 2 to 7	S355
End	S460

Table 3.108: Steel grade of the small top cross arm angles

The distribution of S460 and S355 angle steels in the tower can be seen in Figure 3.75 where S460 grade angles are shown in green and S355 grade angles are shown in blue.

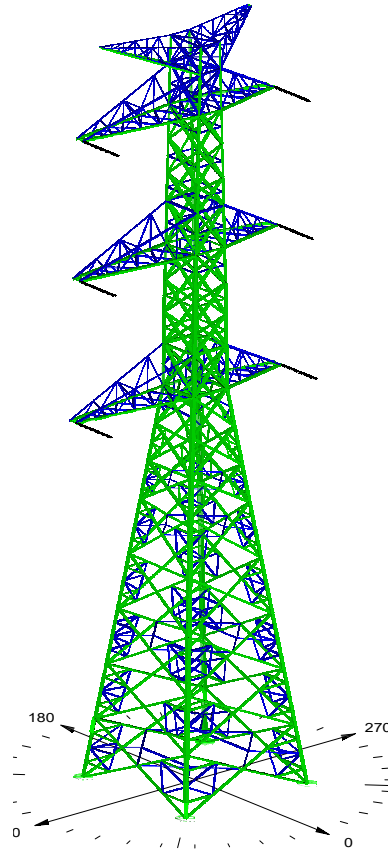


Figure 3.75: Distribution of steel grade S460 and S355 in the tower

Thanks to the TOWER software, the weight of the S355 and S460 angles can be extracted, and a cost study can therefore be carried out. The results obtained are shown in Table 3.109.

Steel grade	Price per weight [€/T]	Steel weight in the tower [T]	Price [€]
S355	950	8,02	7 619
S460	1 000	41,68	41 680
S355 + S460		49,7	49 299

Table 3.109: Cost of steel for the tower

The total cost of steel for the tower angles, using steel grades S460 and S355, is therefore €49 299.

3.7.3 Combination of steel S460, S355 and S235

The results are shown in Tables 3.110 to 3.120 below.

Group	Steel grade
Bottom legs	S460
Diagonal	S460
Redundant 1	S355
Redundant 2	S235
Redundant 3	S460
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.110: Steel grade of bottom section angles

Group	Steel grade
Section 1 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Redundant 1-1	S355
Redundant 1-2	S235
Redundant 1-3	S460
Redundant 2-1	S355
Redundant 2-2	S355
Redundant 2-3	S355
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.111: Steel grade of section 1 angles

Group	Steel grade
Section 2 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Redundant 1-1	S355
Redundant 1-2	S355
Redundant 1-3	S460
Redundant 2-1	S355
Redundant 2-2	S355
Redundant 2-3	S460
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.112: Steel grade of section 2 angles

Group	Steel grade
Section 3 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S460
Redundant 1-2	S355
Redundant 1-3	S460
Redundant 2-1	S460
Redundant 3-1	S460
Redundant 3-2	S355
Horizontal 1	S235
Horizontal 2	S235
Horizontal 3	S235

Table 3.113: Steel grade of section 3 angles

Group	Steel grade
Section 4 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S355
Redundant 1-2	S355
Redundant 2-1	S460
Redundant 3-1	S460
Horizontal 1-1	S460
Horizontal 1-2	S460
Horizontal 1-3	S235
Horizontal 2-1	S460

Table 3.114: Steel grade of section 4 angles

Group	Steel grade
Section 5 legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S460
Redundant 1-1	S235
Redundant 2-1	S235
Redundant 3-1	S235
Horizontal 1-1	S460
Horizontal 1-2	S355
Horizontal 1-3	S235
Horizontal 1-4	S460
Horizontal 2-1	S355
Horizontal 2-2	S355

Table 3.115: Steel grade of section 5 angles

Group	Steel grade
Top legs	S460
Diagonal 1	S460
Diagonal 2	S460
Diagonal 3	S355
Diagonal 4	S355
Redundant 1-1	S235
Redundant 2-1	S235
Redundant 3-1	S235
Horizontal 1-1	S355
Horizontal 1-2	S460
Horizontal 1-3	S355
Horizontal 1-4	S235
Horizontal 2-1	S235
Horizontal 2-2	S235
Horizontal 2-3	S235
Horizontal 3-1	S235
Horizontal 3-2	S235
Horizontal 3-3	S235

Table 3.116: Steel grade of top section angles

Group	Steel grade
Bottom	S460
Top	S235
Diagonal 1	S235
Diagonal 2	S235
Diagonal 3	S235
Vertical 1	S235
Vertical 2	S235
Base 1 to 6	S355
Base 7	S460
Base 8	S460
End	S460
H top	S235
Bracing	S235

Table 3.117: Steel grade of the three first big cross arms angles

Group	Steel grade
Bottom	S460
Top	S355
Diagonal 1	S235
Diagonal 2	S235
Diagonal 3	S235
Vertical 1 to 5	S235
Base 1	S235
Base 2	S235
Base 3	S235
Base 4	S235
Base 5 to 8	S235
End	S460

Table 3.119: Steel grade of the big top cross arm angles

Group	Steel grade
Bottom	S460
Top	S235
Diagonal 1	S235
Diagonal 2	S235
Vertical	S235
Base 1 to 5	S355
Base 6	S460
End	S460

Table 3.118: Steel grade of the three first small cross arms angles

Group	Steel grade
Bottom	S355
Top	S235
Diagonal 1	S235
Diagonal 2	S235
Vertical 1 to 4	S355
Base 1	S235
Base 2 to 7	S235
End	S460

Table 3.120: Steel grade of the small top cross arm angles

When the tower has a distance of 10,2m between legs and is in S460, S355 and S235 steel, the dominant load case is E, G favourable, I unfavourable. That is, the wind is at perpendicular direction to the cross arms and is combined with ice. The dominant loads are always therefore wind and ice combined

The distribution of the 3 steel grades in the tower is shown in Figure 3.76 where grade S460 angles are shown in green, grade S355 angles are shown in blue and grade S235 angles are shown in pink.

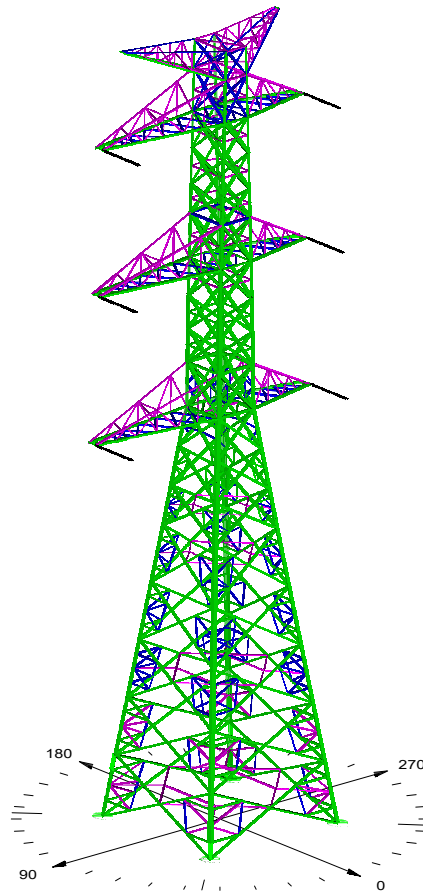


Figure 3.76: Distribution of steel grade S460, S355 and S235 in the tower

Thanks to the TOWER software, the weight of the S235, S355 and S460 angles can be extracted, and a cost study can therefore be carried out. The results obtained are shown in Table 3.121.

Steel grade	Price per weight [€/T]	Steel weight in the tower [T]	Price [€]
S235	900	3,83	3 447
S355	950	4,18	3 971
S460	1 000	41,69	41 690
S235 + S355 + S460		49,7	49 108

Table 3.121: Cost of steel for the tower

The total cost of steel for the tower angles, using steel grades S460, S355 and S235, is therefore €49 108.

3.7.4 Analysis of the results

The different price results per round can be seen in the Table 3.122 below.

Mixing type	Tower steel price [€]	cost saving [€]
S460	49 700	0
S460 + S235	49 316	384
S460 + S355	49 299	401
S460 + S355 + S235	49 108	592

Table 3.122: Tower steel prices depending on the mix of steel grades

In all cases, by mixing different grades of steel, cost savings can be achieved. In fact, by mixing S460 and S35 steel grades, a saving of €384 can be made. Now, if we mix the S460 and S355 steel grades, we save €401. Finally, if we mix the three different steel grades, a saving of €592 can be made.

These savings represent the savings per tower. Bear in mind that a transmission line is made up of a hundred or so towers, so the winnings should be multiplied accordingly.

In this sense, the most interesting case for optimising costs is, as in the initial case, the use of 3 different grades of steel in the towers.

However, the problem of site work remains. Indeed, by using different types of steel, the work of the workers will be more complicated and errors may occur, with repair costs higher than the gains made on the steel mix.

To conclude, the tower offering maximum cost optimisation would be the one with a distance of 10,2 m between the lower legs and built using steel angle sections in grades S460, S355 and S235. However, given the complexities encountered in the field, the tower that appears to be the most ideal in every respect is the one with a distance of 10,2 m between the bottom legs, but built exclusively using grade S460 angle steel.

Chapter 4

Conclusion

The increasing use of renewable energies to generate electricity is a growing trend in Europe. As renewable energies are produced on a decentralized basis, this transition requires the electricity grid to be adapted to meet growing demand and guarantee a secure electricity supply.

As cable tension increases, new types of standardized steel lattice pylons are required, and the aim has been to find a solution to optimize them and reduce their weight.

As a result of the ANGELHY research project, the solution we came up with was to use S460M angle steel instead of S355 or S235. This grade of steel offers high strength, making it particularly suitable for heavily loaded structures such as transmission towers. What's more, it has a number of advantages, such as reduced cross-sections, which make the structure lighter while keeping it safe.

In order to be able to analyse a typology of tower using S460 steel grade angles, it was necessary to determine which standard to follow. We saw that two different standards addressed the dimensioning aspects of steel lattice towers. Following an analysis and an example calculation of compression on an angle, we concluded that standard EN50341 is more economic with regard to optimizing and reducing the weight of the tower.

Subsequently, a study involving numerical optimization of towers was conducted using the structural engineering software TOWER. The results demonstrated that the incorporation of S460 grade steel angles into a suspended tower could lead to a reduction of approximately 16% in material weight. Nevertheless, this improvement proved insufficient to offset the increased costs associated with the use of S460 steel.

On the other hand, analysing the same tower typology applied to a dead-end structure revealed material savings of around 36% through the incorporation of S460 steel angles. This approach also avoided the addition of constructed angles, which would have increased workloads and construction expenses related to the tower. Furthermore, the numerical study suggested that combining different steel grades could amplify these savings, even though it might present challenges in the field.

Continuing our investigations, we questioned the assumption of hinges applied to all nodes of the tower, finding that it did not facilitate weight optimization. However, despite the significant material gain, node embedding did not prove to be physically feasible.

Lastly, an optimization based on the tower's geometry was pursued. We observed that replacing the diagonal bracing with staggered bracing did not result in a significant improvement. However, by increasing the spacing between the lower feet to 10,2 meters, we were able to achieve a material saving of 1,69 tons. The numerical analysis also indicated that the use of different steel grades could potentially enhance these savings, though it might not be sufficient to impose constraints on the construction site.

In conclusion of our study of an initial tower, with a distance of 8.31 metres between legs, built using S235 grade steel (see Figures 4.1 and 4.2), we are able to state that the use of S460 grade steel angles does not lead to the optimisation of suspended towers, but is advantageous for dead-end structures by allowing a sufficient reduction in the weight of materials, which generates cost savings.

Furthermore, it's important to highlight that additional improvements can be made by altering the tower's geometry. For instance, widening the spacing between the lower feet to 10,2 meters (see Figures 4.3 and 4.4) instead of 8,31 meters could also contribute to material and consequently cost reduction. In fact, this change of geometry leads to the best weight optimisation.

Numerically, incorporating three different grades of steel, S460, S355 and S235, (see Figures 4.5 and 4.6) into the construction of the tower would result in the most economical tower. However, it should be noted that the feasibility of this approach on the construction site could pose significant problems and it is therefore not feasible to consider it optimal.

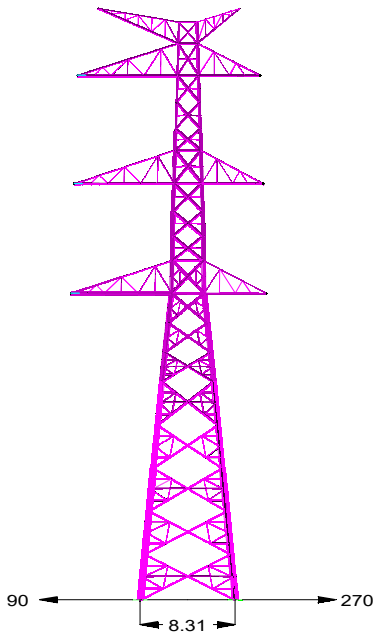


Figure 4.1: Front view of the initial tower geometry in steel grade S235

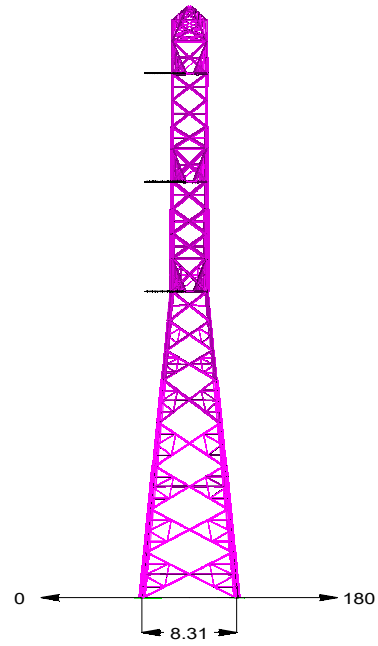


Figure 4.2: Side view of the initial tower geometry in steel grade S235

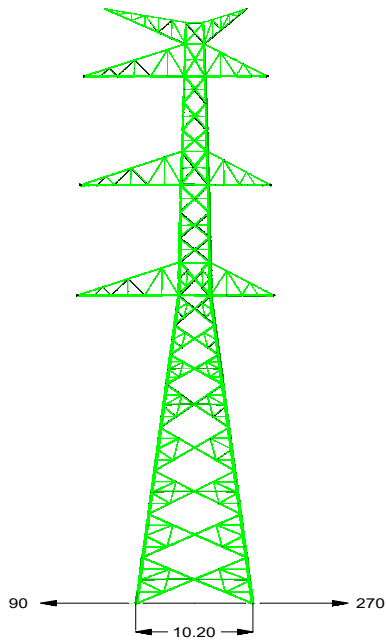


Figure 4.3: Front view of the optimized tower geometry in steel grade S460

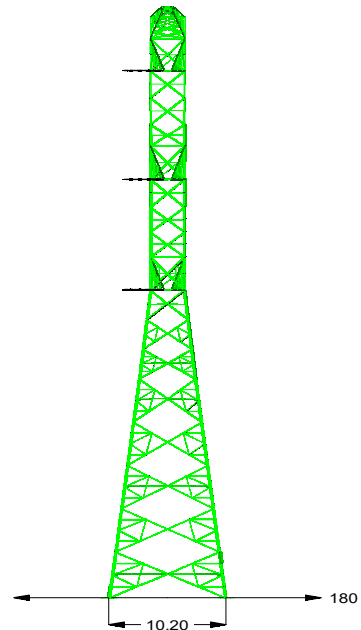


Figure 4.4: Side view of the optimized tower geometry in steel grade S460

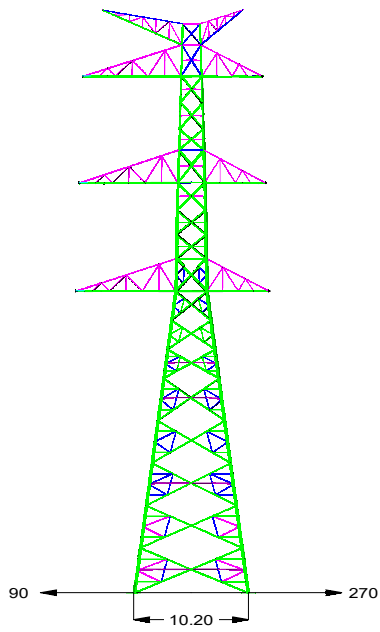


Figure 4.5: Front view of the cost-optimised tower

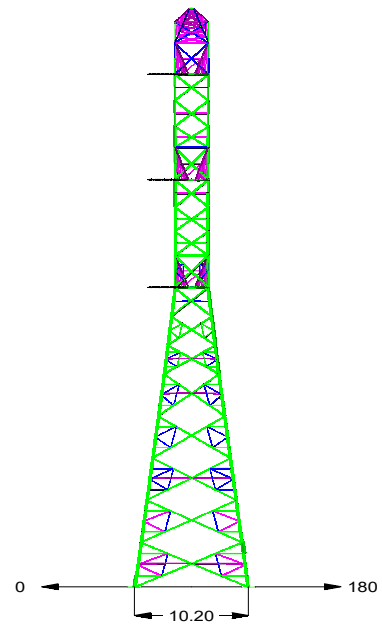


Figure 4.6: Side view of the cost-optimised tower

List of Figures

1.1	Steel lattice tower ^[40]	6
1.2	Body of a steel lattice tower	7
1.3	Cross arms of a steel lattice tower	8
1.4	Body of a steel lattice tower	8
1.5	Different types of built-up members ^[4]	10
1.6	2D view of butterfly connection ^[4]	10
1.7	3D view of butterfly connection ^[41]	10
2.1	Limit between class 3 and class 4 for angle sections in compression ^[6]	14
2.2	Comparison of reduction curves for equal leg angle sections in uniform compression ^[6]	15
2.3	Specific joint configurations for the buckling of diagonals ^[6]	16
2.4	Strength prediction for minor-axis buckling – case 1 ^[6]	17
2.5	Strength prediction for z-z/y-y axis buckling – case 1 ^[6]	17
2.6	Strength prediction for minor-axis buckling – case 2a and 2b ^[6]	17
2.7	Strength prediction for z-z/y-y axis buckling – case 2a and 2b ^[6]	17
2.8	Strength prediction for minor-axis buckling – case 3a, 3b and 3c ^[6]	17
2.9	Strength prediction for z-z/y-y axis buckling – case 3a ^[6]	17
2.10	Strength prediction for z-z/y-y axis buckling – cases 3b and 3c ^[6]	18
2.11	Slenderness modification factor for buckling of leg members ^[6]	19
2.12	Strength prediction for minor-axis buckling – case 1 ^[6]	20
2.13	Strength prediction for minor-axis buckling – case 2 ^[6]	20
2.14	Strength prediction for minor-axis buckling – case 3 ^[6]	20
2.15	Strength prediction for y-y/z-z axis buckling – case 4 ^[6]	20
2.16	Strength prediction for y-y/z-z axis buckling – case 5 ^[6]	20
2.17	Buckling curves ^[4]	30
3.1	M3 transmission tower for a 400kV double track line ^[39]	33
3.2	Dimensions of the suspension tower	34
3.3	Base of lower cross arm	35
3.4	Base of first middle cross arm	35

3.5	Base of second middle cross arm	35
3.6	Base of top cross arm	35
3.7	Aluminium-steel conductor ^[37]	36
3.8	Tower modelled in TOWER software interface	38
3.9	Annotations of the different sections of the tower	43
3.10	Annotations of the bottom section of the tower.	44
3.11	Annotations of the horizontal bracing in the bottom section	44
3.12	Annotations of the section 1 of the tower.	45
3.13	Annotations of the horizontal bracing in the section 1	45
3.14	Annotations of the section 2 of the tower.	46
3.15	Annotations of the horizontal bracing in the section 2	46
3.16	Annotations of the section 3 of the tower.	47
3.17	Annotations of the horizontal bracing in the section 3	47
3.18	Annotations of the section 4 of the tower.	48
3.19	Annotations of the horizontal bracing in the section 4	48
3.20	Annotations of the horizontal bracing in the section 4	48
3.21	Annotations of the section 5 of the tower	49
3.22	Annotations of the horizontal 1 bracing in the section 5	50
3.23	Annotations of the horizontal 2 bracing in the section 5	50
3.24	Annotations of the top of the tower	51
3.25	Annotations of the horizontal 1 bracing in the top section	51
3.26	Annotations of the horizontal 2 bracing in the top section	51
3.27	Annotations of the horizontal 3 bracing in the top section	51
3.28	Annotations of the three first big cross arms (front and bottom view)	52
3.29	Annotations of the three first big cross arms (isometric view)	53
3.30	Annotations of the three first small cross arms (front and bottom view)	54
3.31	Annotations of the big top cross arm (front and bottom view)	55
3.32	Annotations of the small top cross arm (front and bottom view)	56
3.33	Annotations of the different sections of the tower	65
3.34	Annotations of the bottom section of the tower.	66
3.35	Annotations of the horizontal bracing in the bottom section	66
3.36	Annotations of the section 1 of the tower.	67
3.37	Annotations of the horizontal bracing in the section 1	67
3.38	Annotations of the section 2 of the tower.	68
3.39	Annotations of the horizontal bracing in the section 2	68
3.40	Annotations of the section 3 of the tower.	69
3.41	Annotations of the horizontal bracing in the section 3	69
3.42	Annotations of the section 4 of the tower.	70
3.43	Annotations of the horizontal bracing in the section 4	70

3.44	Annotations of the horizontal bracing in the section 4	70
3.45	Annotations of the section 5 of the tower	71
3.46	Annotations of the horizontal 1 bracing in the section 5	72
3.47	Annotations of the horizontal 2 bracing in the section 5	72
3.48	Annotations of the top of the tower	73
3.49	Annotations of the horizontal 1 bracing in the top section	73
3.50	Annotations of the horizontal 2 bracing in the top section	73
3.51	Annotations of the horizontal 3 bracing in the top section	73
3.52	Annotations of the three first big cross arms (front and bottom view)	74
3.53	Annotations of the three first big cross arms (isometric view)	75
3.54	Annotations of the three first small cross arms (front and bottom view)	76
3.55	Annotations of the big top cross arm (front and bottom view) . . .	76
3.56	Annotations of the small top cross arm (front and bottom view) . .	77
3.57	Section of the butterfly angle	79
3.58	Connection of the butterfly angle	79
3.59	Plan view of the butterfly angle for the leg of section 3	79
3.60	Distribution of steel grade S460 and S235 in the tower	85
3.61	Distribution of steel grade S460 and S355 in the tower	90
3.62	Distribution of steel grade S460, S355 and S235 in the tower	94
3.63	Position of the connection studied	102
3.64	Dimensions to be respected when positioning the bolts ^[42]	103
3.65	Position of bolts on the section angle	103
3.66	Front view of the tower with normal bracing	106
3.67	Side view of the tower with normal bracing	106
3.68	Front view of the tower with staggered bracing	107
3.69	Side view of the tower with staggered bracing	107
3.70	Tower with a distance of 7m between the legs	108
3.71	Tower with a distance of 12m between the legs	108
3.72	Evolution of tower weight as a function of distance between legs . .	109
3.73	Evolution of weight as a function of distance between legs	110
3.74	Distribution of steel grade S460 and S235 in the tower	114
3.75	Distribution of steel grade S460 and S355 in the tower	118
3.76	Distribution of steel grade S460, S355 and S235 in the tower	122
4.1	Front view of the initial tower geometry in steel grade S235	126
4.2	Side view of the initial tower geometry in steel grade S235	126
4.3	Front view of the optimized tower geometry in steel grade S460 . .	126
4.4	Side view of the optimized tower geometry in steel grade S460 . . .	126
4.5	Front view of the cost-optimised tower	127
4.6	Side view of the cost-optimised tower	127

C.1	Annotations of the bottom section of the tower.	173
C.2	Annotations of the horizontal bracing in the bottom section	173
C.3	Annotations of the faces of the section 1 of the tower.	174
C.4	Annotations of the sides of the section 1 of the tower.	174
C.5	Annotations of the faces of the section 2 of the tower.	176
C.6	Annotations of the sides of the section 2 of the tower.	176
C.7	Annotations of the faces of the section 3 of the tower.	177
C.8	Annotations of the sides of the section 3 of the tower.	177
C.9	Annotations of the faces of the section 4 of the tower.	179
C.10	Annotations of the sides of the section 4 of the tower.	179
C.11	Annotations of the horizontal bracing in the section 4	179
C.12	Annotations of the horizontal bracing in the section 4	179
C.13	Annotations of the faces of the section 5 of the tower.	181
C.14	Annotations of the sides of the section 5 of the tower.	181
C.15	Annotations of the horizontal 1 bracing in the section 5	181
C.16	Annotations of the horizontal 2 bracing in the section 5	181
C.17	Annotations of the faces of the top of the tower	183
C.18	Annotations of the sides of the top of the tower	183
C.19	Annotations of the horizontal 1 bracing in the top section	183
C.20	Annotations of the horizontal 2 bracing in the top section	183
C.21	Annotations of the horizontal 3 bracing in the top section	184

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Appendix A

Comparative table of norms

EN50341 ^[2]	EN1993-3-1 ^[5]
SCOPE	
New overhead electric lines with nominal system voltages exceeding AC 1 kV and with rated frequencies below 100 Hz.	Towers, masts, and chimney structures.
Tower and Cables	Just the Tower
ACTIONS ON LINES	
WIND LOADS	1991-1-4
The rules are extracted from EN 1991-1-4 models	EUROCODE 1 Actions on structures – general actions, wind actions.
Details about wind forces on conductors	This part does not give guidance on wind actions on lattice towers with non-parallel chords. For this, see EN 1993-3-1, Annex A.
1. Wind and mean wind velocity	1. Wind and mean wind velocity
$V_{b,0}$ = basic wind velocity	V_b = basic wind velocity $= c_{dir} \times c_{season} \times V_{b,0}$

$$V_h(h) = \text{mean wind velocity} \\ = V_{b,0} \times c_{dir} \times c_0 \times k_r \times \ln \frac{h}{z_0}$$

with

$$k_r = 0,189 \left(\frac{z_0}{0,05} \right)^{0,07}$$

and can be determined in Table 4.1 – Terrain categories, roughness length, z_0 and terrain factor, k_r

2. Wind turbulence and peak velocity pressure

$$I_v(h) = \text{turbulence intensity} \\ = \frac{1}{c_0 \ln(h/z_0)}$$

$$q_p(h) = \text{peak wind pressure} \\ = [1 + 7I_v(h)] \times q_h(h)$$

Where

$q_h(h)$ is the mean wind pressure and is equal to $\frac{1}{2} \rho V_h^2(z)$

ρ depends on the temperature and the altitude.

where $V_{b,0}$ is the fundamental value of the basic wind velocity, c_{season} is a seasonal factor equal to 1 (value recommended) and c_{dir} is a directional factor also equal to 1.

$$V_m(z) = \text{mean wind velocity} \\ V_{b,0} \times c_{dir} \times c_0 \times c_r(z)$$

Where

$$c_r(z) = k_r \times \ln \frac{z}{z_0} \text{ if } z_{min} < z < 200$$

$$c_r(z) = c_r(z_{min}) \text{ if } z < z_{min}$$

with

$$k_r = 0,19 \left(\frac{z_0}{0,05} \right)^{0,07}$$

and z_0 and z_{min} are determined in Table 4.1 – Terrain categories and terrain parameters.

2. Wind turbulence and peak velocity pressure

$$I_v(z) = \text{turbulence intensity} \\ = \frac{\sigma_v}{V_m(z)}$$

Where $\sigma_v = k_r \times v_b \times k_l$ So

$$I_v(z) = \frac{k_l}{c_0 \ln(z/z_0)} \text{ if } z_{min} < z < 200$$

$$I_v(z) = I_v(z_{min}) \text{ if } z < z_{min}$$

With k_l is a turbulence factor equal to 1 (recommended value).

$$q_p(z) = \text{peak velocity pressure} \\ = [1 + 7I_v(z)] \frac{1}{2} \rho V_m^2(z)$$

Where

$$\rho = 1,25 [kg/m^3] \text{ (conservative value)}$$

3. Wind forces

Q_{wx} = wind forces due to wind blowing horizontally at reference height, perpendicular to any line component.

$$Q_{wx} = q_p(h) \cdot G_x \cdot C_x \cdot A_x$$

With

G_x the structural factor calculated following the method given in EN 1991-1-4

C_x , the drag factor (or force coefficient) depending on the shape.

A_x , the area of the line component projected on a plane perpendicular to the wind direction

valid for the reference return period of 50 years. Can be transformed for a return period of 50 years or 3 years, assuming a conservative value of $G_x = 1$. (see 4.3.5 of EN50341)

3. Wind forces

F_w = wind forces acting on a structure or a structural component.

Can be calculated by 2 ways :

(1) Using force coefficients

$F_w = c_s c_d \cdot c_f \cdot q_p(z_e) \cdot A_{ref}$ or vectorial summation

$$F_w = c_s c_d \sum_{element} c_f \cdot q_p(z_e) \cdot A_{ref}$$

With

$c_s c_d$ the structural factor

c_f , the force coefficient.

A_{ref} , the reference area.

(2) From surface pressure

$$F_w = F_{w,e} + F_{w,i} + F_{fr}$$

With

$F_{w,e}$ = external forces

$$= c_s c_d \cdot \sum_{surfaces} w_e \cdot A_{ref}$$

$F_{w,i}$ = internal forces

$$= \sum_{surfaces} w_i \cdot A_{ref}$$

F_{fr} = friction forces

$$= c_{fr} \cdot q_p(z_e) \cdot A_{fr}$$

4. Wind forces on overhead line components

4.1. Wind forces on conductors

4.2. Wind forces on insulator sets

4.3. Wind forces on lattice tower

Wind forces on the tower itself can be determined by 2 methods :

(1) The tower is divided into several sections :

The force component acting in the wind direction :

$$Q_{wt} = q_p(h)G_t(1 + 0,2 \sin^2 2\phi)(C_{t1}A_{t1} \cos^2 \phi + C_{t2}A_{t2} \sin^2 \phi)$$

Where C_{t1} and C_{t2} are the drag factor for the lattice tower panel face 1 and 2, A_{t1} and A_{t2} are the effective areas of the elements of lattice tower panel face 1 and 2, ϕ is the angle between wind direction and the longitudinal axis of the lattice cross-arm and

G_t is the structural factor for lattice tower and is defined as

$$G_t = \frac{1+6I_v(h)\sqrt{B^2}}{1+7I_v(h)}$$

With

$$B^2 = \frac{1}{1+\frac{3}{2} \times \frac{H_t}{L(H)}}$$

Where H_t is the total height of the tower and $L(H)$ is the turbulent length and is given in Annex B of EN 1991-1-4:2005

Not covered in EN1994-1-1

see point 3

$c_s c_d$ the structural factor is defined as

$$G_t = \frac{1+2k_p I_v(z_s)\sqrt{B^2+R^2}}{1+7I_v(z_s)}$$

With

$$B^2 = \frac{1}{1+0,9\left(\frac{b+h}{L(z_s)}\right)^{0,63}}$$

Where b and h are the width and height of the structure and $L(z_s)$ is the turbulent length. Using $B^2=1$ is on the safe side.

k_p is the peak factor and is defined as

$$k_p = \sqrt{2 \cdot \ln(\nu T)} + \frac{0,6}{\sqrt{2 \cdot \ln(\nu T)}} \text{ or } k_p = 3, \text{ whichever is larger}$$

For lattice cross-arms :

$$Q_{wtc} = q_p(h)G_{tc}A_{tc}(\sin \phi + 0,4 \cos \phi)$$

Where the structural factor G_{tc} is recommended to 1 and C_{tc} is defined as (like C_{t1} and C_{t2})

$$C_{tc} = 3,96(1 - 1,5\chi + \chi^2)$$

With the solidity ratio χ .

(2) each individual member of the tower considered :

Wind force :

$$Q_{Wm} = q_p(h)G_m C_m A_m \cos^2 \phi$$

R^2 is the resonance response factor and is defined as

$$R^2 = \frac{\pi^2}{2\delta} S_L(z_s, n_{1,x}) R_h(\eta_h) R_b(\eta_b)$$

With

δ the total logarithmic decrement of damping defined in annex F.5 of EN1991-1-4:2005,

S_L the non-dimensional power spectral density function and is defined in annex B.1 of EN1991-1-4:2005 and

R_h and R_b are the aerodynamic admittance functions and are defined in annex B.2 of EN1991-1-4:2005.

The force coefficient of lattice structures is defined as

$$c_f = c_{f,0} \cdot \psi_\lambda$$

With $c_{f,0}$, the force coefficient of lattice structures without end-effects. It is given by Figures 7.33 to 7.35 as a function of solidity ratio $\varphi = A/A_c$ and Reynolds number Re . And with ψ_λ , the end-effect factor as a function of the slenderness of the structure.

Low probability of ice load, I_T with a theoretical return period of T years is defined as $I_T = \gamma_I I_{50}$
Where γ_I is the partial factor of ice load.

Associated with icing, the high probability wind velocity, V_{IH} is equal to $V_{IH} = V_3 B_I$
Where V_3 is the wind velocity with a theoretical return period of T = 3 years and B_I is a reduction factor depending on the type of ice.

Or is equal to $V_{IH} = V_{50} \sqrt{\Psi_W}$
Where Ψ_W is the combination factor for wind loads and includes the effect of the reduction factor B_I .

- Nominal (or high probability) ice load, I_3 combined with a low probability wind velocity, V_{IL} :

High probability of ice load, I_3 with a theoretical return period of 3 years is defined $I_3 = \Psi_I I_{50}$
Where Ψ_I is the combination factor for ice loads.

Associated with icing, the low probability wind velocity, V_{IL} is determined as $V_{IL} = V_T B_I = (V_{50} \sqrt{\gamma_W}) B_I$
Where γ_W is the partial factor for wind loads and V_T the extreme wind velocity with a return period of T years.

- Dominant ice and accompanying wind:

$$\gamma_G G_k + \gamma_{ice} Q_{k,ice} + \gamma_W k \Psi_W Q_{k,W}$$

Where γ_G , γ_{ice} and γ_W are the partial factor on dead loads, ice loads and wind loads and k is a factor given in ISO 12494 depending on the Ice Class.

SUPPORT	EN1993
1. Materials	

Structural steel : EN1993-1-1
Bolts, nuts, washers, and welding
consumables : EN 1993-1-8
Cold formed steel : EN 1993-1-3

2. Lattice tower

Refers to self-supporting lattice towers
predominantly made of angle members
with bolted connections.

The general requirements of the relevant
parts of EN 1993 shall be complied with,
except where otherwise specified below.

3. Ultimate limit states

3.1. Resistance of cross-section areas.

Based on EN 1993-1-1

3.2. Tension, bending, and compression resistance of members

Based on EN 1993-1-1:2005.

Except: tension resistance for angles
connected through one leg: Annex J.3 of
EN50341.

(a) Case of one leg connected with one
bolt:

$$N_{u,Rd} = \frac{(b_1 - d_0) \cdot t \cdot f_u}{\gamma_{M2}}$$

(b) Case of one leg connected with 2 or
more bolts:

$$N_{u,Rd} = \frac{(b_1 - d_0 + b_2/2) \cdot t \cdot f_u}{\gamma_{M2}}$$

3.2. Tension, bending, and compression resistance of members

EN1993-1-8:2005.

(a) With one bolt:

$$N_{u,Rd} = \frac{2(e_2 - 0.5d_0) \cdot t \cdot f_u}{\gamma_{M2}}$$

(b) With 2 bolts :

$$N_{u,Rd} = \frac{\beta_2 A_{net} f_u}{\gamma_{M2}}$$

(c) With 3 bolts or more :

$$N_{u,Rd} = \frac{\beta_3 A_{net} f_u}{\gamma_{M2}}$$

Where

b_1 and b_2 are the dimensions of the section
 d_0 is the hole diameter
 t is the thickness
 f_u is the ultimate tensile strength.
 γ_{M2} is the partial factor for resistance of net section equal to 1,25.

3.3. Buckling resistance of members in compression

(a) Compression members Annex J.4 of EN50341 only if Full-scale tests (if not, Annex G and Annex H of EN 1993-3-1:2005.) .

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1$$

Where

$N_{b,Rd}$ is the design buckling resistance of the compression member and is defined as

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}}$$

for Class 1,2,3 cross-sections

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}} \text{ for Class 4 cross-sections}$$

With γ_{M1} the partial factor for resistance of member to buckling equal to 1 and χ the reduction factor, defined for axial compression as

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \lambda_{eff}^2}}$$

With

$$\Phi = 0,5 \times [1 + \alpha(\lambda_{eff}^- - 0,2) + \lambda_{eff}^2]$$

Where α is the imperfection factor equal to 0,13 due to the buckling curve a_0 .

λ_{eff}^- is defined as

Where

β_2 and β_3 are reduction factors dependent on the pitch, p_1 as given in Table 3.8 of EN1993-1-8:2005.

A_{net} is the net area of the angle.

f_u is the ultimate tensile strength.

γ_{M2} is the partial factor for resistance of net section equal to 1,25.

3.3. Buckling resistance of members in compression

Annex G and Annex H of EN 1993-3-1:2005.

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1$$

Where

$N_{b,Rd}$ is the design buckling resistance of the compression member and is defined as

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}}$$

for Class 1,2,3 cross-sections

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}} \text{ for Class 4 cross-sections}$$

With γ_{M1} the partial factor for resistance of member to buckling equal to 1,1 and χ the reduction factor, defined for axial compression as

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \lambda_{eff}^2}}$$

With

$$\Phi = 0,5 \times [1 + \alpha(\lambda_{eff}^- - 0,2) + \lambda_{eff}^2]$$

Where α is the imperfection factor equal to 0,34 due to the buckling curve b .

λ_{eff}^- is defined as

- For leg member: $\lambda_{eff}^- = \bar{\lambda}$
- For bracing member : 5 cases of linear transformation of $\bar{\lambda}$ defined in tables J.1 and J.2 in EN50341.

$\bar{\lambda}$ is defined as

$$\bar{\lambda} = \frac{\lambda}{\lambda_1} \text{ for class 1,2,3}$$

$$\bar{\lambda} = \frac{\lambda}{\lambda_1} \times \sqrt{\frac{A_{eff}}{A}} \text{ for class 4}$$

With λ defined as

- For leg members and chords with symmetrical bracing or intermediate transverse support: $\lambda = L/i_{vv}$
- For leg members and chords with staggered bracing : $\lambda = 1, 2 \times L/i_{vv}$
- For primary bracing members : $\lambda = L_{di}/i_{vv}$ with L_{di} is defined in Figure H.1 of EN 1993-3-1:2006.

Except : Horizontal edge members with horizontal plan bracing :

Alternative to H.3.9 (5) of EN1993-3-1:2005 :

The horizontal plan bracing has to resist a concentrated horizontal load $F = 1,5 L$ placed in the middle of the horizontal member, where: L = length of the horizontal edge member."

Deflection of the horizontal bracing under this load is limited to $L / 1\,000$.

Except : Horizontal edge members without horizontal plan bracing :

For all members: $\lambda_{eff}^- = k \times \bar{\lambda}$

Different cases for k defined in annex G.2 of EN1993-3-1.

$\bar{\lambda}$ is defined as

$$\bar{\lambda} = \frac{\lambda}{\lambda_1} \text{ for all classes}$$

With λ defined as

- For leg members : $\lambda = L/i_{vv}$
Where L is the buckling length of the member.

- For primary bracing members : $\lambda = L_{di}/i_{vv}$
with L_{di} is defined in figure H.1 of EN 1993-3-1:2006.

Horizontal edge members with horizontal plan bracing :

H.3.9 (5) of EN1993-3-1:2005 : "The horizontal plan bracing should be designed to resist a concentrated horizontal force of $p \times H$ applied at the middle of the member where p is the percentage of the maximum axial compression force, H , in the members of the horizontal plan bracing."

Deflection of the horizontal bracing under this load is limited to $L / 500$.

Horizontal edge members without horizontal plan bracing :

“For buckling transverse to the frame and when the horizontal member has compression in one half of its length and tension in the other, an effective reduced length, L_{eff} may be used instead of L_{th} to determine λ according to the following formula: $L_{eff} = kL_{th}$ “

- For secondary bracing members : annex H.4 of EN 1993-3-1:2006

Alternative formula for the percentage p of H.4 (2) of 1993-3-1:2005 :

$$p = (\lambda + 32)/60 \text{ with } 1 \leq p \leq 3,5$$

(b) The torsional and/or flexural-torsional mode :

Same verification as for compression but using the effective area defines as :

$$A_{eff} = A - 2t(1 - \rho)h$$

where the reduction factor is defined as

$$\rho = 1 \text{ if } \bar{\lambda}_p \leq 0,748$$

$$\rho = \frac{\bar{\lambda}_p - 0,188}{\bar{\lambda}_p} \leq 1 \text{ if } \bar{\lambda}_p > 0,748$$

With $\bar{\lambda}_p = \frac{(b-2t/t)}{28,4\varepsilon\sqrt{k_\sigma}}$ where $k_\sigma = 0,43$ and $\varepsilon = \sqrt{\frac{235}{f_y}}$.

3.4 Buckling resistance of members in bending

Part 6.3.2 EN 1993-1-1

3.5 Resistance of connections

EN 1993-1-8

Bolted connections in lattice towers :
Clause 3 of EN 1993-1-8:2005 or

- For secondary bracing members :

(b) The torsional and/or flexural-torsional mode : Part 6.3.1.4 of EN1993-1-1,

Same verification as for compression but using the non-dimensional slenderness for torsional-flexural buckling defined as

$$\bar{\lambda}_T = \sqrt{\frac{Af_y}{N_{cr,TF}}} \text{ for class 1,2,3}$$

$$\bar{\lambda}_T = \sqrt{\frac{A_{eff}f_y}{N_{cr,TF}}} \text{ for class 4}$$

Where $N_{cr,TF}$ is the elastic torsional-flexural buckling force.

3.4 Buckling resistance of members in bending

Part 6.3.2 EN 1993-1-1

3.5 Resistance of connections

EN 1993-1-8

Bolted connections in lattice towers :

Annex J.5 of EN50341 :

The design resistance for an individual fastener subjected to shear and/or tension is given in Table J.3. of EN50341. When filler plate is used for packing, the design shear resistance of bolts should be reduced with a reduction factor β_p

$$\beta_p = \frac{9d}{8d+3t_p}$$

Block tearing resistance of bolted connections :

For gussets plates with a bolt group subject to concentric loading, the design block shearing resistance $V_{eff,1,Rd}$ is given by:

$$V_{eff,1,Rd} = 0,95 \left(\frac{f_u A_{nt}}{\gamma_{M2}} + \frac{0,5 f_u A_{gv}}{\gamma_{M2}} \right)$$

For an angle section with a bolt group subject to eccentric loading, the design block shearing resistance $V_{eff,2,Rd}$ is given by:

$$V_{eff,2,Rd} = 0,80 \left(\frac{f_u A_{nt}}{\gamma_{M2}} + \frac{0,5 f_u A_{gv}}{\gamma_{M2}} \right)$$

Where A_{nt} is the net cross-section area subjected to tension and A_{gv} is the gross cross-section area subjected to shear.

ANNEX B : CONVERSION OF WIND VELOCITIES AND ICE LOADS

1. Evaluation of extreme wind velocity data

Clause 3 of EN 1993-1-8:2005 :

The design resistance for an individual fastener subjected to shear and/or tension is given in Table 3.4. of EN1993-1-8:2005. When filler plate is used for packing, the design shear resistance of bolts should be reduced with a reduction factor β_p

$$\beta_p = \frac{9d}{8d+3t_p}$$

Block tearing resistance of bolted connections :

For a symmetric bolt group subject to concentric loading the design block tearing resistance, given by:

$$V_{eff,1,Rd} = \frac{f_u A_{nt}}{\gamma_{M2}} + \frac{1}{\sqrt{3}} \frac{f_y A_{nv}}{\gamma_{M0}}$$

For a bolt group subject to eccentric loading the design block shear tearing resistance $V_{eff,2,Rd}$ is given by:

$$V_{eff,1,Rd} = 0,5 \frac{f_u A_{nt}}{\gamma_{M2}} + \frac{1}{\sqrt{3}} \frac{f_y A_{nv}}{\gamma_{M0}}$$

Where A_{nt} is the net area subjected to tension and A_{nv} is the net area subjected to shear.

EN1993-1-4

Note 4 of part 4.2

Conversion of the extreme velocity, V_{50} , associated with a reference 50-years return period, into another wind velocity, V_T associated with another return period T can be made using the conversion factor, C_T (probability factor, C_{prob} in EN 1991-1-4) given by :

$$C_T = \frac{V_T}{V_{50}} = \left(\frac{1-K_{sp} \ln(-\ln(1-1/T))}{1-K_{sp} \ln(-\ln(1-1/50))} \right)^n$$

Where T is the return period, n is the exponent, recommended equal to 1 and K_{sp} is the shape parameter and is defined as

$$K_{sp} = \frac{\nu_w}{C_1 - C_2 \cdot \nu_w}$$

The 10 minutes mean wind velocity having the probability p for an annual exceedance is determined by multiplying the basic wind velocity v_b by the probability factor, c_{prob} given by :

$$C_{prob} = \left(\frac{1-K \ln(-\ln(1-p))}{1-K \ln(-\ln(0,98))} \right)^n$$

Where n is the exponent, recommended equal to 0,5 and K is the shape parameter recommended equal to 0,2

Appendix B

Internal forces in embedded nodes

Angle Label	Group Label	Torsion (N-m)	Origin X Moment (N-m)	Origin Y Moment (N-m)	End X Moment (N-m)	End Y Moment (N-m)	X Shear (N)	Y Shear (N)	Axial Force (N)
1P	1	0	-34230.89	38897.86	-34230.89	38897.86	-67463.11	76660.9	-2636682.48
1X	1	0	26836.31	50845.41	26836.31	50845.41	52889.68	100207.42	1849419.82
1XY	1	0	35709.93	-34510.18	35709.93	-34510.18	70378.05	-68013.54	2381372.44
1Y	1	0	-24925.8	-46510.61	-24925.8	-46510.61	-49124.41	-91664.29	-2113218.56
F1389P	1	0	-58061.46	32903.07	-58061.46	32903.07	-114429.01	64846.21	-2627648.43
F1389X	1	0	43509.06	42567.3	43509.06	42567.3	85748.76	83892.71	1847325.35
F1389XY	1	0	56532.29	-29560.11	56532.29	-29560.11	111415.28	-58257.81	2377215.97
F1389Y	1	0	-44807.91	-39275.84	-44807.91	-39275.84	-88308.57	-77405.84	-2106494.58
F1390P	1	0	-91511.46	41812.25	-91511.46	41812.25	-180353.11	82404.65	-2636717.55
F1390X	1	0	68011.77	53964.73	68011.77	53964.73	134039.34	106355.06	1855262.55
F1390XY	1	0	88013	-37531.49	88013	-37531.49	173458.26	-73968.01	2387204.64
F1390Y	1	0	-71251.71	-49734.36	-71251.71	-49734.36	-140424.68	-98017.75	-2113505.36
7P	6	0	-183.99	28288.02	-183.99	28288.02	-300.37	46182.24	-399646.93
7X	6	0	-5506.68	28783.17	-5506.68	28783.17	-8990.05	46990.62	224296.47
7XY	6	0	1040.46	-28323.67	1040.46	-28323.67	1698.62	-46240.45	322960.28
7Y	6	0	6188.18	-28511.89	6188.18	-28511.89	10102.65	-46547.73	-361935.12
F7393P	6	0	-1846.64	30802.16	-1846.64	30802.16	-3014.78	50286.77	-400286.16
F7393X	6	0	-4859.04	30287.39	-4859.04	30287.39	-7932.73	49446.37	225703.43
F7393XY	6	0	2382.1	-30346.35	2382.1	-30346.35	3888.96	-49542.62	324778.56
F7393Y	6	0	4703.34	-30879.57	4703.34	-30879.57	7678.54	-50413.14	-362213.3
F7P	6	0	-3159.4	25059.04	-3159.4	25059.04	-4384.25	34774.09	-106283.38
F7X	6	0	-2355.78	25456.26	-2355.78	25456.26	-3269.09	35325.31	4862.23
F7XY	6	0	3898.86	-25605.58	3898.86	-25605.58	5410.39	-35532.53	28583.81
F7Y	6	0	1435.42	-25214.06	1435.42	-25214.06	1991.92	-34989.21	-79970.11
FF7P	6	0	-2232.82	25649.34	-2232.82	25649.34	-3098.45	35593.25	-106906.44
FF7X	6	0	-3808.67	25576.88	-3808.67	25576.88	-5285.24	35492.69	6163.31
FF7XY	6	0	2553.84	-25801.6	2553.84	-25801.6	3543.94	-35804.53	30346.09
FF7Y	6	0	2638.57	-25688.93	2638.57	-25688.93	3661.51	-35648.19	-80127.02
F7381P	6	0	-5029.18	37926.95	-5029.18	37926.95	-10736.82	80970.33	-272539.84
F7381X	6	0	-2999.58	38028.64	-2999.58	38028.64	-6403.81	81187.43	128290.94

F7381XY	6	0	6065.91	-38080.18	6065.91	-38080.18	12950.12	-81297.48	149769.66
F7381Y	6	0	3846.5	-38316.73	3846.5	-38316.73	8211.91	-81802.49	-151756.44
FF7381P	6	0	-7079.99	39484.14	-7079.99	39484.14	-15115.08	84294.79	-273632.64
FF7381X	6	0	-2119.3	38701.4	-2119.3	38701.4	-4524.51	82623.72	129947.02
FF7381XY	6	0	7076.54	-38904.08	7076.54	-38904.08	15107.72	-83056.41	151946.71
FF7381Y	6	0	2652.69	-39104.91	2652.69	-39104.91	5663.22	-83485.17	-152230.21
g381P	8	0	902.74	342.2	902.74	342.2	812.7	308.07	295974.16
g381X	8	0	-358.47	-168.05	-358.47	-168.05	-322.72	-151.29	-327859.2
g381XY	8	0	-551.12	-561.07	-551.12	-561.07	-496.16	-505.12	-293502.74
g381Y	8	0	516.81	435.77	516.81	435.77	465.27	392.31	299358.46
Fg381P	8	0	519.52	16.22	519.52	16.22	424.96	13.27	271813.96
Fg381X	8	0	-662.59	87.09	-662.59	87.09	-542	71.24	-287926.59
Fg381XY	8	0	-565.84	-210.15	-565.84	-210.15	-462.86	-171.9	-261986.68
Fg381Y	8	0	655.48	79.85	655.48	79.85	536.18	65.32	264822.54
iFg381PP	8	0	667.87	905.61	667.87	905.61	668.49	906.44	271740.83
iFg381PX	8	0	-499.55	-97.19	-499.55	-97.19	-500.01	-97.28	-284600.69
iFg381PXY	8	0	-656.79	-817.17	-656.79	-817.17	-657.39	-817.92	-258809.74
iFg381PY	8	0	608.37	-288.3	608.37	-288.3	608.94	-288.57	264092.26
Fg381383P	8	0	5381.99	1381.66	5381.99	1381.66	4845.21	1243.86	213786.71
Fg381383X	8	0	-4488.37	580.58	-4488.37	580.58	-4040.72	522.68	-237217.03
Fg381383XY	8	0	-5043	-1129.46	-5043	-1129.46	-4540.03	-1016.82	-203724.1
Fg381383Y	8	0	4637.5	-1122.43	4637.5	-1122.43	4174.98	-1010.49	214960.68
g382P	8	0	1434.68	1758.54	1434.68	1758.54	1291.59	1583.15	-121687.02
g382X	8	0	-1431.35	1677.12	-1431.35	1677.12	-1288.6	1509.85	23995.57
g382XY	8	0	-1132.27	-1626.56	-1132.27	-1626.56	-1019.34	-1464.33	122736.23
g382Y	8	0	1566.56	-1760.53	1566.56	-1760.53	1410.32	-1584.95	-51594.93
Fg382P	8	0	-665.03	1180.79	-665.03	1180.79	-543.99	965.89	-74538.33
Fg382X	8	0	464.24	911.18	464.24	911.18	379.75	745.34	-9211.7
Fg382XY	8	0	575.49	-913.14	575.49	-913.14	470.75	-746.94	82622.6
Fg382Y	8	0	-526.48	-1206.67	-526.48	-1206.67	-430.66	-987.05	-12859.47
iFg382PP	8	0	577.32	1829.03	577.32	1829.03	577.86	1830.72	-70118.6
iFg382PX	8	0	-563.25	2215.53	-563.25	2215.53	-563.77	2217.58	-8659.92
iFg382PXY	8	0	-501.53	-2266.46	-501.53	-2266.46	-502	-2268.56	81041.26
iFg382PY	8	0	711.38	-2095.77	711.38	-2095.77	712.04	-2097.71	-10170.1
Fg382386P	8	0	2280.81	2272.32	2280.81	2272.32	2053.33	2045.69	-100337.39
Fg382386X	8	0	-3190.09	2617.3	-3190.09	2617.3	-2871.92	2356.26	32737.74
Fg382386XY	8	0	-1883.53	-2519.59	-1883.53	-2519.59	-1695.67	-2268.3	108409.97
Fg382386Y	8	0	3383.98	-2683.19	3383.98	-2683.19	3046.47	-2415.58	-53175.81
g392P	54	0	-127.03	69.71	-127.03	69.71	-123.41	67.73	21999.11
g392X	54	0	155.2	37.82	155.2	37.82	150.78	36.75	-29846.14
g392XY	54	0	127.51	-65.24	127.51	-65.24	123.88	-63.38	-24704.34
g392Y	54	0	-150.62	-27.23	-150.62	-27.23	-146.33	-26.46	27190.53
g393P	54	0	123.54	136.34	123.54	136.34	120.02	132.46	-26526.09
g393X	54	0	-81.1	145.69	-81.1	145.69	-78.79	141.54	17457.75
g393XY	54	0	-119.04	-124.39	-119.04	-124.39	-115.64	-120.84	23944.31
g393Y	54	0	88.77	-142.02	88.77	-142.02	86.24	-137.97	-20138.68
g394P	55	0	-96.09	1.38	-96.09	1.38	-80.05	1.15	6630.95
g394X	55	0	103.34	-15.43	103.34	-15.43	86.1	-12.86	-4795.02
g394XY	55	0	92.31	-13.46	92.31	-13.46	76.91	-11.22	-5799.23
g394Y	55	0	-100.96	26.63	-100.96	26.63	-84.11	22.18	3686.03
g395P	55	0	138.19	-1.02	138.19	-1.02	135.06	-1	-21185.05
g395X	55	0	-152.82	18.41	-152.82	18.41	-149.36	17.99	24125.92
g395XY	55	0	-136.62	-20.27	-136.62	-20.27	-133.52	-19.81	22099.42
g395Y	55	0	146.56	-10.13	146.56	-10.13	143.24	-9.9	-21088.41
g396P	55	0	40.27	75.05	40.27	75.05	33.55	62.53	7990.19
g396X	55	0	-13.67	64.9	-13.67	64.9	-11.39	54.07	-9996.7
g396XY	55	0	-41.81	-66.85	-41.81	-66.85	-34.84	-55.69	-7313.91
g396Y	55	0	18.08	-74.29	18.08	-74.29	15.07	-61.89	8974.8
g397P	55	0	-64.54	-79.01	-64.54	-79.01	-63.08	-77.22	7453.37
g397X	55	0	23.73	-81.1	23.73	-81.1	23.19	-79.26	543.74
g397XY	55	0	64.11	77.09	64.11	77.09	62.65	75.34	-6460.62

g397Y	55	0	-32.15	68.71	-32.15	68.71	-31.42	67.15	2389.64
g398P	56	0	-312.7	9.71	-312.7	9.71	-300.93	9.34	-50738.7
g398X	56	0	-370.53	19	-370.53	19	-356.58	18.29	59744.07
g398XY	56	0	318.7	-52.79	318.7	-52.79	306.7	-50.8	52045.09
g398Y	56	0	352.15	8.01	352.15	8.01	338.89	7.71	-55799.73
g399P	56	0	-147.23	-12.53	-147.23	-12.53	-156.69	-13.33	1448.38
g399X	56	0	-124.73	-26.56	-124.73	-26.56	-132.75	-28.27	8206.9
g399XY	56	0	124.93	-26.07	124.93	-26.07	132.95	-27.75	3628.13
g399Y	56	0	132.67	49.44	132.67	49.44	141.2	52.61	-6629.02
g400P	56	0	-230.84	-1.17	-230.84	-1.17	-222.15	-1.12	34895.53
g400X	56	0	-130.07	-15.35	-130.07	-15.35	-125.17	-14.77	-18427.11
g400XY	56	0	220.23	11.3	220.23	11.3	211.94	10.87	-33600.74
g400Y	56	0	154.02	-12.44	154.02	-12.44	148.22	-11.97	22282.2
g401P	56	0	37.21	34.5	37.21	34.5	39.6	36.71	29168.2
g401X	56	0	62.61	14.83	62.61	14.83	66.64	15.78	-26137.24
g401XY	56	0	-19.64	-26.78	-19.64	-26.78	-20.91	-28.5	-24414.65
g401Y	56	0	-66.73	-40.2	-66.73	-40.2	-71.02	-42.78	27910.54
g402P	79	0	296.36	10.71	296.36	10.71	212.35	7.67	-1013.48
g402X	79	0	371.46	8.02	371.46	8.02	266.15	5.74	2685.16
g402XY	79	0	370.56	-15.44	370.56	-15.44	265.51	-11.06	1657.2
g402Y	79	0	295.25	-16.28	295.25	-16.28	211.55	-11.66	-2610.72
Fg402P	79	0	-358.65	-31.8	-358.65	-31.8	-256.98	-22.78	-1105.09
Fg402X	79	0	-325.91	7.08	-325.91	7.08	-233.52	5.07	2196.29
Fg402XY	79	0	-313.42	-16.38	-313.42	-16.38	-224.57	-11.73	443.34
Fg402Y	79	0	-345.94	27.23	-345.94	27.23	-247.87	19.51	-3428.26
g404P	80	0	408.46	-8.57	408.46	-8.57	291	-6.1	-536.49
g404X	80	0	232.93	8.89	232.93	8.89	165.94	6.33	-882.06
g404XY	80	0	248.9	-16.93	248.9	-16.93	177.33	-12.06	-829.21
g404Y	80	0	424.91	5.73	424.91	5.73	302.72	4.08	-489.84
g383P	9	0	3444.23	1035.09	3444.23	1035.09	3407.75	1024.13	287006.33
g383X	9	0	-2523.16	172.37	-2523.16	172.37	-2496.43	170.54	-302324.55
g383XY	9	0	-2961.75	-1170.62	-2961.75	-1170.62	-2930.38	-1158.22	-274900.51
g383Y	9	0	2778.23	-112.76	2778.23	-112.76	2748.81	-111.56	276999.31
Fg383P	9	0	1734.63	557.09	1734.63	557.09	858.13	275.59	259921.5
Fg383X	9	0	-1733.24	39.64	-1733.24	39.64	-857.44	19.61	-257065.57
Fg383XY	9	0	-1730.58	-773.59	-1730.58	-773.59	-856.13	-382.7	-239323.28
Fg383Y	9	0	1767.69	-239.15	1767.69	-239.15	874.48	-118.31	237741.45
Fg383385P	9	0	8446.05	1087.21	8446.05	1087.21	8356.6	1075.7	206427.49
Fg383385X	9	0	-7617.04	845.23	-7617.04	845.23	-7536.37	836.28	-216550.22
Fg383385XY	9	0	-8080.98	-1042.81	-8080.98	-1042.81	-7995.4	-1031.77	-189710.84
Fg383385Y	9	0	7802.92	-1104.65	7802.92	-1104.65	7720.28	-1092.96	194560.36
g384P	9	0	2435.39	2211.79	2435.39	2211.79	2409.6	2188.37	-71655.03
g384X	9	0	-2823.09	2463.88	-2823.09	2463.88	-2793.2	2437.78	-12522.27
g384XY	9	0	-1965.03	-2352.95	-1965.03	-2352.95	-1944.22	-2328.03	81540.66
g384Y	9	0	3085.52	-2407.73	3085.52	-2407.73	3052.84	-2382.23	-11038.27
Fg384P	9	0	-241.74	1941.21	-241.74	1941.21	-119.59	960.32	-16012.28
Fg384X	9	0	-125.13	2042.22	-125.13	2042.22	-61.9	1010.3	-52263.7
Fg384XY	9	0	260.68	-2170.22	260.68	-2170.22	128.96	-1073.62	33914.06
Fg384Y	9	0	143.66	-2252.66	143.66	-2252.66	71.07	-1114.4	35095.18
Fg384387P	9	0	1509.09	1869.62	1509.09	1869.62	1493.11	1849.82	-54437.01
Fg384387X	9	0	-3125.74	1958.73	-3125.74	1958.73	-3092.64	1937.99	-5123.09
Fg384387XY	9	0	-1117.26	-1828.92	-1117.26	-1828.92	-1105.43	-1809.55	68353.78
Fg384387Y	9	0	3288.74	-2221.22	3288.74	-2221.22	3253.91	-2197.7	-14521.95
g389P	54	0	-216.29	217.12	-216.29	217.12	-224.15	225.01	21640.22
g389X	54	0	262.23	118.13	262.23	118.13	271.76	122.42	-31030.59
g389XY	54	0	217.2	-204.29	217.2	-204.29	225.09	-211.72	-24964.5
g389Y	54	0	-264.95	-101.18	-264.95	-101.18	-274.58	-104.86	27907.95
g390P	54	0	216.17	390.91	216.17	390.91	224.02	405.12	-31617.18
g390X	54	0	-158.75	431.95	-158.75	431.95	-164.52	447.65	21920.75
g390XY	54	0	-215.3	-377.8	-215.3	-377.8	-223.12	-391.54	28480.16
g390Y	54	0	156.16	-414.34	156.16	-414.34	161.83	-429.4	-25184.03

g391P	55	0	-220.92	46.79	-220.92	46.79	-201.94	42.77	8986.99
g391X	55	0	220.59	-19.82	220.59	-19.82	201.64	-18.12	-6741.57
g391XY	55	0	215.75	-46.19	215.75	-46.19	197.22	-42.22	-7864.33
g391Y	55	0	-220.62	24.01	-220.62	24.01	-201.67	21.95	5665.17
g403P	55	0	297.1	-37.32	297.1	-37.32	319.69	-40.15	-21406.32
g403X	55	0	-299.02	-11.02	-299.02	-11.02	-321.76	-11.85	23747.33
g403XY	55	0	-294.54	24.82	-294.54	24.82	-316.93	26.71	21798.41
g403Y	55	0	293.31	-0.23	293.31	-0.23	315.61	-0.25	-20981.99
g406P	55	0	25.31	212.17	25.31	212.17	23.13	193.95	9178.86
g406X	55	0	24.66	217.2	24.66	217.2	22.54	198.55	-11331.17
g406XY	55	0	-30.8	-211.82	-30.8	-211.82	-28.16	-193.62	-8240.29
g406Y	55	0	-24.15	-213.17	-24.15	-213.17	-22.08	-194.86	10415.37
g407P	55	0	-28.18	-189.85	-28.18	-189.85	-30.32	-204.29	6331.14
g407X	55	0	-44.36	-193.38	-44.36	-193.38	-47.73	-208.08	1079.33
g407XY	55	0	31.49	176.8	31.49	176.8	33.89	190.24	-5830.67
g407Y	55	0	37.68	181.36	37.68	181.36	40.55	195.15	1575.03
g408P	56	0	-620.34	66.34	-620.34	66.34	-660.2	70.6	-45055.26
g408X	56	0	-666	-25.92	-666	-25.92	-708.79	-27.59	55925.21
g408XY	56	0	627.28	-75.24	627.28	-75.24	667.58	-80.08	46947.86
g408Y	56	0	649.85	31.29	649.85	31.29	691.61	33.3	-51091.22
g409P	56	0	-462.59	-33.87	-462.59	-33.87	-546.55	-40.02	-1836.02
g409X	56	0	-406.61	-66.7	-406.61	-66.7	-480.41	-78.8	13610.72
g409XY	56	0	433.25	11.98	433.25	11.98	511.89	14.16	8145.38
g409Y	56	0	420.85	49.63	420.85	49.63	497.23	58.63	-11400.88
g410P	56	0	-209.3	221.04	-209.3	221.04	-222.75	235.24	39891.55
g410X	56	0	-46.34	233.6	-46.34	233.6	-49.31	248.61	-24022.38
g410XY	56	0	204.27	-230.42	204.27	-230.42	217.4	-245.22	-38029.64
g410Y	56	0	64.89	-228.7	64.89	-228.7	69.06	-243.39	28821.74
g411P	56	0	128.57	-59.41	128.57	-59.41	151.91	-70.19	36060.02
g411X	56	0	211.44	-66.04	211.44	-66.04	249.82	-78.03	-30788.65
g411XY	56	0	-98.69	36	-98.69	36	-116.6	42.54	-30219.03
g411Y	56	0	-224.7	47.24	-224.7	47.24	-265.48	55.81	33404.37
g412P	9	0	6498.12	1237.33	6498.12	1237.33	6992.18	1331.4	246363.78
g412X	9	0	-5624.37	184.42	-5624.37	184.42	-6052	198.45	-264638.66
g412XY	9	0	-5925.14	-1822.85	-5925.14	-1822.85	-6375.64	-1961.44	-232509.37
g412Y	9	0	5910.22	-151.74	5910.22	-151.74	6359.58	-163.28	233583.02
Fg412P	9	0	6134.07	859.08	6134.07	859.08	5911.21	827.87	220695.7
Fg412X	9	0	-6104.06	327.89	-6104.06	327.89	-5882.29	315.97	-221990.84
Fg412XY	9	0	-6094.89	-1531.45	-6094.89	-1531.45	-5873.46	-1475.81	-198317.58
Fg412Y	9	0	6206.06	-442.63	6206.06	-442.63	5980.59	-426.55	196967.94
iFg412PP	9	0	7782.9	1459.62	7782.9	1459.62	9480.01	1777.9	216459.54
iFg412PX	9	0	-7790.71	-194.82	-7790.71	-194.82	-9489.52	-237.3	-215673.31
iFg412PXY	9	0	-7849.87	-1825.73	-7849.87	-1825.73	-9561.58	-2223.84	-191444.19
iFg412PY	9	0	7917.26	-749.02	7917.26	-749.02	9643.67	-912.35	192305.17
Fg412404P	9	0	11855.93	1942.46	11855.93	1942.46	12757.36	2090.15	167491.09
Fg412404X	9	0	-11067.04	244.62	-11067.04	244.62	-11908.49	263.22	-178719.5
Fg412404XY	9	0	-11446.95	-2164.96	-11446.95	-2164.96	-12317.28	-2329.56	-146548.83
Fg412404Y	9	0	11198.36	-1356.14	11198.36	-1356.14	12049.79	-1459.25	152207.47
g413P	9	0	1671.07	4345.58	1671.07	4345.58	1798.13	4675.98	-70495.47
g413X	9	0	-2727.55	4474.83	-2727.55	4474.83	-2934.93	4815.06	-4992.05
g413XY	9	0	-1136.86	-4565.86	-1136.86	-4565.86	-1223.29	-4913.01	81259.98
g413Y	9	0	2970.14	-4840.93	2970.14	-4840.93	3195.96	-5208.99	-23640.17
Fg413P	9	0	-891.76	3711.84	-891.76	3711.84	-859.37	3576.98	-18905.69
Fg413X	9	0	-471.98	3695.56	-471.98	3695.56	-454.83	3561.29	-41467.5
Fg413XY	9	0	928.81	-3926.84	928.81	-3926.84	895.07	-3784.17	37577.12
Fg413Y	9	0	471.48	-4297.88	471.48	-4297.88	454.35	-4141.74	19315.54
iFg413PP	9	0	-865.04	4571.59	-865.04	4571.59	-1053.67	5568.45	-16536.24
iFg413PX	9	0	-785.23	5024.32	-785.23	5024.32	-956.46	6119.9	-38442.68
iFg413PXY	9	0	929.21	-5473.34	929.21	-5473.34	1131.83	-6666.83	37236.38
iFg413PY	9	0	889.9	-5438.56	889.9	-5438.56	1083.95	-6624.47	18965.01
Fg413406P	9	0	1210.25	5738.27	1210.25	5738.27	1302.27	6174.56	-51768.63

Fg413406X	9	0	-3508.62	6165.82	-3508.62	6165.82	-3775.39	6634.62	3656.8
Fg413406XY	9	0	-681.15	-6512.1	-681.15	-6512.1	-732.94	-7007.23	68248.28
Fg413406Y	9	0	3639.55	-6733.5	3639.55	-6733.5	3916.27	-7245.46	-25989.55
g414P	82	0	-24.59	14.35	-24.59	14.35	-21.81	12.73	-2471.66
g414X	82	0	479.59	10.99	479.59	10.99	425.48	9.75	4813.45
g414XY	82	0	510.7	-42.11	510.7	-42.11	453.08	-37.36	3668.39
g414Y	82	0	5.14	-43.83	5.14	-43.83	4.56	-38.89	-4564.38
Fg414P	82	0	-553.11	-49.36	-553.11	-49.36	-490.71	-43.79	-2521.72
Fg414X	82	0	-22.26	-21.44	-22.26	-21.44	-19.75	-19.02	4406
Fg414XY	82	0	63.21	-13.26	63.21	-13.26	56.08	-11.76	2125.02
Fg414Y	82	0	-466.25	22.16	-466.25	22.16	-413.65	19.66	-5771.6
g415P	83	0	-498.25	7.65	-498.25	7.65	-438.53	6.73	-498.76
g415X	83	0	49.6	14.74	49.6	14.74	43.65	12.97	-750.18
g415XY	83	0	17.89	-51.34	17.89	-51.34	15.74	-45.19	-1157.26
g415Y	83	0	-532.74	-28.3	-532.74	-28.3	-468.89	-24.91	-934
g416P	84	0	393.03	9.79	393.03	9.79	246.56	6.14	-588.45
g416Y	84	0	394.1	-42.65	394.1	-42.65	247.23	-26.76	-1698.77
g417P	57	0	341.56	227.84	341.56	227.84	353.98	236.12	20567.92
g417X	57	0	-380.91	149.13	-380.91	149.13	-394.76	154.55	-30245.14
g417XY	57	0	-335.13	-230.29	-335.13	-230.29	-347.32	-238.66	-24397.64
g417Y	57	0	380.45	-141.17	380.45	-141.17	394.28	-146.3	26605.79
g418P	57	0	221.03	338.46	221.03	338.46	229.06	350.77	-31752.35
g418X	57	0	-136.35	380.61	-136.35	380.61	-141.3	394.45	22068.89
g418XY	57	0	-225.5	-334.02	-225.5	-334.02	-233.7	-346.16	28187.29
g418Y	57	0	141.73	-379.7	141.73	-379.7	146.89	-393.51	-25876.53
g419P	58	0	-206.91	12.36	-206.91	12.36	-204.72	12.23	1923.63
g419X	58	0	205.92	-9.58	205.92	-9.58	203.74	-9.48	684.56
g419XY	58	0	201.68	-31.23	201.68	-31.23	199.54	-30.9	-222.12
g419Y	58	0	-206.5	6.63	-206.5	6.63	-204.31	6.56	-1412.26
g420P	58	0	-270.51	-17.86	-270.51	-17.86	-318.09	-21	-14585.78
g420X	58	0	272.95	16.61	272.95	16.61	320.96	19.53	17081.34
g420XY	58	0	268.49	-5.6	268.49	-5.6	315.72	-6.58	15061.83
g420Y	58	0	-269.41	-25.35	-269.41	-25.35	-316.8	-29.8	-14058.48
g421P	58	0	26.99	100.04	26.99	100.04	26.7	98.98	10426.1
g421X	58	0	19.14	96.66	19.14	96.66	18.94	95.63	-10472.46
g421XY	58	0	-31.75	-106.54	-31.75	-106.54	-31.41	-105.41	-9015.49
g421Y	58	0	-17.4	-113.17	-17.4	-113.17	-17.21	-111.98	9971.28
g422P	58	0	-35.51	-155.71	-35.51	-155.71	-41.76	-183.1	5769.74
g422X	58	0	-29.26	-159.27	-29.26	-159.27	-34.41	-187.29	-52.2
g422XY	58	0	37.51	144.6	37.51	144.6	44.11	170.03	-5132.89
g422Y	58	0	23.01	137.63	23.01	137.63	27.05	161.84	2894.06
g423P	59	0	-498.59	-7.79	-498.59	-7.79	-589.09	-9.2	-36472.77
g423X	59	0	-520.77	6.38	-520.77	6.38	-615.29	7.54	45952.16
g423XY	59	0	499.27	-45.75	499.27	-45.75	589.89	-54.05	38412.8
g423Y	59	0	512.47	-18.35	512.47	-18.35	605.49	-21.68	-41372.97
g424P	59	0	-430.97	-16.05	-430.97	-16.05	-572.24	-21.31	-5722.75
g424X	59	0	-403.45	-20.23	-403.45	-20.23	-535.7	-26.86	15890.5
g424XY	59	0	412.51	-30.64	412.51	-30.64	547.74	-40.69	11632.45
g424Y	59	0	413.21	7.12	413.21	7.12	548.66	9.45	-14016.83
g425P	59	0	133.07	-41.11	133.07	-41.11	157.22	-48.57	33931.67
g425X	59	0	8.88	-49.08	8.88	-49.08	10.49	-57.99	-20930.41
g425XY	59	0	-132.31	19.04	-132.31	19.04	-156.33	22.49	-32052.92
g425Y	59	0	-23.22	3.83	-23.22	3.83	-27.43	4.53	25482.37
g426P	59	0	-26.62	0.5	-26.62	0.5	-35.34	0.66	31717.99
g426X	59	0	-111.76	-11.62	-111.76	-11.62	-148.4	-15.43	-26072.63
g426XY	59	0	8.97	-20.21	8.97	-20.21	11.91	-26.83	-26396.3
g426Y	59	0	117.21	-31.22	117.21	-31.22	155.63	-41.46	28423.23
g427P	81	0	81.11	11.53	81.11	11.53	41.09	5.84	-694.49
g427Y	81	0	81.35	-21.02	81.35	-21.02	41.21	-10.65	-1172.6
g405P	10	0	6173.47	1306.11	6173.47	1306.11	7259.31	1535.84	248365.25
g405X	10	0	-5547.23	230.62	-5547.23	230.62	-6522.92	271.18	-267439.92

g405XY	10	0	-5758.83	-1477.09	-5758.83	-1477.09	-6771.74	-1736.89	-228987.52
g405Y	10	0	5721.96	-299.83	5721.96	-299.83	6728.38	-352.56	231815.09
Fg405P	10	0	3434.76	566.74	3434.76	566.74	2019.45	333.21	213479.42
Fg405X	10	0	-3475.17	-187.63	-3475.17	-187.63	-2043.2	-110.32	-213524.97
Fg405XY	10	0	-3425.52	-1000.39	-3425.52	-1000.39	-2014.01	-588.18	-183991.99
Fg405Y	10	0	3499.44	-256.97	3499.44	-256.97	2057.47	-151.08	183565.95
Fg405408P	10	0	10514.1	1441.38	10514.1	1441.38	12363.41	1694.91	160598.72
Fg405408X	10	0	-9733.98	935.59	-9733.98	935.59	-11446.07	1100.15	-174805.59
Fg405408XY	10	0	-10130.5	-1532.43	-10130.5	-1532.43	-11912.34	-1801.97	-136534.59
Fg405408Y	10	0	9976.09	-1282.72	9976.09	-1282.72	11730.77	-1508.33	140795.38
g428P	10	0	1241.77	3285.76	1241.77	3285.76	1460.18	3863.69	-75143.54
g428X	10	0	-2311.59	3528.5	-2311.59	3528.5	-2718.17	4149.12	3224.96
g428XY	10	0	-826.37	-3457.53	-826.37	-3457.53	-971.72	-4065.67	89817.25
g428Y	10	0	2485.31	-3598.45	2485.31	-3598.45	2922.44	-4231.38	-35049.5
Fg428P	10	0	-598.03	2963.24	-598.03	2963.24	-351.61	1742.22	-14815.7
Fg428X	10	0	-153.02	3046.82	-153.02	3046.82	-89.97	1791.36	-38967.65
Fg428XY	10	0	644.98	-3386.92	644.98	-3386.92	379.21	-1991.32	38251.1
Fg428Y	10	0	137.69	-3481.7	137.69	-3481.7	80.96	-2047.05	13983.59
Fg428410P	10	0	1078.56	2945.37	1078.56	2945.37	1268.27	3463.43	-55587.85
Fg428410X	10	0	-3043.3	3108.71	-3043.3	3108.71	-3578.58	3655.5	8206.58
Fg428410XY	10	0	-614.32	-3017.54	-614.32	-3017.54	-722.37	-3548.28	73149.71
Fg428410Y	10	0	3201.99	-3437.41	3201.99	-3437.41	3765.19	-4042.01	-36644.21
g429P	10	0	9314.2	1733.78	9314.2	1733.78	12023.08	2238.02	200528.33
g429X	10	0	-8558.59	305.87	-8558.59	305.87	-11047.72	394.82	-225611.9
g429XY	10	0	-8716.39	-2507.13	-8716.39	-2507.13	-11251.41	-3236.29	-177079.07
g429Y	10	0	8811.81	-517.4	8811.81	-517.4	11374.58	-667.88	179137.14
Fg429P	10	0	8805.53	1158.68	8805.53	1158.68	9866.23	1298.25	168029.39
Fg429X	10	0	-8735.2	238.03	-8735.2	238.03	-9787.42	266.7	-173740.22
Fg429XY	10	0	-8709.11	-2216.04	-8709.11	-2216.04	-9758.2	-2482.98	-132691.67
Fg429Y	10	0	8870.84	-678.42	8870.84	-678.42	9939.41	-760.14	132797.21
iFg429PP	10	0	11999.42	1636.29	11999.42	1636.29	18266.9	2490.95	155082.91
iFg429PX	10	0	-12197.7	-371.82	-12197.7	-371.82	-18568.75	-566.02	-160050.35
iFg429PXY	10	0	-12164.63	-2513.13	-12164.63	-2513.13	-18518.4	-3825.77	-120158.63
iFg429PY	10	0	12336.97	-1124.23	12336.97	-1124.23	18780.76	-1711.43	121789.19
Fg429412P	10	0	13826.6	1962.01	13826.6	1962.01	17847.84	2532.63	101486.7
Fg429412X	10	0	-13377.03	-296.51	-13377.03	-296.51	-17267.52	-382.74	-120983.81
Fg429412XY	10	0	-13439.49	-2759.45	-13439.49	-2759.45	-17348.14	-3561.99	-72588.01
Fg429412Y	10	0	13458.46	-1346.9	13458.46	-1346.9	17372.64	-1738.62	77483.71
g430P	10	0	959.26	6207.31	959.26	6207.31	1238.24	8012.61	-77669.46
g430X	10	0	-2606.73	6441.02	-2606.73	6441.02	-3364.86	8314.29	15444.52
g430XY	10	0	-379.32	-6629.49	-379.32	-6629.49	-489.64	-8557.57	94759.2
g430Y	10	0	2781.51	-6970.31	2781.51	-6970.31	3590.47	-8997.51	-55025.04
Fg430P	10	0	-1172.87	5488.08	-1172.87	5488.08	-1314.15	6149.17	-16823.98
Fg430X	10	0	-706.59	5578.44	-706.59	5578.44	-791.7	6250.41	-27224.11
Fg430XY	10	0	1318.4	-6050	1318.4	-6050	1477.22	-6778.77	43460.2
Fg430Y	10	0	668.55	-6427.62	668.55	-6427.62	749.08	-7201.88	-4503.58
iFg430PP	10	0	-1886.27	6267.98	-1886.27	6267.98	-2871.49	9541.85	-14412.06
iFg430PX	10	0	-704.52	6747.28	-704.52	6747.28	-1072.5	10271.48	-23836.45
iFg430PXY	10	0	2006.76	-7511.5	2006.76	-7511.5	3054.92	-11434.86	44413.68
iFg430PY	10	0	714.16	-7525.21	714.16	-7525.21	1087.18	-11455.74	-8480.7
Fg430414P	10	0	-86.74	8322.27	-86.74	8322.27	-111.97	10742.66	-56049.57
Fg430414X	10	0	-2581.68	8752.8	-2581.68	8752.8	-3332.52	11298.41	22832.27
Fg430414XY	10	0	728.22	-9486.16	728.22	-9486.16	940.01	-12245.05	78674.86
Fg430414Y	10	0	2567.02	-9643.82	2567.02	-9643.82	3313.6	-12448.56	-59030.39
g431P	85	0	-256.97	-20.21	-256.97	-20.21	-298.02	-23.44	3186.67
g431X	85	0	428.51	10.29	428.51	10.29	496.96	11.93	-7004.33
g431XY	85	0	519.97	-51.34	519.97	-51.34	603.04	-59.55	-6133.01
g431Y	85	0	-168.86	-26.39	-168.86	-26.39	-195.83	-30.6	8191.68
Fg431P	85	0	-429.49	-50.75	-429.49	-50.75	-498.1	-58.86	4727.94
Fg431X	85	0	125.27	-52.14	125.27	-52.14	145.28	-60.47	-5792.57
Fg431XY	85	0	170.43	4.37	170.43	4.37	197.66	5.07	-5738.82

Fg431Y	85	0	-380.96	0.4	-380.96	0.4	-441.82	0.47	8927.76
g432P	86	0	159.02	-59.63	159.02	-59.63	181.69	-68.13	-1118.99
g432X	86	0	-419.99	-40.38	-419.99	-40.38	-479.87	-46.14	-972.72
g432XY	86	0	-379.15	10.96	-379.15	10.96	-433.2	12.52	-855.43
g432Y	86	0	194.96	14.28	194.96	14.28	222.76	16.32	-1087.64
g433P	87	0	-487.13	-58.65	-487.13	-58.65	-399.48	-48.1	-1696.46
g433Y	87	0	-484.18	-4.34	-484.18	-4.34	-397.06	-3.56	-1067.68
g434P	60	0	-708.98	-212.54	-708.98	-212.54	-734.76	-220.27	34193.35
g434X	60	0	602.67	-426.47	602.67	-426.47	624.58	-441.97	-31546.44
g434XY	60	0	705.71	236.97	705.71	236.97	731.36	245.58	-38210.11
g434Y	60	0	-593.5	450.36	-593.5	450.36	-615.08	466.73	26823.97
g435P	60	0	396.11	-944.74	396.11	-944.74	410.51	-979.08	-30551.63
g435X	60	0	-542.13	-869.3	-542.13	-869.3	-561.84	-900.9	33903.59
g435XY	60	0	-394.05	967.53	-394.05	967.53	-408.37	1002.7	26005.02
g435Y	60	0	545.97	891.73	545.97	891.73	565.82	924.14	-37993.16
g436P	61	0	-320.23	28.87	-320.23	28.87	-344.58	31.07	4230.42
g436X	61	0	312.59	-48.5	312.59	-48.5	336.36	-52.19	-5743.63
g436XY	61	0	321.05	-30.78	321.05	-30.78	345.46	-33.12	-5203.76
g436Y	61	0	-314.07	48.96	-314.07	48.96	-337.95	52.68	7916.86
g437P	61	0	411.37	-50.49	411.37	-50.49	531.01	-65.18	-18621.81
g437X	61	0	-416.13	3.21	-416.13	3.21	-537.15	4.14	19196
g437XY	61	0	-418.61	32.27	-418.61	32.27	-540.35	41.66	21317.43
g437Y	61	0	414.23	-20.82	414.23	-20.82	534.7	-26.88	-19847.19
g438P	61	0	-9.33	-288.51	-9.33	-288.51	-10.03	-310.44	10327.94
g438X	61	0	-62.85	-284.94	-62.85	-284.94	-67.63	-306.61	-8110.65
g438XY	61	0	12.27	285.45	12.27	285.45	13.21	307.15	-10916.35
g438Y	61	0	59.25	284.38	59.25	284.38	63.76	306	9865.09
g439P	61	0	50.18	293.84	50.18	293.84	64.77	379.29	641.21
g439X	61	0	39.59	297.84	39.59	297.84	51.11	384.46	-4596.29
g439XY	61	0	-60.38	-310.98	-60.38	-310.98	-77.94	-401.42	1817.56
g439Y	61	0	-38.4	-314.27	-38.4	-314.27	-49.57	-405.67	4172.46
g440P	62	0	777.5	-68.85	777.5	-68.85	1032.37	-91.41	41786.95
g440X	62	0	794.93	27.18	794.93	27.18	1055.51	36.09	-44771.46
g440XY	62	0	-762.95	57.27	-762.95	57.27	-1013.05	76.04	-39541.54
g440Y	62	0	-809.98	-37.5	-809.98	-37.5	-1075.49	-49.79	50643.55
g441P	62	0	681.25	-11.99	681.25	-11.99	1032.4	-18.17	17458.9
g441X	62	0	674.54	-0.55	674.54	-0.55	1022.22	-0.84	-19995.87
g441XY	62	0	-698.1	-18.41	-698.1	-18.41	-1057.93	-27.9	-9727.86
g441Y	62	0	-665.65	-35.01	-665.65	-35.01	-1008.75	-53.06	21686.53
g442P	62	0	53.93	-271.53	53.93	-271.53	71.61	-360.54	30043.89
g442X	62	0	215.91	-268.27	215.91	-268.27	286.69	-356.21	-36551.29
g442XY	62	0	-32	260.31	-32	260.31	-42.48	345.63	-24062.68
g442Y	62	0	-223.54	256.03	-223.54	256.03	-296.82	339.96	38575.45
g443P	62	0	-187.28	97.94	-187.28	97.94	-283.81	148.42	32963.67
g443X	62	0	-18.93	99.03	-18.93	99.03	-28.68	150.07	-31351.09
g443XY	62	0	182.26	-133.8	182.26	-133.8	276.21	-202.76	-30231.17
g443Y	62	0	39.89	-129.44	39.89	-129.44	60.45	-196.16	37923.49
g444P	63	0	764.84	-525.84	764.84	-525.84	792.64	-544.96	-30137.77
g444X	63	0	-856.27	-342.18	-856.27	-342.18	-887.39	-354.62	31812.7
g444XY	63	0	-781.5	508.56	-781.5	508.56	-809.91	527.04	24160.68
g444Y	63	0	852.95	344.91	852.95	344.91	883.96	357.45	-36533.87
g445P	63	0	287.56	-832.46	287.56	-832.46	298.01	-862.72	-33440.18
g445X	63	0	-471.78	-733.74	-471.78	-733.74	-488.93	-760.41	34986.73
g445XY	63	0	-273.4	823.31	-273.4	823.31	-283.33	853.24	27538.88
g445Y	63	0	451.5	728.75	451.5	728.75	467.91	755.24	-39758.52
g446P	64	0	-324.46	-2.3	-324.46	-2.3	-381.52	-2.7	-3142.3
g446X	64	0	318.92	-54.18	318.92	-54.18	375.01	-63.71	2342.15
g446XY	64	0	322.55	-14.01	322.55	-14.01	379.28	-16.48	1915.3
g446Y	64	0	-325.92	19.51	-325.92	19.51	-383.25	22.95	769.29
g447P	64	0	419.47	-55.21	419.47	-55.21	596.53	-78.51	-7788.29
g447X	64	0	-424.98	-7.72	-424.98	-7.72	-604.36	-10.99	8753.26

g447XY	64	0	-422.84	29.71	-422.84	29.71	-601.32	42.25	10926.74
g447Y	64	0	426.55	-30.01	426.55	-30.01	606.59	-42.68	-10153.85
g448P	64	0	-30.58	-186.29	-30.58	-186.29	-35.96	-219.06	8365.92
g448X	64	0	-43.51	-176.67	-43.51	-176.67	-51.16	-207.74	-7423.05
g448XY	64	0	34.14	155.77	34.14	155.77	40.14	183.17	-8905.74
g448Y	64	0	35.15	158.21	35.15	158.21	41.33	186.03	9816.9
g449P	64	0	62.78	256.13	62.78	256.13	89.28	364.24	-436.69
g449X	64	0	28.22	267.1	28.22	267.1	40.13	379.84	-1232.9
g449XY	64	0	-73.34	-291.11	-73.34	-291.11	-104.29	-413.99	3117.68
g449Y	64	0	-23.72	-286.63	-23.72	-286.63	-33.73	-407.62	279.79
g450P	65	0	-873.84	-42.15	-873.84	-42.15	-1324.25	-63.87	-42803.76
g450X	65	0	-865.83	-66.06	-865.83	-66.06	-1312.12	-100.11	40685.02
g450XY	65	0	881.39	-19.92	881.39	-19.92	1335.69	-30.18	49022.64
g450Y	65	0	864.45	-51.34	864.45	-51.34	1310.02	-77.81	-37899.78
g451P	65	0	-823.58	-6	-823.58	-6	-1453.48	-10.59	-24033.65
g451X	65	0	-824.71	-50.63	-824.71	-50.63	-1455.48	-89.35	22195.88
g451XY	65	0	807.06	-52.15	807.06	-52.15	1424.33	-92.03	25091.7
g451Y	65	0	847.7	-45.89	847.7	-45.89	1496.04	-80.98	-13317.21
g452P	65	0	-24.72	33.13	-24.72	33.13	-37.47	50.21	30815.33
g452X	65	0	157.33	54.55	157.33	54.55	238.43	82.66	-35926.17
g452XY	65	0	49.17	-134.08	49.17	-134.08	74.52	-203.19	-23799.07
g452Y	65	0	-152.34	-115.88	-152.34	-115.88	-230.87	-175.62	37934.82
g453P	65	0	-196.04	-54.45	-196.04	-54.45	-345.99	-96.1	32412.09
g453X	65	0	3.56	-36.36	3.56	-36.36	6.28	-64.17	-31193.78
g453XY	65	0	192.63	-38.59	192.63	-38.59	339.95	-68.11	-29475.37
g453Y	65	0	23.49	-16.55	23.49	-16.55	41.46	-29.21	38189.73
g454P	4	0	111103.37	-118858.56	111103.37	-118858.56	340895.73	-364690.77	1511033.08
g454X	4	0	-82830.04	-145799.5	-82830.04	-145799.5	-254145.37	-447353.01	-1411836.01
g454XY	4	0	-105697.17	124655.63	-105697.17	124655.63	-324308.01	382477.79	-1680167.38
g454Y	4	0	84969.08	151328.34	84969.08	151328.34	260708.52	464317	1177388.37
Fg454419P	4	0	128131.31	-122966.46	128131.31	-122966.46	393142.12	-377294.94	1520371.69
Fg454419X	4	0	-98541.85	-150377.43	-98541.85	-150377.43	-302353.53	-461399.35	-1419504.8
Fg454419XY	4	0	-124167.87	127447.5	-124167.87	127447.5	-380981.21	391044.03	-1689316.27
Fg454419Y	4	0	98177.53	154318.27	98177.53	154318.27	301235.7	473490.93	1184728.06
Fg454420P	4	0	134433.49	-123028.77	134433.49	-123028.77	412478.96	-377486.14	1542107.91
Fg454420X	4	0	-104220.8	-150250.74	-104220.8	-150250.74	-319778.11	-461010.64	-1436089.45
Fg454420XY	4	0	-130935.1	127782.46	-130935.1	127782.46	-401744.92	392071.76	-1709035.55
Fg454420Y	4	0	102960.05	154345.65	102960.05	154345.65	315909.77	473574.94	1201636.49
Fg454421P	4	0	145921.65	-120353.31	145921.65	-120353.31	447727.77	-369277.09	1548983.93
Fg454421X	4	0	-115445.7	-146902.69	-115445.7	-146902.69	-354219.19	-450737.9	-1441819.38
Fg454421XY	4	0	-143946.81	126371.59	-143946.81	126371.59	-441668.43	387742.81	-1715807.12
Fg454421Y	4	0	111991.93	151987.83	111991.93	151987.83	343622.07	466340.49	1207127.9
Fg454P	4	0	118195.65	-104856.24	118195.65	-104856.24	181328.4	-160863.89	1542132.58
Fg454X	4	0	-92797.84	-127678.22	-92797.84	-127678.22	-142364.65	-195875.96	-1439585.56
Fg454XY	4	0	-114846.03	108953.97	-114846.03	108953.97	-176189.61	167150.38	-1707028.41
Fg454Y	4	0	90858.73	132920.4	90858.73	132920.4	139389.8	203918.18	1201095.11
FFg454P	4	0	140543.72	-105531.18	140543.72	-105531.18	215613.4	-161899.35	1525927.63
FFg454X	4	0	-114033.01	-127927.99	-114033.01	-127927.99	-174942.33	-196259.14	-1425450.99
FFg454XY	4	0	-139732.71	109335.52	-139732.71	109335.52	-214369.2	167735.73	-1689799.55
FFg454Y	4	0	108538.88	133067.81	108538.88	133067.81	166513.57	204144.33	1188666.99
Fg454412P	4	0	122509.7	-131346.96	122509.7	-131346.96	187946.73	-201504.32	1234711.42
Fg454412X	4	0	-92215.82	-160435.71	-92215.82	-160435.71	-141471.76	-246130.46	-1153504.47
Fg454412XY	4	0	-115415.2	137457.05	-115415.2	137457.05	-177062.8	210878.04	-1376760.57
Fg454412Y	4	0	92951.35	163963.85	92951.35	163963.85	142600.16	251543.12	936640.4
FFg454412P	4	0	134984.79	-135155.78	134984.79	-135155.78	207085.25	-207347.57	1241836.87
FFg454412X	4	0	-103316.63	-165127.3	-103316.63	-165127.3	-158501.93	-253328	-1169074.96
FFg454412XY	4	0	-128452.32	141176.2	-128452.32	141176.2	-197063.54	216583.72	-1385574.02
FFg454412Y	4	0	101148.97	166993.94	101148.97	166993.94	155176.44	256191.69	953203.55
g455P	11	0	-653.83	-6513.61	-653.83	-6513.61	-1050.74	-10467.82	22557.65
g455X	11	0	-2038.2	-6645.27	-2038.2	-6645.27	-3275.52	-10679.41	-65983.05
g455XY	11	0	147.48	5327.62	147.48	5327.62	237.01	8561.84	1568.44

g455Y	11	0	2171.34	5515.42	2171.34	5515.42	3489.49	8863.66	34615.46
Fg455P	11	0	-1852.57	-5210.08	-1852.57	-5210.08	-3434.62	-9659.36	-12709.5
Fg455X	11	0	-925.35	-5314.38	-925.35	-5314.38	-1715.57	-9852.73	-19016.81
Fg455XY	11	0	1774.49	3985.36	1774.49	3985.36	3289.86	7388.75	43828.5
Fg455Y	11	0	976.54	4265.82	976.54	4265.82	1810.49	7908.72	-9619.91
iFg455PP	11	0	-1010.64	-4381.96	-1010.64	-4381.96	-1433.29	-6214.48	-15422.87
iFg455PX	11	0	-1039.62	-4585.47	-1039.62	-4585.47	-1474.39	-6503.11	-13317.15
iFg455PXY	11	0	850.48	3549.2	850.48	3549.2	1206.15	5033.47	41293.63
iFg455PY	11	0	1060.6	3652.46	1060.6	3652.46	1504.14	5179.92	-12259.4
Fg455425P	11	0	224.24	-4862.82	224.24	-4862.82	360.36	-7814.89	34462.37
Fg455425X	11	0	-2271.59	-5035.18	-2271.59	-5035.18	-3650.6	-8091.87	-59144.38
Fg455425XY	11	0	-710.16	4214.35	-710.16	4214.35	-1141.28	6772.75	-16092.98
Fg455425Y	11	0	2189.66	4360.94	2189.66	4360.94	3518.94	7008.33	26416.37
g456P	11	0	7950.41	-538.15	7950.41	-538.15	12712.29	-860.47	-105405.83
g456X	11	0	-7888.63	-1886.91	-7888.63	-1886.91	-12613.5	-3017.07	106731.55
g456XY	11	0	-7790.69	-73.64	-7790.69	-73.64	-12456.9	-117.74	64453.89
g456Y	11	0	8292	942.92	8292	942.92	13258.48	1507.68	-77553.62
Fg456P	11	0	9273.34	-852.73	9273.34	-852.73	13245.28	-1217.98	-160972.52
Fg456X	11	0	-9178.69	-1833.14	-9178.69	-1833.14	-13112.91	-2618.87	160126.12
Fg456XY	11	0	-9128.93	-26	-9128.93	-26	-13041.82	-37.15	124116.75
Fg456Y	11	0	9189.55	619.58	9189.55	619.58	13125.6	884.96	-119908.36
iFg456PP	11	0	12671.9	-1131.55	12671.9	-1131.55	23010.6	-2054.75	-168181.91
iFg456PX	11	0	-12552.76	-2079.12	-12552.76	-2079.12	-22788.02	-3774.39	168859.57
iFg456PXY	11	0	-12453.12	-468.95	-12453.12	-468.95	-22607.14	-851.32	136298.62
iFg456PY	11	0	12380.72	752.23	12380.72	752.23	22481.87	1365.96	-131235.91
Fg456427P	11	0	11485.17	-1008.97	11485.17	-1008.97	18364.19	-1613.28	-198149.62
Fg456427X	11	0	-11499.43	-1928.8	-11499.43	-1928.8	-18386.99	-3084.05	202206.21
Fg456427XY	11	0	-11406.96	-675.17	-11406.96	-675.17	-18239.13	-1079.55	161044.16
Fg456427Y	11	0	11785.23	651.26	11785.23	651.26	18843.97	1041.33	-169756.17
g457P	11	0	642.98	-5519.15	642.98	-5519.15	1141.95	-9802.16	40158.98
g457X	11	0	2415.14	-5808.21	2415.14	-5808.21	4289.35	-10315.54	7026.65
g457XY	11	0	22.06	5063.87	22.06	5063.87	39.18	8993.57	12500.99
g457Y	11	0	-2618.9	5386.52	-2618.9	5386.52	-4651.25	9566.61	-55649.75
Fg457P	11	0	1500.53	-7308.51	1500.53	-7308.51	1332.49	-6490.06	18245.77
Fg457X	11	0	82.32	-7427.8	82.32	-7427.8	73.1	-6595.99	26235.84
Fg457XY	11	0	-1391.04	6231.57	-1391.04	6231.57	-1235.26	5533.72	37513.02
Fg457Y	11	0	-148.98	6337.15	-148.98	6337.15	-132.29	5627.47	-70894.17
Fg457429P	11	0	-130.22	-5006.38	-130.22	-5006.38	-231.28	-8891.47	32519.04
Fg457429X	11	0	4286.1	-5536.39	4286.1	-5536.39	7612.24	-9832.78	9098.32
Fg457429XY	11	0	1052.67	4626.51	1052.67	4626.51	1869.57	8216.8	21944.65
Fg457429Y	11	0	-4346.17	4954.53	-4346.17	4954.53	-7718.93	8799.39	-55464.03
g458P	11	0	12781.03	-1144.42	12781.03	-1144.42	22351.22	-2001.33	187202.83
g458X	11	0	-12702.05	-2489.11	-12702.05	-2489.11	-22213.11	-4352.91	-189034.02
g458XY	11	0	-12693.54	512.56	-12693.54	512.56	-22198.21	896.36	-240509.44
g458Y	11	0	13202.25	1891.33	13202.25	1891.33	23087.85	3307.53	236009.52
Fg458P	11	0	7211.1	-659.61	7211.1	-659.61	6305.32	-576.75	160014.38
Fg458X	11	0	-7040.46	-2031.95	-7040.46	-2031.95	-6156.11	-1776.72	-162657.37
Fg458XY	11	0	-7160.85	-902.4	-7160.85	-902.4	-6261.38	-789.05	-210905.7
Fg458Y	11	0	7010.34	556.26	7010.34	556.26	6129.77	486.39	213297.57
Fg458431P	11	0	17030.15	-2245.86	17030.15	-2245.86	29782	-3927.52	156434.06
Fg458431X	11	0	-17160.87	-2950.6	-17160.87	-2950.6	-30010.6	-5159.95	-157318.67
Fg458431XY	11	0	-16771.1	1347.77	-16771.1	1347.77	-29328.98	2356.96	-209256.81
Fg458431Y	11	0	17527.82	2298.85	17527.82	2298.85	30652.31	4020.18	207390.3
g459P	12	0	-698.7	-9207.62	-698.7	-9207.62	-1378.57	-18167.14	148033.99
g459X	12	0	6241.17	-9774.68	6241.17	-9774.68	12314.17	-19285.99	-130956.19
g459XY	12	0	2308.49	8398.09	2308.49	8398.09	4554.78	16569.88	-103154.07
g459Y	12	0	-6171.7	8910.35	-6171.7	8910.35	-12177.1	17580.62	43895.1
Fg459433P	12	0	3965.46	-7943.19	3965.46	-7943.19	7824.06	-15672.34	143791.17
Fg459433X	12	0	1955.42	-8606.32	1955.42	-8606.32	3858.16	-16980.75	-132942.27
Fg459433XY	12	0	-3157.76	7084.5	-3157.76	7084.5	-6230.43	13978.1	-97860.91
Fg459433Y	12	0	-2845.06	7744.04	-2845.06	7744.04	-5613.47	15279.41	47302.79

g461P	88	0	321.07	5.42	321.07	5.42	427.63	7.22	-3762.88
g461X	88	0	-218.46	-7.38	-218.46	-7.38	-290.96	-9.83	444.77
g461XY	88	0	-140.5	-32.12	-140.5	-32.12	-187.13	-42.78	8248.65
g461Y	88	0	402.18	-39.54	402.18	-39.54	535.66	-52.66	-5767.1
Fg461P	88	0	125.56	-49.41	125.56	-49.41	167.23	-65.81	-2711.42
Fg461X	88	0	-334.43	-47.96	-334.43	-47.96	-445.5	-63.89	1807.71
Fg461XY	88	0	-306.07	1.69	-306.07	1.69	-407.73	2.25	8224.41
Fg461Y	88	0	150.8	3.67	150.8	3.67	200.85	4.89	-6121.56
g462P	89	0	-155.62	-40.84	-155.62	-40.84	-205.34	-53.88	-946.14
g462X	89	0	362.19	-31.23	362.19	-31.23	477.9	-41.21	-862.68
g462XY	89	0	333.48	-3.47	333.48	-3.47	440.01	-4.58	-55.34
g462Y	89	0	-178.42	-3.32	-178.42	-3.32	-235.42	-4.38	-249.43
g463P	90	0	-417.81	-59.75	-417.81	-59.75	-392.27	-56.1	-1490.05
g463Y	90	0	-414.97	-4.18	-414.97	-4.18	-389.6	-3.92	34.52
g464P	66	0	579.16	268.14	579.16	268.14	876.02	405.58	-28954.55
g464X	66	0	-529.75	367.45	-529.75	367.45	-801.28	555.8	18540.7
g464XY	66	0	-579.41	-272.36	-579.41	-272.36	-876.4	-411.96	25406.38
g464Y	66	0	518.97	-382.38	518.97	-382.38	784.97	-578.37	-23629.35
g465P	66	0	255.82	470.7	255.82	470.7	385.7	709.69	-34336.17
g465X	66	0	-134.05	528.08	-134.05	528.08	-202.11	796.21	25128.18
g465XY	66	0	-276.87	-480.92	-276.87	-480.92	-417.44	-725.09	31055.95
g465Y	66	0	147.39	-539.95	147.39	-539.95	222.23	-814.1	-30202.77
g466P	67	0	345.79	-16.54	345.79	-16.54	507.95	-24.3	19788.03
g466X	67	0	-348.52	11.2	-348.52	11.2	-511.95	16.45	-16326.15
g466XY	67	0	-347.06	-16.97	-347.06	-16.97	-509.82	-24.93	-21098.96
g466Y	67	0	342.76	-57.08	342.76	-57.08	503.49	-83.84	20038.29
g467P	67	0	-446.72	14.15	-446.72	14.15	-781.21	24.75	-1821.99
g467X	67	0	447.26	-28.69	447.26	-28.69	782.16	-50.17	4178.77
g467XY	67	0	443.85	-58.42	443.85	-58.42	776.19	-102.16	5468.56
g467Y	67	0	-447.09	-23.81	-447.09	-23.81	-781.87	-41.64	-5113.11
g468P	67	0	26.36	112.82	26.36	112.82	38.55	165.02	14940.56
g468X	67	0	45.4	113.5	45.4	113.5	66.42	166.03	-9763.96
g468XY	67	0	-37.09	-144.86	-37.09	-144.86	-54.25	-211.9	-12531.02
g468Y	67	0	-41.21	-150.06	-41.21	-150.06	-60.27	-219.51	9602.28
g469P	67	0	-31.07	-242.04	-31.07	-242.04	-55.18	-429.86	3452.92
g469X	67	0	-68.46	-241.5	-68.46	-241.5	-121.58	-428.92	-3284.01
g469XY	67	0	39.3	207.89	39.3	207.89	69.79	369.22	-4219.88
g469Y	67	0	57.81	200.75	57.81	200.75	102.67	356.54	6565.17
g470P	68	0	622.51	-23.54	622.51	-23.54	1098.63	-41.54	23969.24
g470X	68	0	612.38	-36.49	612.38	-36.49	1080.75	-64.4	-13593.53
g470XY	68	0	-618.55	-48.52	-618.55	-48.52	-1091.63	-85.63	-18114.53
g470Y	68	0	-613.9	-57.7	-613.9	-57.7	-1083.43	-101.82	15945.99
g471P	68	0	584.99	-28.83	584.99	-28.83	1163.38	-57.34	44992.71
g471X	68	0	603.81	-21.33	603.81	-21.33	1200.81	-42.41	-34566.31
g471XY	68	0	-593.5	-35.13	-593.5	-35.13	-1180.32	-69.85	-45190.28
g471Y	68	0	-593.48	-60.24	-593.48	-60.24	-1180.27	-119.8	43436.72
g472P	68	0	87.35	-88.92	87.35	-88.92	154.15	-156.93	33238.83
g472X	68	0	-49.27	-90.75	-49.27	-90.75	-86.95	-160.17	-25634.21
g472XY	68	0	-96.6	24.6	-96.6	24.6	-170.48	43.42	-32286.73
g472Y	68	0	33.91	18.16	33.91	18.16	59.85	32.04	32472.15
g473P	68	0	-3.32	-19.37	-3.32	-19.37	-6.69	-39.05	37183.71
g473X	68	0	-124.67	-21.7	-124.67	-21.7	-251.41	-43.76	-24240.34
g473XY	68	0	-16.77	-36.49	-16.77	-36.49	-33.82	-73.59	-31120.71
g473Y	68	0	124.3	-43.39	124.3	-43.39	250.66	-87.5	26494.37
g474P	69	0	382.07	-913.1	382.07	-913.1	576.05	-1376.7	-22102.55
g474X	69	0	-510.96	-859.96	-510.96	-859.96	-770.38	-1296.58	23686.08
g474XY	69	0	-370.61	928.73	-370.61	928.73	-558.78	1400.27	18628.33
g474Y	69	0	510.01	872.07	510.01	872.07	768.96	1314.84	-26716.4
g475P	69	0	571.78	-364.8	571.78	-364.8	864.86	-551.79	-20239.12
g475X	69	0	-676.4	-184.21	-676.4	-184.21	-1023.09	-278.62	21789.64
g475XY	69	0	-544.19	400.02	-544.19	400.02	-823.12	605.05	16702.37

g475Y	69	0	657.5	209.97	657.5	209.97	994.51	317.6	-23745.51
g476P	69	0	18.2	-618.84	18.2	-618.84	29.24	-994.52	18296.42
g476X	69	0	-161.77	-611.33	-161.77	-611.33	-259.98	-982.44	-15360.61
g476XY	69	0	-1.79	600.58	-1.79	600.58	-2.88	965.17	-17198.35
g476Y	69	0	151.95	598.44	151.95	598.44	244.2	961.74	17761.59
g477P	69	0	101.48	755.13	101.48	755.13	200.22	1489.91	11211.16
g477X	69	0	75.25	774.47	75.25	774.47	148.47	1528.07	-15515.05
g477XY	69	0	-133.2	-797.56	-133.2	-797.56	-262.8	-1573.63	-7788.93
g477Y	69	0	-68.44	-812.97	-68.44	-812.97	-135.03	-1604.03	17166.05
g478P	69	0	-692.4	44.97	-692.4	44.97	-1107.1	71.91	4353.84
g478X	69	0	674.22	-85.8	674.22	-85.8	1078.04	-137.19	-6150.49
g478XY	69	0	688.17	-60.82	688.17	-60.82	1100.35	-97.25	-3829.65
g478Y	69	0	-670.15	83.53	-670.15	83.53	-1071.54	133.57	8537.83
g479P	69	0	-842.61	-208.17	-842.61	-208.17	-1618.69	-399.91	-32018.01
g479X	69	0	856.97	-63.05	856.97	-63.05	1646.28	-121.13	31676.32
g479XY	69	0	849.91	135.52	849.91	135.52	1632.71	260.33	34036.6
g479Y	69	0	-853.23	-11.92	-853.23	-11.92	-1639.1	-22.9	-29395.46
g480P	71	0	366.03	808.65	366.03	808.65	551.88	1219.22	-18097.03
g480X	71	0	-265.65	870.95	-265.65	870.95	-400.53	1313.15	10545.74
g480XY	71	0	-384.72	-799.98	-384.72	-799.98	-580.05	-1206.15	16456.37
g480Y	71	0	261.65	-864.31	261.65	-864.31	394.5	-1303.13	-12793.52
g484P	72	0	54.64	635.25	54.64	635.25	97.04	1128.23	11661.24
g484X	72	0	69.13	650.92	69.13	650.92	122.77	1156.06	-14875.17
g484XY	72	0	-80.99	-654.94	-80.99	-654.94	-143.84	-1163.2	-9132.24
g484Y	72	0	-70.12	-674.16	-70.12	-674.16	-124.53	-1197.32	14897.77
g485P	72	0	97.77	-902.12	97.77	-902.12	215.04	-1984.09	3504.2
g485X	72	0	-273.71	-906.83	-273.71	-906.83	-601.99	-1994.45	6283.16
g485XY	72	0	-69.49	871.01	-69.49	871.01	-152.84	1915.67	-4847.12
g485Y	72	0	265.09	856.09	265.09	856.09	583.02	1882.86	-4593.45
g483P	91	0	-2528.97	-1302.94	-2528.97	-1302.94	-3568.22	-1838.36	-282532.31
g483X	91	0	-1236.78	-1222.35	-1236.78	-1222.35	-1745.01	-1724.65	228575.71
Fg483P	91	0	-1414.13	-1233.51	-1414.13	-1233.51	-1995.24	-1740.4	-241078.71
Fg483X	91	0	-3103.54	-1314.72	-3103.54	-1314.72	-4378.89	-1854.99	188090.51
g486P	91	0	18132.62	-3069.25	18132.62	-3069.25	24160.73	-4089.61	30804.75
g486Y	91	0	18580.37	-1282.91	18580.37	-1282.91	24757.32	-1709.41	-11991.09
Fg486P	91	0	18009.94	-3301.71	18009.94	-3301.71	23997.26	-4399.35	-12535.67
Fg486Y	91	0	17917.13	-1072.79	17917.13	-1072.79	23873.59	-1429.44	30384.16
g482P	93	0	977.43	-146.55	977.43	-146.55	946.88	-141.97	30093.54
g482X	93	0	-1193.86	-146.91	-1193.86	-146.91	-1156.54	-142.32	-29595.89
g482XY	93	0	-980.97	-146.49	-980.97	-146.49	-950.3	-141.91	29431.76
g482Y	93	0	1190.32	-147.67	1190.32	-147.67	1153.11	-143.05	-29616.8
g487P	94	0	-218.15	-156.46	-218.15	-156.46	-153.89	-110.38	-401.63
g492P	95	0	-521.43	-252.53	-521.43	-252.53	-382.2	-185.1	-5298.98
g492X	95	0	-492.1	-309.03	-492.1	-309.03	-360.7	-226.51	78788.24
g490P	95	0	-4152.18	-544.76	-4152.18	-544.76	-2767.01	-363.02	19513.33
g490Y	95	0	-4176.43	-660.87	-4176.43	-660.87	-2783.18	-440.41	-11251.29
g385P	15	0	9575.24	-34392.57	9575.24	-34392.57	10677.77	-38352.69	-99534.65
g385X	15	0	772.34	-33835.42	772.34	-33835.42	861.28	-37731.39	165291.03
g385XY	15	0	-8322.45	30340.09	-8322.45	30340.09	-9248.07	33714.47	52339.62
g385Y	15	0	521.55	30172.45	521.55	30172.45	579.55	33528.18	-169658.14
ig385PP	15	0	3650.28	-32505.81	3650.28	-32505.81	4286.86	-38174.5	-107296.05
ig385PX	15	0	6677.57	-32296.88	6677.57	-32296.88	7842.07	-37929.14	168352.98
ig385PXY	15	0	-4228.34	28419.47	-4228.34	28419.47	-4984.2	33499.76	61356.77
ig385PY	15	0	-6336.82	28611.53	-6336.82	28611.53	-7469.6	33726.15	-174641.79
g386P	15	0	-36716.4	-3190.72	-36716.4	-3190.72	-37916.63	-3295.02	-410389.27
g386X	15	0	37326.58	2380.2	37326.58	2380.2	38546.76	2458	396144.25
g386XY	15	0	36821.23	-3058.41	36821.23	-3058.41	38024.88	-3158.38	356894.24
g386Y	15	0	-36842.49	-9465.31	-36842.49	-9465.31	-38046.84	-9774.72	-349695.54
ig386PP	15	0	-39963.56	-6527.22	-39963.56	-6527.22	-41269.93	-6740.59	-402202.36
ig386PX	15	0	40608.07	-1275.09	40608.07	-1275.09	41935.51	-1316.77	388939.21
ig386PXY	15	0	40857.53	-154.24	40857.53	-154.24	42193.13	-159.28	349377.89

ig386PY	15	0	-39914.32	-6152.93	-39914.32	-6152.93	-41219.08	-6354.07	-340000.83
g387P	15	0	3170.04	-35759.9	3170.04	-35759.9	3297.64	-37199.31	-256989.26
g387X	15	0	5615.23	-36037.67	5615.23	-36037.67	5841.26	-37488.26	204153.04
g387XY	15	0	-4134.71	32809.34	-4134.71	32809.34	-4300.24	34122.89	105847.92
g387Y	15	0	-4721.34	32517.31	-4721.34	32517.31	-4910.36	33819.17	-125033.64
ig387PP	15	0	4763.8	-33512.13	4763.8	-33512.13	5333.35	-37518.79	-258269.42
ig387PX	15	0	6021.23	-33629.86	6021.23	-33629.86	6741.11	-37650.59	202544.67
ig387PXY	15	0	-4763.22	30450.85	-4763.22	30450.85	-5333.89	34099.13	108284.39
ig387PY	15	0	-4217.64	30064.65	-4217.64	30064.65	-4722.95	33666.66	-121251.31
g388P	15	0	-6525.88	33858.67	-6525.88	33858.67	-8792.49	45618.69	-38168.71
g388X	15	0	-4266.63	33794.43	-4266.63	33794.43	-5748.55	45532.14	14732.22
g388XY	15	0	8130.42	-38716.42	8130.42	-38716.42	11001.52	-52388.37	29595.47
g388Y	15	0	5335.31	-39170.81	5335.31	-39170.81	7219.38	-53003.22	4499.19
ig388PP	15	0	-3511.67	31957.78	-3511.67	31957.78	-5018.31	45668.83	-26643.79
ig388PX	15	0	-10574	32036.66	-10574	32036.66	-15110.63	45781.55	7250.25
ig388PXY	15	0	2800.03	-36619.75	2800.03	-36619.75	3983.17	-52093.19	18574.61
ig388PY	15	0	10637.95	-37206.99	10637.95	-37206.99	15132.94	-52928.57	8217.82
g506P	15	0	-36880.19	-6295.55	-36880.19	-6295.55	-35458.46	-6052.85	-226800.66
g506X	15	0	37338.05	-100.03	37338.05	-100.03	35898.67	-96.17	202690.87
g506XY	15	0	37657.32	-112.99	37657.32	-112.99	36205.64	-108.64	173827.31
g506Y	15	0	-36792.26	-5743.78	-36792.26	-5743.78	-35373.93	-5522.36	-181260.22
ig506PP	15	0	-37745.02	-6487.19	-37745.02	-6487.19	-36289.95	-6237.11	-224390.24
ig506PX	15	0	37729.68	-658.39	37729.68	-658.39	36275.21	-633.01	200652.45
ig506PXY	15	0	37816.57	-1554.01	37816.57	-1554.01	36358.75	-1494.11	171379.27
ig506PY	15	0	-37722.99	-6819.26	-37722.99	-6819.26	-36268.77	-6556.38	-178745.43
g507P	15	0	43583.59	-2816.53	43583.59	-2816.53	49288.59	-3185.2	89773.87
g507X	15	0	-43548.87	-8275.98	-43548.87	-8275.98	-49249.32	-9359.28	-88381.76
g507XY	15	0	-43698.86	-8261.54	-43698.86	-8261.54	-49418.95	-9342.96	-61590.08
g507Y	15	0	43668.19	-2037.53	43668.19	-2037.53	49384.26	-2304.24	57647.29
ig507PP	15	0	45580.29	-740.53	45580.29	-740.53	51546.66	-837.46	86355.3
ig507PX	15	0	-44762.06	-5929.94	-44762.06	-5929.94	-50621.31	-6706.16	-82405.72
ig507PXY	15	0	-44650.34	-10172.75	-44650.34	-10172.75	-50494.97	-11504.34	-56669.4
ig507PY	15	0	45101.51	-4305.28	45101.51	-4305.28	51005.2	-4868.83	54730.01
g508P	77	0	-175.62	-184.06	-175.62	-184.06	-282.4	-295.98	1930.54
g508X	77	0	-48.62	-171.94	-48.62	-171.94	-78.19	-276.49	-2496.07
g508XY	77	0	162.26	47.42	162.26	47.42	259.08	75.72	-828.58
g508Y	77	0	29.46	58.23	29.46	58.23	47.04	92.98	3230.52
g509P	77	0	-765.9	-94.87	-765.9	-94.87	-1021.19	-126.49	4566.68
g509X	77	0	-765.19	-78.98	-765.19	-78.98	-1020.25	-105.3	-2900.65
g509XY	77	0	763.22	-90.03	763.22	-90.03	1017.63	-120.04	-3947.84
g509Y	77	0	773.17	-93.59	773.17	-93.59	1030.89	-124.79	4530.57
g510P	77	0	-103.04	-221.96	-103.04	-221.96	-176.33	-379.82	-2186.69
g510X	77	0	-123.28	-213.5	-123.28	-213.5	-210.97	-365.34	1573.53
g510XY	77	0	121.72	83.23	121.72	83.23	208.19	142.35	2223.04
g510Y	77	0	126.71	91.36	126.71	91.36	216.71	156.26	-735.52
g511P	77	0	-802.85	-114.54	-802.85	-114.54	-1070.47	-152.71	1344.54
g511X	77	0	-807.78	-100.76	-807.78	-100.76	-1077.04	-134.35	-678.85
g511XY	77	0	814.1	-103.59	814.1	-103.59	1085.47	-138.12	-1006.47
g511Y	77	0	805.78	-107.16	805.78	-107.16	1074.37	-142.87	1407.93
g512P	77	0	-92.29	-162.85	-92.29	-162.85	-168.92	-298.06	2027.3
g512X	77	0	-194.67	-155.63	-194.67	-155.63	-356.29	-284.85	-2443.24
g512XY	77	0	74.67	21.18	74.67	21.18	135.62	38.46	-1705.86
g512Y	77	0	176.21	25.61	176.21	25.61	320.05	46.51	4952.86
g513P	77	0	-832.14	-123.6	-832.14	-123.6	-1109.52	-164.8	3740.05
g513X	77	0	-824.6	-112.55	-824.6	-112.55	-1099.46	-150.07	-1843.83
g513XY	77	0	825.88	-118.39	825.88	-118.39	1101.17	-157.85	-2412.85
g513Y	77	0	830.45	-121.03	830.45	-121.03	1107.27	-161.37	2349.82
g235P	7	0	2646.27	-15429.65	2646.27	-15429.65	4526.35	-26391.89	-107279.5
g235X	7	0	1149.98	-15483.14	1149.98	-15483.14	1967	-26483.39	71804.37
g235XY	7	0	-2647.06	15728.84	-2647.06	15728.84	-4527.7	26903.64	54178.11
g235Y	7	0	-1242.11	15472.54	-1242.11	15472.54	-2124.59	26465.26	-145489.96

Fg235252P	7	0	1756.18	-16006.2	1756.18	-16006.2	3003.88	-27378.06	-107757.79
Fg235252X	7	0	1683.85	-15845.82	1683.85	-15845.82	2880.16	-27103.73	73637.34
Fg235252XY	7	0	-2195.41	16049.56	-2195.41	16049.56	-3755.18	27452.22	55424.15
Fg235252Y	7	0	-2379.52	16229.81	-2379.52	16229.81	-4070.09	27760.54	-146660.06
Fg235236P	7	0	2399.77	-15841.92	2399.77	-15841.92	4104.73	-27097.06	20903.7
Fg235236X	7	0	2242.53	-15993.66	2242.53	-15993.66	3835.77	-27356.61	-117539.78
Fg235236XY	7	0	-1788.18	16256.88	-1788.18	16256.88	-3058.62	27806.84	-93643.51
Fg235236Y	7	0	-1731.97	16069.59	-1731.97	16069.59	-2962.48	27486.48	73285.63
FFg235236P	7	0	2543.79	-15679.88	2543.79	-15679.88	4351.06	-26819.9	20654.31
FFg235236X	7	0	1249.59	-15315.05	1249.59	-15315.05	2137.39	-26195.87	-115815.8
FFg235236XY	7	0	-2492.73	15685.23	-2492.73	15685.23	-4263.73	26829.04	-92533.78
FFg235236Y	7	0	-1072.01	15678.19	-1072.01	15678.19	-1833.64	26817.02	72363.2
Fg235P	7	0	427.13	-12213.93	427.13	-12213.93	608.83	-17409.59	57620.36
Fg235X	7	0	2032.7	-12475.42	2032.7	-12475.42	2897.38	-17782.32	-118037.57
Fg235XY	7	0	-1136.24	12740.8	-1136.24	12740.8	-1619.58	18160.58	-93842.06
Fg235Y	7	0	-1434.72	12741.75	-1434.72	12741.75	-2045.04	18161.95	91946.19
FFg235254P	7	0	1080.22	-11780.2	1080.22	-11780.2	1539.73	-16791.35	57413.13
FFg235254X	7	0	1104.68	-11821.72	1104.68	-11821.72	1574.6	-16850.54	-116270.45
FFg235254XY	7	0	-1746.43	12198.38	-1746.43	12198.38	-2489.34	17387.42	-92760.51
FFg235254Y	7	0	-597.48	12190.89	-597.48	12190.89	-851.64	17376.74	90938.42
FFg235P	7	0	1007.44	-8952.4	1007.44	-8952.4	1077	-9570.49	13372.07
FFg235X	7	0	1214.89	-8931.18	1214.89	-8931.18	1298.77	-9547.8	-2150.33
FFg235XY	7	0	-940.19	8917.93	-940.19	8917.93	-1005.11	9533.63	-18753.51
FFg235Y	7	0	-1217.35	8913.32	-1217.35	8913.32	-1301.4	9528.71	3884.11
g239P	16	0	4832.96	-24619.26	4832.96	-24619.26	5992.73	-30527.17	18345.76
g239X	16	0	1998.82	-24476.64	1998.82	-24476.64	2478.48	-30350.33	38885.8
g239XY	16	0	-4796.66	22407.71	-4796.66	22407.71	-5947.72	27784.91	-31889.62
g239Y	16	0	-2217.87	22267.49	-2217.87	22267.49	-2750.09	27611.04	-29076.35
ig239PP	16	0	4820.07	-23565.5	4820.07	-23565.5	6394.95	-31265.14	15462.58
ig239PX	16	0	4188.58	-23522.84	4188.58	-23522.84	5557.12	-31208.54	39587.79
ig239PXY	16	0	-3319.5	20464.12	-3319.5	20464.12	-4404.1	27150.44	-27832.45
ig239PY	16	0	-3323.73	20466.41	-3323.73	20466.41	-4409.71	27153.47	-26644.23
g240P	16	0	-23709.95	-3630.32	-23709.95	-3630.32	-24933	-3817.58	-212585.27
g240X	16	0	24017.08	689.05	24017.08	689.05	25255.98	724.59	203237.43
g240XY	16	0	23747.53	-1758.96	23747.53	-1758.96	24972.52	-1849.7	165920.92
g240Y	16	0	-23518.05	-5483.72	-23518.05	-5483.72	-24731.2	-5766.59	-164385.11
ig240PP	16	0	-24734.66	-4017.34	-24734.66	-4017.34	-26010.56	-4224.57	-209404.27
ig240PX	16	0	24931.59	-43.81	24931.59	-43.81	26217.65	-46.07	200577.8
ig240PXY	16	0	24700.32	-1225.07	24700.32	-1225.07	25974.45	-1288.27	163263.76
ig240PY	16	0	-24320.08	-4550.77	-24320.08	-4550.77	-25574.6	-4785.51	-160844.31
g241P	16	0	-24768.77	-3854.26	-24768.77	-3854.26	-26046.44	-2053.08	-202313.93
g241X	16	0	24903.23	-206.67	24903.23	-206.67	26187.83	-217.33	209724.32
g241XY	16	0	24708.45	-732.19	24708.45	-732.19	25983	-769.96	151642.29
g241Y	16	0	-24263.56	-5041.82	-24263.56	-5041.82	-25515.16	-5301.89	-155160.27
ig241PP	16	0	-24157.55	-4419.59	-24157.55	-4419.59	-25403.69	-4647.57	-203016.07
ig241PX	16	0	23995.87	-1142.62	23995.87	-1142.62	25233.67	-11201.56	210688.63
ig241PXY	16	0	24240.44	-208.53	24240.44	-208.53	25490.85	-219.29	152156.49
ig241PY	16	0	-23477.77	-4099.15	-23477.77	-4099.15	-24688.85	-4310.6	-154558.08
g242P	16	0	-3247.67	23519.59	-3247.67	23519.59	-4137.86	29966.32	-10800.05
g242X	16	0	-3227.69	23543.82	-3227.69	23543.82	-4112.41	29997.19	-56496.52
g242XY	16	0	4132.03	-26368.08	4132.03	-26368.08	5264.62	-33595.58	33175.57
g242Y	16	0	4525.16	-26381.13	4525.16	-26381.13	5765.51	-33612.21	17536.26
ig242PP	16	0	-5215.25	21470.53	-5215.25	21470.53	-7144.68	29413.73	-12554.13
ig242PX	16	0	-2281.34	21134.73	-2281.34	21134.73	-3125.34	28953.7	-54202.16
ig242PXY	16	0	5091.6	-25435.58	5091.6	-25435.58	6975.27	-34845.67	33909.77
ig242PY	16	0	2098.79	-25143.55	2098.79	-25143.55	2875.25	-34445.61	14628.39
g243P	17	0	492.69	-9518.46	492.69	-9518.46	567.03	-10954.58	-71872.76
g243X	17	0	1614.74	-9668.55	1614.74	-9668.55	1858.36	-11127.32	3422.58
g243XY	17	0	-854.72	8474.87	-854.72	8474.87	-983.68	9753.55	-44456.07
g243Y	17	0	-1280.15	8499.03	-1280.15	8499.03	-1473.3	9781.35	71809.27
ig243PP	17	0	612.26	-9437.14	612.26	-9437.14	774.57	-11938.88	-72960.61

ig243PX	17	0	1583.76	-9471.44	1583.76	-9471.44	2003.61	-11982.26	3129.1
ig243PXY	17	0	-875.55	7524.39	-875.55	7524.39	-1107.65	9519.06	-43498.24
ig243PY	17	0	-1099.83	7466.16	-1099.83	7466.16	-1391.39	9445.39	73449.82
g245P	18	0	214.02	-1750.66	214.02	-1750.66	172.37	-1409.97	-7767.72
g245X	18	0	267.17	-1748.53	267.17	-1748.53	215.17	-1408.26	37882.36
g245XY	18	0	-197.31	1278.01	-197.31	1278.01	-158.91	1029.3	12653.14
g245Y	18	0	-267.97	1278.7	-267.97	1278.7	-215.83	1029.86	-30634.66
g246P	18	0	-1415.06	-319.15	-1415.06	-319.15	-800.48	-180.54	-8345.67
g246X	18	0	1410.68	-138.54	1410.68	-138.54	798	-78.37	4545.92
g246XY	18	0	1408.67	-126.99	1408.67	-126.99	796.86	-71.84	919.25
g246Y	18	0	-1405	-313.06	-1405	-313.06	-794.79	-177.09	-1401.15
g247P	17	0	-8676.96	-1556.2	-8676.96	-1556.2	-8448.99	-1515.32	-66038.47
g247X	17	0	8625.76	-215.36	8625.76	-215.36	8399.13	-209.7	64212.64
g247XY	17	0	8606.03	-125.7	8606.03	-125.7	8379.93	-122.39	-12803.35
g247Y	17	0	-8346.5	-1407.11	-8346.5	-1407.11	-8127.22	-1370.14	2427.63
ig247PP	17	0	-8299.31	-1583.72	-8299.31	-1583.72	-8081.26	-1542.11	-66193.94
ig247PX	17	0	8257.51	-618.14	8257.51	-618.14	8040.57	-601.9	64984.44
ig247PXY	17	0	8114.95	-689.1	8114.95	-689.1	7901.75	-671	-13356.28
ig247PY	17	0	-8080.78	-1578.92	-8080.78	-1578.92	-7868.48	-1537.44	3330.69
g256P	77	0	172.53	-260.25	172.53	-260.25	333.61	-503.24	964.59
g256X	77	0	106.25	-245.31	106.25	-245.31	205.45	-474.34	-1223.39
g256XY	77	0	-187.05	78.36	-187.05	78.36	-361.7	151.52	-530.98
g256Y	77	0	-144.82	92.72	-144.82	92.72	-280.03	179.29	2563.26
g258P	77	0	-214.59	-285.29	-214.59	-285.29	-444.92	-591.52	-804.73
g258X	77	0	-134.79	-267.91	-134.79	-267.91	-279.47	-555.47	1388.44
g258XY	77	0	174.34	25.66	174.34	25.66	361.47	53.21	1448.39
g258Y	77	0	117.81	44.07	117.81	44.07	244.27	91.37	-532.64
g260P	77	0	-148.9	-423.18	-148.9	-423.18	-334.87	-951.71	-1546.57
g260X	77	0	-158.12	-417.32	-158.12	-417.32	-355.61	-938.53	1009.31
g260XY	77	0	148.75	37.32	148.75	37.32	334.54	83.94	1099.71
g260Y	77	0	173.06	43.86	173.06	43.86	389.21	98.64	-540.34
g261P	77	0	823.55	-142.86	823.55	-142.86	1098.06	-190.47	735.5
g261X	77	0	834.42	-124.61	834.42	-124.61	1112.56	-166.15	-408.77
g261XY	77	0	-831.55	-125.9	-831.55	-125.9	-1108.74	-167.87	287.2
g261Y	77	0	-831.75	-144.28	-831.75	-144.28	-1109	-192.37	-284.54
g262P	77	0	862.76	-107.33	862.76	-107.33	1150.34	-143.1	716.43
g262X	77	0	856.36	-116.84	856.36	-116.84	1141.82	-155.79	203.2
g262XY	77	0	-867.05	-107.13	-867.05	-107.13	-1156.07	-142.84	522.52
g262Y	77	0	-861.72	-116.54	-861.72	-116.54	-1148.96	-155.38	-176.03
g263P	77	0	857.23	-117.68	857.23	-117.68	1142.97	-156.91	1891.54
g263X	77	0	854.19	-116.56	854.19	-116.56	1138.92	-155.41	-1496.81
g263XY	77	0	-862.22	-103.15	-862.22	-103.15	-1149.63	-137.54	-1102.22
g263Y	77	0	-860.67	-126.42	-860.67	-126.42	-1147.56	-168.57	1876.69
g270P	105	0	2446.54	-3798.72	2446.54	-3798.72	2895.66	-4496.05	-196726.09
g270X	105	0	2315.65	-3752.58	2315.65	-3752.58	2740.73	-4441.45	256724.06
g268P	105	0	-12337.98	-2616.1	-12337.98	-2616.1	-8225.32	-1744.06	-1586.93
g268Y	105	0	-12296.1	-2031.38	-12296.1	-2031.38	-8197.4	-1354.25	-8034.88
g269P	106	0	-6539.81	-1503.58	-6539.81	-1503.58	-3798.71	-873.37	33570.47
g269Y	106	0	-7402.22	-1459.31	-7402.22	-1459.31	-4299.66	-847.66	-27083.75
g271P	107	0	-3764.51	-678.38	-3764.51	-678.38	-2509.67	-452.25	-33.61
g271Y	107	0	-3772.25	-730.56	-3772.25	-730.56	-2514.84	-487.04	-2230.3
g272P	107	0	823.46	-1305.6	823.46	-1305.6	1043.67	-1654.75	-41289.5
g272X	107	0	795.59	-1313.87	795.59	-1313.87	1008.36	-1665.24	53454.91
g273P	107-i	0	-7593.07	-1501.07	-7593.07	-1501.07	-4480.08	-885.66	-5948.31
g273X	107-i	0	6737.3	-1514.44	6737.3	-1514.44	3975.16	-893.55	7115
g274P	96	0	2104.82	-1437.64	2104.82	-1437.64	3476	-2374.19	-232304.07
g274X	96	0	4219.46	-1899.06	4219.46	-1899.06	6968.2	-3136.2	205421.74
Fg274P	96	0	3433.05	-1875.45	3433.05	-1875.45	5669.5	-3097.2	-265256.36
Fg274X	96	0	1756.25	-1399.27	1756.25	-1399.27	2900.36	-2310.82	236897.76
g275P	97	0	-761.1	-122.29	-761.1	-122.29	-1014.79	-163.05	-10985.51
g275Y	97	0	-656.64	-65.07	-656.64	-65.07	-875.52	-86.75	27748.85

Fg275P	97	0	-836.78	-118.84	-836.78	-118.84	-1115.71	-158.46	28690.22
Fg275Y	97	0	-952.37	-67.34	-952.37	-67.34	-1269.83	-89.79	-10552.62
g278P	98	0	1378	-208.33	1378	-208.33	1429.56	-216.13	-24966.61
g278X	98	0	-1639.73	-205.91	-1639.73	-205.91	-1701.09	-213.61	25374.32
g278XY	98	0	-1710.34	-207.23	-1710.34	-207.23	-1774.33	-214.99	-24789.08
g278Y	98	0	1307.39	-206.32	1307.39	-206.32	1356.31	-214.04	26368.63
g279P	99	0	88.96	-275.88	88.96	-275.88	73.45	-227.8	-626.65
g280P	100	0	-5613.91	-716.5	-5613.91	-716.5	-3742.61	-477.66	-7396.6
g280Y	100	0	-5588.09	-909.93	-5588.09	-909.93	-3725.39	-606.62	6299.61
g281P	100	0	843.95	-476.53	843.95	-476.53	750.4	-423.71	-43706.32
g281X	100	0	889.8	-439.58	889.8	-439.58	791.17	-390.86	126078.57
g288P	24	0	10790.7	-8664.93	10790.7	-8664.93	14577.59	-11705.79	449994.03
g288X	24	0	-1223.84	-8377.5	-1223.84	-8377.5	-1653.34	-11317.49	-465037.48
Fg288P	24	0	8310.91	-10759.6	8310.91	-10759.6	11227.54	-14535.57	361466.3
Fg288X	24	0	1453.12	-11083.98	1453.12	-11083.98	1963.08	-14973.79	-379360.87
Fg288291P	24	0	10290.36	-13433.87	10290.36	-13433.87	13901.66	-18148.35	354519.73
Fg288291X	24	0	-571.44	-12913.36	-571.44	-12913.36	-771.98	-17445.16	-339260.7
Fg288292P	24	0	7576.17	-15527.22	7576.17	-15527.22	10234.95	-20976.33	205632.81
Fg288292X	24	0	2639.56	-15950.11	2639.56	-15950.11	3565.88	-21547.63	-190939.59
Fg288293P	24	0	19055.71	-29896.91	19055.71	-29896.91	51486.22	-80777.84	197911.92
Fg288293X	24	0	-3596.48	-29184.71	-3596.48	-29184.71	-9717.25	-78853.54	-162756.96
FFg288293P	24	0	3254.68	-30741.53	3254.68	-30741.53	8793.76	-83059.9	153937.84
FFg288293X	24	0	11480	-31379.97	11480	-31379.97	31017.57	-84784.88	-119693.21
Fg288294P	24	0	4487.94	-36538.03	4487.94	-36538.03	12125.86	-98721.34	129924.36
Fg288294X	24	0	9931.12	-35078.71	9931.12	-35078.71	26832.68	-94778.43	-91333.55
FFg288294P	24	0	1094.09	-34170.06	1094.09	-34170.06	2956.09	-92323.37	7951.37
FFg288294X	24	0	13020.18	-43280.11	13020.18	-43280.11	35178.94	-116937.62	-25233.29
g282P	24	0	16587.33	-10989.56	16587.33	-10989.56	22606.61	-14977.49	441591.36
g282X	24	0	-3833.71	-9438.08	-3833.71	-9438.08	-5224.91	-12863	-431329.17
Fg282P	24	0	13894.36	-11839.64	13894.36	-11839.64	18936.4	-16136.06	351545.48
Fg282X	24	0	-1002.38	-13086.63	-1002.38	-13086.63	-1366.13	-17835.56	-341067.1
Fg282296P	24	0	15586.81	-15140.32	15586.81	-15140.32	21243.01	-20634.49	365372.41
Fg282296X	24	0	-3173.17	-13900.51	-3173.17	-13900.51	-4324.66	-18944.78	-322035.97
Fg282297P	24	0	12654.64	-16648.79	12654.64	-16648.79	17246.81	-22690.36	215177.58
Fg282297X	24	0	265.73	-17540.75	265.73	-17540.75	362.15	-23906	-169323.18
Fg282298P	24	0	25890.45	-32289.32	25890.45	-32289.32	70571.36	-88013.18	214898.05
Fg282298X	24	0	-7417.98	-31102.9	-7417.98	-31102.9	-20219.69	-84779.3	-154546.32
FFg282298P	24	0	8766.91	-32807.57	8766.91	-32807.57	23896.57	-89425.83	176919.95
FFg282298X	24	0	8953.8	-33688.13	8953.8	-33688.13	24405.98	-91826.01	-115754.41
Fg282299P	24	0	8019.24	-38689.34	8019.24	-38689.34	21858.59	-105458.14	154571.72
Fg282299X	24	0	8186.81	-37137.12	8186.81	-37137.12	22315.33	-101227.16	-94290.87
FFg282299P	24	0	4745.84	-36196.22	4745.84	-36196.22	12936.05	-98662.5	41753.45
FFg282299X	24	0	11212.26	-45532.97	11212.26	-45532.97	30562	-124112.29	-38111.34
g283P	24	0	17041.29	-12051.11	17041.29	-12051.11	23230.07	-16427.63	431143.03
g283X	24	0	-5960.89	-11959.14	-5960.89	-11959.14	-8125.67	-16302.26	-428199.91
Fg283P	24	0	14214.6	-14055.04	14214.6	-14055.04	19376.82	-19159.32	337176.56
Fg283X	24	0	-2926.13	-14363.7	-2926.13	-14363.7	-3988.8	-19580.07	-340206.05
Fg283301P	24	0	15818.85	-16519.47	15818.85	-16519.47	21563.68	-22518.74	351498.68
Fg283301X	24	0	-4829.68	-15868.4	-4829.68	-15868.4	-6583.64	-21631.22	-317036.08
Fg283302P	24	0	12883.13	-18382.74	12883.13	-18382.74	17561.82	-25058.67	197841.48
Fg283302X	24	0	-1335.4	-18977.29	-1335.4	-18977.29	-1820.37	-25869.15	-165801.58
Fg283303P	24	0	25401.57	-34675.05	25401.57	-34675.05	69252.99	-94535.51	197692.5
Fg283303X	24	0	-8650.59	-33855.21	-8650.59	-33855.21	-23584.35	-92300.38	-147390.3
FFg283303P	24	0	9428.6	-35361.12	9428.6	-35361.12	25705.46	-96405.98	166470.7
FFg283303X	24	0	6610.01	-36071.27	6610.01	-36071.27	18021.04	-98342.08	-116757.19
Fg283304P	24	0	8160.48	-40814.93	8160.48	-40814.93	22248.15	-111274.83	149069.66
Fg283304X	24	0	6918.83	-39342.33	6918.83	-39342.33	18862.99	-107260.06	-97797.25
FFg283304P	24	0	5206.02	-38233.16	5206.02	-38233.16	14193.32	-104236.09	46064.18
FFg283304X	24	0	9611.64	-47524.59	9611.64	-47524.59	26204.48	-129567.56	-51386.4
g284P	25	0	13573.33	7304.31	13573.33	7304.31	17009.09	9153.21	309095.88
g284X	25	0	-6633.79	7691.93	-6633.79	7691.93	-8312.98	9638.95	-260032.84

Fg284P	25	0	4467.16	1236.79	4467.16	1236.79	2883.77	798.41	234256.15
Fg284X	25	0	499.49	1581.74	499.49	1581.74	322.44	1021.09	-206078.33
Fg284288P	25	0	4707.3	-3187.1	4707.3	-3187.1	4011.21	-2715.81	88827.81
Fg284288X	25	0	1607.11	-3304.09	1607.11	-3304.09	1369.46	-2815.5	-107015.78
Fg284289P	25	0	1871.18	-6225.66	1871.18	-6225.66	1594.48	-5305.05	39170.89
Fg284289X	25	0	3202.77	-6581.24	3202.77	-6581.24	2729.16	-5608.04	-52408.1
g285P	25	0	14802.46	11175.22	14802.46	11175.22	18604.45	14045.56	307465.89
g285X	25	0	-4170.11	11570.22	-4170.11	11570.22	-5241.2	14542.02	-283984.46
Fg285P	25	0	7207.29	3676.12	7207.29	3676.12	4666.49	2380.17	211644.83
Fg285X	25	0	-739.9	4087.61	-739.9	4087.61	-479.06	2646.6	-208475.44
Fg285306P	25	0	7786.26	-1524.08	7786.26	-1524.08	6654.58	-1302.57	39575.3
Fg285306X	25	0	74.27	-1605.11	74.27	-1605.11	63.47	-1371.82	-84957.85
Fg285307P	25	0	3445.11	-5459.4	3445.11	-5459.4	2944.39	-4665.92	-1780.98
Fg285307X	25	0	2364.24	-5774.26	2364.24	-5774.26	2020.62	-4935.02	-31608
g286P	25	0	12872.48	10919.08	12872.48	10919.08	16251.91	13785.69	287219.4
g286X	25	0	-2358.32	11270.31	-2358.32	11270.31	-2977.45	14229.13	-251372.54
Fg286P	25	0	7408.18	2662.47	7408.18	2662.47	4818.24	1731.66	191477.92
Fg286X	25	0	-1698.13	2980.01	-1698.13	2980.01	-1104.46	1938.19	-175467.73
Fg286309P	25	0	7954.45	-2573.63	7954.45	-2573.63	6829.07	-2209.51	24182.96
Fg286309X	25	0	-906.26	-2704.7	-906.26	-2704.7	-778.04	-2322.04	-55463.71
Fg286310P	25	0	3540.97	-6482.29	3540.97	-6482.29	3040	-5565.19	-11714.61
Fg286310X	25	0	1829.27	-6842.51	1829.27	-6842.51	1570.47	-5874.44	-10645.91
g312P	26	0	-5941.21	-1654.13	-5941.21	-1654.13	-3755.31	-1045.54	-85179.13
g312X	26	0	6958.07	-1666.8	6958.07	-1666.8	4398.04	-1053.54	83828.76
g313P	26	0	7511.94	-2473.26	7511.94	-2473.26	5330.57	-1755.06	97557.95
g313X	26	0	-6205.11	-2461.03	-6205.11	-2461.03	-4403.23	-1746.38	-94756.99
g314P	26	0	-6436.47	-3485.58	-6436.47	-3485.58	-5173.9	-2801.85	-105769.77
g314X	26	0	8103.53	-3473.77	8103.53	-3473.77	6513.95	-2792.36	101082.94
g315P	26	0	-6552.12	-4769.19	-6552.12	-4769.19	-6011.06	-4375.36	-140113.58
g315X	26	0	8830.6	-4714	8830.6	-4714	8101.39	-4324.73	135010.21
g318P	26	0	-12515.88	-6960.11	-12515.88	-6960.11	-16626.44	-9245.99	-57748.86
g318X	26	0	14409.68	-6930.24	14409.68	-6930.24	19142.2	-9206.31	60248.25
g319P	26	0	17056.24	-8234.87	17056.24	-8234.87	25539	-12330.41	61683.56
g319X	26	0	-14772.6	-8308.05	-14772.6	-8308.05	-22119.63	-12439.99	-59726.85
g320P	27	0	3182.76	-1383.86	3182.76	-1383.86	5418.01	-2355.74	59596.11
g320X	27	0	-2789.61	-1406.99	-2789.61	-1406.99	-4748.74	-2395.12	-69951.62
g321P	28	0	-1774.83	-723.58	-1774.83	-723.58	-3455.24	-1408.66	-48095.33
g321X	28	0	2000.22	-785.23	2000.22	-785.23	3894.01	-1528.67	110683.13
g326P	26	0	-9202.87	-2039.91	-9202.87	-2039.91	-5831.06	-1292.51	-86528.17
g326X	26	0	10541.69	-2068.96	10541.69	-2068.96	6679.35	-1310.92	90387.98
g327P	26	0	10955.56	-2849	10955.56	-2849	7796.52	-2027.49	100822.71
g327X	26	0	-9249.9	-2875.31	-9249.9	-2875.31	-6582.69	-2046.22	-100430.15
g328P	26	0	-9048.98	-3886.19	-9048.98	-3886.19	-7299.25	-3134.75	-107385.46
g328X	26	0	11156.54	-3872.47	11156.54	-3872.47	8999.29	-3123.68	102704.63
g329P	26	0	11139.58	-5113.16	11139.58	-5113.16	10263.93	-4711.23	137392.92
g329X	26	0	-8282.43	-5240.68	-8282.43	-5240.68	-7631.37	-4828.73	-147879.68
g330P	26	0	16382.78	-7509.93	16382.78	-7509.93	21816.71	-10000.87	59420.59
g330X	26	0	-14145.45	-7547.56	-14145.45	-7547.56	-18837.3	-10050.98	-53736.85
g331P	26	0	-15428.21	-9005.62	-15428.21	-9005.62	-23169.41	-13524.24	-56528.44
g331X	26	0	18146.24	-8885.23	18146.24	-8885.23	27251.23	-13343.45	57289.44
g332P	27	0	3180.78	-1490.73	3180.78	-1490.73	5434.37	-2546.92	54644.1
g332X	27	0	-2742.76	-1518.5	-2742.76	-1518.5	-4686.01	-2594.37	-64656.55
g333P	28	0	-1663.87	-786.59	-1663.87	-786.59	-3254.15	-1538.4	-39667.83
g333X	28	0	1916.53	-845.08	1916.53	-845.08	3748.3	-1652.78	103458.77
g342P	26	0	-9873.78	-2408.32	-9873.78	-2408.32	-6256.43	-1526.01	-91781.28
g342X	26	0	11036.58	-2403.13	11036.58	-2403.13	6993.24	-1522.72	87529.9
g334P	26	0	11268.88	-3253.38	11268.88	-3253.38	8019.95	-2315.4	104961.08
g334X	26	0	-9775.83	-3248.49	-9775.83	-3248.49	-6957.36	-2311.92	-98977.96
g335P	26	0	-9362.61	-4328.18	-9362.61	-4328.18	-7552.78	-3491.52	-110639.76
g335X	26	0	11227.64	-4290.18	11227.64	-4290.18	9057.29	-3460.87	101754.59
g336P	26	0	10832.14	-5602.51	10832.14	-5602.51	9981.6	-5162.59	140658.13

g336X	26	0	-8279.44	-5696.13	-8279.44	-5696.13	-7629.33	-5248.87	-147212.85
g337P	26	0	-13465.36	-8152.9	-13465.36	-8152.9	-17932.5	-10857.63	-50021.24
g337X	26	0	15493.32	-8106.14	15493.32	-8106.14	20633.24	-10795.36	53368.23
g338P	26	0	16739.41	-9547.6	16739.41	-9547.6	25140.08	-14339.06	51608.15
g338X	26	0	-14280.46	-9651.74	-14280.46	-9651.74	-21447.1	-14495.46	-49938.32
g339P	27	0	2881.53	-1586.66	2881.53	-1586.66	4923.5	-2711.04	48399.43
g339X	27	0	-2474.2	-1613.89	-2474.2	-1613.89	-4227.52	-2757.56	-58666.58
g340P	28	0	-1479.02	-834.54	-1479.02	-834.54	-2892.94	-1632.35	-31714.99
g340X	28	0	1713.9	-893.98	1713.9	-893.98	3352.35	-1748.6	95299.52
g341P	28-Jan	0	-3878.41	-727.56	-3878.41	-727.56	-12510.99	-2346.96	137144.79
g343P	28-Jan	0	-3569.91	-832.23	-3569.91	-832.23	-11515.84	-2684.6	136320.86
g344P	28-Jan	0	-3161.41	-897.28	-3161.41	-897.28	-10198.11	-2894.46	136544.34
g350P	29	0	1874.98	-6613.85	1874.98	-6613.85	1336.93	-4715.95	-47362.4
g350X	29	0	-111.38	-6847.06	-111.38	-6847.06	-79.42	-4882.23	33741.58
g345P	29	0	1344.23	4620.44	1344.23	4620.44	953.44	3277.21	82770.06
g345X	29	0	446.7	4835	446.7	4835	316.84	3429.4	-58512.23
g346P	30	0	-129.34	643.54	-129.34	643.54	-108.18	538.28	6263.7
g346X	30	0	293.59	601.95	293.59	601.95	245.57	503.49	-4659.53
g347P	31	0	1737.79	-5632.25	1737.79	-5632.25	1698.09	-5503.58	-78675.33
g347X	31	0	73.14	-5742.75	73.14	-5742.75	71.47	-5611.55	52273.31
g348P	31	0	1201.32	1618	1201.32	1618	1152.62	1552.4	116475.27
g348X	31	0	579.39	1731.42	579.39	1731.42	555.9	1661.23	-77067.58
g349P	32	0	62.9	874.94	62.9	874.94	87.33	1214.66	10135.72
g349X	32	0	215.66	875.79	215.66	875.79	299.39	1215.84	-15404.89
g351P	32	0	118.34	-1280.6	118.34	-1280.6	231.28	-2502.69	22071.09
g351X	32	0	231.31	-1209.45	231.31	-1209.45	452.04	-2363.64	-19986.22
g352P	32	0	177.52	225.94	177.52	225.94	340.64	433.55	45080.14
g352X	32	0	147.37	294.5	147.37	294.5	282.79	565.13	-49420.98
g353P	29	0	2923.55	-9082.51	2923.55	-9082.51	2105.42	-6540.85	-65516.12
g353X	29	0	-538.92	-9310.05	-538.92	-9310.05	-388.11	-6704.71	55189.41
g354P	29	0	2308.41	6535.93	2308.41	6535.93	1628.83	4611.81	104827.09
g354X	29	0	38.95	6758.04	38.95	6758.04	27.48	4768.53	-79455.51
g355P	30	0	31.01	903.28	31.01	903.28	25.94	755.37	10451.61
g355X	30	0	195.11	892.27	195.11	892.27	163.17	746.17	-8953.01
g356P	31	0	2708.78	-7155.68	2708.78	-7155.68	2681.44	-7083.44	-96816.8
g356X	31	0	-354.63	-7257.42	-354.63	-7257.42	-351.05	-7184.16	68945.91
g357P	31	0	2080.34	2597.27	2080.34	2597.27	1988.2	2482.23	135515.36
g357X	31	0	141.77	2724.97	141.77	2724.97	135.49	2604.27	-93419.61
g358P	32	0	171.18	1148.94	171.18	1148.94	237.55	1594.37	14077.79
g358X	32	0	185.45	1159.27	185.45	1159.27	257.34	1608.71	-23682.36
g359P	32	0	385.79	-1464.18	385.79	-1464.18	763.78	-2898.8	-15162.65
g359X	32	0	47.39	-1540.7	47.39	-1540.7	93.82	-3050.3	20958.52
g360P	32	0	308.45	381.02	308.45	381.02	589.58	728.3	38791.92
g360X	32	0	76.79	454.75	76.79	454.75	146.78	869.22	-49019.41
g361P	29	0	949.15	-9609.84	949.15	-9609.84	695.1	-7037.62	58070.37
g361X	29	0	-3053.12	-9351.69	-3053.12	-9351.69	-2235.91	-6848.57	-67367.86
g362P	29	0	-342.01	6663.21	-342.01	6663.21	-246.65	4805.39	-78027.71
g362X	29	0	2438.24	6456.98	2438.24	6456.98	1758.42	4656.65	102433.93
g363P	30	0	167.49	918.68	167.49	918.68	143.86	789.07	-9342.73
g363X	30	0	32.56	936.86	32.56	936.86	27.96	804.68	10899.3
g364P	31	0	-684.78	-7520.84	-684.78	-7520.84	-684.83	-7521.33	67672.14
g364X	31	0	2789.07	-7399.86	2789.07	-7399.86	2789.25	-7400.35	-94517.61
g365P	31	0	2173.53	2360.52	2173.53	2360.52	2110.31	2291.86	129730.19
g365X	31	0	-163.04	2471.82	-163.04	2471.82	-158.3	2399.92	-89494.22
g366P	32	0	183.17	1190.36	183.17	1190.36	261.09	1696.73	14005.94
g366X	32	0	139.53	1193.74	139.53	1193.74	198.89	1701.54	-23274.53
g367P	32	0	396.82	-1498.3	396.82	-1498.3	793.68	-2996.8	-12659.77
g367X	32	0	-4.04	-1573.54	-4.04	-1573.54	-8.07	-3147.28	16882.19
g368P	32	0	321.23	320.24	321.23	320.24	623.77	621.85	33680.41
g368X	32	0	32.44	390.91	32.44	390.91	62.99	759.08	-41267.15
g369P	33	0	-10439	290.57	-10439	290.57	-14859.4	413.62	-487941.93

g369X	33	0	3754.47	386.7	3754.47	386.7	5344.31	550.44	364095.9
Fg369P	33	0	-7916.2	2448.71	-7916.2	2448.71	-11268.32	3485.62	-397506.64
Fg369X	33	0	2082.59	2656.6	2082.59	2656.6	2964.47	3781.53	278476.66
Fg369375P	33	0	-16678.57	7635.63	-16678.57	7635.63	-47482.25	21737.89	-378217.95
Fg369375X	33	0	11317.06	8589.04	11317.06	8589.04	32218.56	24452.14	271594.98
FFg369375P	33	0	-6957.11	10701.89	-6957.11	10701.89	-19806.2	30467.24	-315695.39
FFg369375X	33	0	1312.5	9971.95	1312.5	9971.95	3736.57	28389.17	205757.51
Fg369376P	33	0	-6269.2	11523.28	-6269.2	11523.28	-17847.78	32805.64	-245759.77
Fg369376X	33	0	7016.85	13596.16	7016.85	13596.16	19976.28	38706.92	166106.31
FFg369376P	33	0	6097.04	23266.76	6097.04	23266.76	17357.67	66238.17	-144410.34
FFg369376X	33	0	-5680.21	14833.07	-5680.21	14833.07	-16171	42228.29	-8355.93
g370P	33	0	-18213.49	-2798.28	-18213.49	-2798.28	-26331.38	-4045.5	-533242.26
g370X	33	0	8184.71	-1552.29	8184.71	-1552.29	11832.7	-2244.15	383410.43
Fg370P	33	0	-15669.62	288.48	-15669.62	288.48	-22653.7	417.06	-436604.63
Fg370X	33	0	6564.21	-9.66	6564.21	-9.66	9489.93	-13.96	299886.45
Fg370378P	33	0	-28865.91	3441.83	-28865.91	3441.83	-83463.33	9951.76	-435674.06
Fg370378X	33	0	19185.26	5190.41	19185.26	5190.41	55472.56	15007.62	304472.94
FFg370378P	33	0	-16579.25	7326.12	-16579.25	7326.12	-47937.5	21182.86	-366002.75
FFg370378X	33	0	6712.63	6363.13	6712.63	6363.13	19409	18398.45	233734.05
Fg370379P	33	0	-13842.61	8302.49	-13842.61	8302.49	-40024.73	24005.96	-290932.46
Fg370379X	33	0	11733.66	10502.93	11733.66	10502.93	33926.87	30368.33	191051.5
FFg370379P	33	0	338.22	20818.13	338.22	20818.13	977.94	60193.87	-180576.26
FFg370379X	33	0	-2839.06	12306.24	-2839.06	12306.24	-8208.91	35582.45	8770.01
g371P	33	0	-18143.81	-3756.2	-18143.81	-3756.2	-26239.45	-5432.19	-526741.87
g371X	33	0	9290.61	-1982.43	9290.61	-1982.43	13436.03	-2866.98	379592.31
Fg371P	33	0	-15518.86	-321.34	-15518.86	-321.34	-22443.27	-464.72	-429743.56
Fg371X	33	0	7604.33	-850.62	7604.33	-850.62	10997.33	-1230.16	298369.06
Fg371381P	33	0	-29478.14	2028.94	-29478.14	2028.94	-85262.2	5686.47	-436377.59
Fg371381X	33	0	21485.07	4099.86	21485.07	4099.86	62143.13	11858.37	309995.24
FFg371381P	33	0	-16351.23	6179.3	-16351.23	6179.3	-47294.09	17872.92	-364732.66
FFg371381X	33	0	8148.13	5100.91	8148.13	5100.91	23567.54	14753.8	237984.6
Fg371382P	33	0	-14219.35	7097.02	-14219.35	7097.02	-41127.86	20527.32	-291332.79
Fg371382X	33	0	13404.44	9347.9	13404.44	9347.9	38770.84	27037.74	196057.32
FFg371382P	33	0	983.46	19801.87	983.46	19801.87	2844.56	57274.67	-177125.51
FFg371382X	33	0	-2153.75	11258.65	-2153.75	11258.65	-6229.47	32564.37	9998.88
g372P	34	0	-6176.46	-15207.28	-6176.46	-15207.28	-7468.31	-18388	-121998.34
g372X	34	0	3305.83	-15897.49	3305.83	-15897.49	3997.27	-19222.57	240585.47
Fg372P	34	0	-2186.61	-3446.9	-2186.61	-3446.9	-1909.52	-3010.11	-47111.22
Fg372X	34	0	510.28	-3679.73	510.28	-3679.73	445.62	-3213.44	153260.96
Fg372384P	34	0	-552.75	-242.77	-552.75	-242.77	-457.3	-200.85	-3314.19
Fg372384X	34	0	259.96	-557.04	259.96	-557.04	215.07	-460.85	86416.2
g373P	34	0	-7439.56	-21706.81	-7439.56	-21706.81	-9032.63	-26354.98	-121660.38
g373X	34	0	2677.33	-22695.05	2677.33	-22695.05	3250.63	-27554.82	260248.11
Fg373P	34	0	-4322.36	-5766.53	-4322.36	-5766.53	-3790.17	-5056.53	-14560.68
Fg373X	34	0	1720.99	-6077.99	1720.99	-6077.99	1509.09	-5329.64	145103.49
Fg373386P	34	0	-1799.98	-1460	-1799.98	-1460	-1495.28	-1212.86	31343.79
Fg373386X	34	0	982.11	-1810.68	982.11	-1810.68	815.86	-1504.18	71444.59
g374P	34	0	-6177.87	-21770.53	-6177.87	-21770.53	-7572.68	-26685.79	-145674.57
g374X	34	0	1525.88	-22671.34	1525.88	-22671.34	1870.39	-27789.98	278108.43
Fg374P	34	0	-4313.57	-5755.97	-4313.57	-5755.97	-3818.73	-5095.66	-29486.06
Fg374X	34	0	2042.48	-6035.87	2042.48	-6035.87	1808.17	-5343.45	151332.26
Fg374388P	34	0	-1798.29	-1486.48	-1798.29	-1486.48	-1508.2	-1246.69	23196.6
Fg374388X	34	0	1205.88	-1821.78	1205.88	-1821.78	1011.36	-1527.91	71711.06
g514P	35	0	-5509.83	-178.02	-5509.83	-178.02	-3633.38	-117.39	-78778.28
g514X	35	0	4990.03	-115.47	4990.03	-115.47	3290.61	-76.15	80175.67
g515P	35	0	5921.81	322.53	5921.81	322.53	4706.56	256.34	92131.63
g515X	35	0	-6579.81	232.64	-6579.81	232.64	-5229.53	184.9	-95030.43
g516P	35	0	-10424.99	722.19	-10424.99	722.19	-11594.01	803.17	-74439.91
g516X	35	0	10111.84	804.62	10111.84	804.62	11245.74	894.84	74330.82
g517P	35	0	12494.68	1354.66	12494.68	1354.66	16360.94	1773.83	87504.37
g517X	35	0	-12950.13	1254.64	-12950.13	1254.64	-16957.32	1642.87	-81467.17

g518P	35	0	-17045.52	1985.64	-17045.52	1985.64	-26875.37	3130.72	-111910.63
g518X	35	0	17132.5	2103.98	17132.5	2103.98	27012.51	3317.31	91825.91
g519P	36	0	-4494.25	522.3	-4494.25	522.3	-8719.97	1013.39	-89674.47
g519X	36	0	4507.08	654.08	4507.08	654.08	8744.87	1269.07	171913.91
g520P	37	0	-2622.6	5416.84	-2622.6	5416.84	-2046.5	4226.93	42025.79
g520X	37	0	808.44	5700.78	808.44	5700.78	630.85	4448.49	-49291.96
g521P	37	0	-1754.72	-5115.61	-1754.72	-5115.61	-1379.8	-4022.6	-83911.91
g521X	37	0	165.65	-5341.14	165.65	-5341.14	130.26	-4199.94	91837.26
g522P	37	0	5576.76	5927.87	5576.76	5927.87	5231.77	5561.16	-4450.77
g522X	37	0	-3899.12	7159.59	-3899.12	7159.59	-3657.91	6716.68	6521.35
g523P	38	0	-430.67	1181.99	-430.67	1181.99	-675.27	1853.31	21847.06
g523X	38	0	147.15	1205.82	147.15	1205.82	230.73	1890.67	-35736.66
g524P	38	0	55.7	-768.72	55.7	-768.72	83.93	-1158.43	73577.45
g524X	38	0	-264.12	-753.6	-264.12	-753.6	-398.02	-1135.63	-49132.16
g525P	35	0	-8334.61	-563.53	-8334.61	-563.53	-5517.07	-373.03	-78133.81
g525X	35	0	7571.73	-466.78	7571.73	-466.78	5012.08	-308.98	87375.46
g526P	35	0	8371.77	-111.7	8371.77	-111.7	6688.4	-89.24	88684.04
g526X	35	0	-9379.05	-181.44	-9379.05	-181.44	-7493.14	-144.95	-99113.96
g527P	35	0	-13734.58	197.18	-13734.58	197.18	-15317.29	219.91	-78423.31
g527X	35	0	13181.31	306.67	13181.31	306.67	14700.27	342.01	83014.37
g528P	35	0	15409.2	809.1	15409.2	809.1	20250.13	1063.28	93505.59
g528X	35	0	-16189.44	703.79	-16189.44	703.79	-21275.48	924.9	-89577.91
g529P	35	0	-20163.67	1387.77	-20163.67	1387.77	-31949.37	2198.92	-118944.96
g529X	35	0	19922.25	1538.55	19922.25	1538.55	31566.84	2437.83	99905.88
g530P	36	0	4949.72	553.36	4949.72	553.36	9673.29	1081.44	179125.97
g530X	36	0	-5027.05	416.66	-5027.05	416.66	-9824.43	814.28	-97267.69
g531P	37	0	-4636.4	7162.98	-4636.4	7162.98	-3669.13	5668.61	65654.04
g531X	37	0	1943.52	7688.08	1943.52	7688.08	1538.06	6084.16	-70058.06
g532P	37	0	7354.35	-9008.62	7354.35	-9008.62	6900.11	-8452.19	-8384.19
g532X	37	0	-9143.86	-6526.55	-9143.86	-6526.55	-8579.08	-6123.43	10413.76
g533P	37	0	3570.79	-7430.85	3570.79	-7430.85	2795.01	-5816.44	-121402
g533X	37	0	-1171.55	-7767.51	-1171.55	-7767.51	-917.02	-6079.96	122829.81
g534P	38	0	-845.58	1481.79	-845.58	1481.79	-1343.07	2353.59	22755.65
g534X	38	0	385.37	1541.57	385.37	1541.57	612.1	2448.53	-39072.72
g535P	38	0	-614.98	-1141	-614.98	-1141	-922.65	-1711.83	-52751.33
g535X	38	0	257.62	-1173.14	257.62	-1173.14	386.51	-1760.06	82418.92
g536P	35	0	-8746.03	-743.42	-8746.03	-743.42	-5789.81	-492.14	-75396.04
g536X	35	0	8073.47	-629.49	8073.47	-629.49	5344.58	-416.72	87986.27
g537P	35	0	9002.36	-318.12	9002.36	-318.12	7192.93	-254.18	85563.99
g537X	35	0	-9876.98	-380.21	-9876.98	-380.21	-7891.75	-303.79	-98924.91
g538P	35	0	-14607.08	-104.37	-14607.08	-104.37	-16291.15	-116.41	-78726.82
g538X	35	0	14151.1	12.83	14151.1	12.83	15782.6	14.31	85121.07
g539P	35	0	16594.6	464.71	16594.6	464.71	21809.44	610.75	94799.59
g539X	35	0	-17242.14	362.05	-17242.14	362.05	-22660.47	475.82	-91516.92
g540P	35	0	-21529.99	981.61	-21529.99	981.61	-34117.76	1555.52	-121268.87
g540X	35	0	21437	1129.66	21437	1129.66	33970.39	1790.13	102471.45
g541P	36	0	5324.62	465.36	5324.62	465.36	10407.56	909.59	182330.19
g541X	36	0	-5360.14	330.41	-5360.14	330.41	-10476.99	645.82	-100436.07
g542P	37	0	-4646.3	6846.38	-4646.3	6846.38	-3730	5496.19	72205.58
g542X	37	0	2226.07	7384.07	2226.07	7384.07	1787.06	5927.84	-78688.66
g543P	37	0	8233.34	-8268.22	8233.34	-8268.22	7932.88	-7966.49	-9020.27
g543X	37	0	-9577.58	-5855.59	-9577.58	-5855.59	-9228.07	-5641.9	11083.13
g544P	37	0	3594.84	-7485.18	3594.84	-7485.18	2879.13	-5994.93	-129235.9
g544X	37	0	-1452.22	-7798.2	-1452.22	-7798.2	-1163.09	-6245.63	133695.99
g545P	38	0	454	1483.75	454	1483.75	732.52	2394.01	-41991.1
g545X	38	0	-853.82	1428.99	-853.82	1428.99	-1377.62	2305.65	26157.39
g546P	38	0	322.12	-1175.08	322.12	-1175.08	494.24	-1802.99	88078.32
g546X	38	0	-624.92	-1150.15	-624.92	-1150.15	-958.85	-1764.73	-59596.48
g548P	39	0	1096.81	-1755.66	1096.81	-1755.66	1693.79	-2711.25	34512.89
g548X	39	0	-326.25	-1823.72	-326.25	-1823.72	-503.82	-2816.35	-47016.31
Fg548P	39	0	910.83	-1831.69	910.83	-1831.69	1406.58	-2828.66	22156.61

Fg548X	39	0	-128.55	-1879.35	-128.55	-1879.35	-198.51	-2902.26	-35576.8
Fg548431P	39	0	1142.93	-1882.63	1142.93	-1882.63	1765.02	-2907.33	32534.66
Fg548431X	39	0	-252.22	-1949.93	-252.22	-1949.93	-389.5	-3011.25	-35301.7
Fg548432P	39	0	976.35	-1960.51	976.35	-1960.51	1507.77	-3027.59	6106.76
Fg548432X	39	0	-100.9	-2027.42	-100.9	-2027.42	-155.82	-3130.93	-10432.11
Fg548433P	39	0	1198.35	-1936.57	1198.35	-1936.57	1850.61	-2990.62	-22008.83
Fg548433X	39	0	-254.51	-2002.96	-254.51	-2002.96	-393.03	-3093.15	24079.89
Fg548434P	39	0	3828.7	-4848.27	3828.7	-4848.27	17737.89	-22461.42	-19990.29
Fg548434X	39	0	-1705.48	-5040.1	-1705.48	-5040.1	-7901.28	-23350.13	31867.51
FFg548434P	39	0	2316.84	-4784.62	2316.84	-4784.62	10733.63	-22166.52	-15853.79
FFg548434X	39	0	-434.3	-4903.57	-434.3	-4903.57	-2012.07	-22717.63	28166.65
FFg5484P	39	0	1415.6	-4591.1	1415.6	-4591.1	6558.28	-21269.99	-6452.21
FFg5484X	39	0	162.8	-4761.52	162.8	-4761.52	754.23	-22059.53	16192.57
g547P	40	0	-375.07	223.74	-375.07	223.74	-617.13	368.14	-51305.98
g547X	40	0	1411.69	205.56	1411.69	205.56	2322.74	338.22	86706.75
Fg547P	40	0	-164.18	-1179.09	-164.18	-1179.09	-270.14	-1940.04	-35164.32
Fg547X	40	0	1246.96	-1155.17	1246.96	-1155.17	2051.7	-1900.67	62089.95
Fg547436P	40	0	-312.7	-1847.29	-312.7	-1847.29	-514.5	-3039.47	-35393.85
Fg547436X	40	0	1527.16	-1812.92	1527.16	-1812.92	2512.73	-2982.91	62709.62
Fg547437P	40	0	-141.32	-2387.08	-141.32	-2387.08	-232.52	-3927.62	-18585.38
Fg547437X	40	0	1345.61	-2326.75	1345.61	-2326.75	2214.03	-3828.35	29633.74
Fg547438P	40	0	-353.49	-2486.21	-353.49	-2486.21	-581.62	-4090.73	3132.42
Fg547438X	40	0	1619.1	-2414.1	1619.1	-2414.1	2664.01	-3972.08	-12182.49
Fg547439P	40	0	-333.12	-2472.51	-333.12	-2472.51	-548.1	-4068.18	1959.74
Fg547439X	40	0	1208.02	-2394.21	1208.02	-2394.21	1987.64	-3939.35	-991.76
g549P	41	0	5270.33	-1493.97	5270.33	-1493.97	3452.66	-978.72	15231.88
g549X	41	0	-4708.09	-1701.54	-4708.09	-1701.54	-3084.33	-1114.7	-15112.86
g550P	41	0	-5132.8	-2237.63	-5132.8	-2237.63	-3875.75	-1689.62	-15828.74
g550X	41	0	5894.51	-1973.63	5894.51	-1973.63	4450.92	-1490.28	15802.15
g551P	42	0	1978.48	-793.96	1978.48	-793.96	1748.77	-701.78	18127.9
g551X	42	0	-1625.43	-919.02	-1625.43	-919.02	-1436.71	-812.32	-17789.36
g552P	43	0	-981.77	-765.4	-981.77	-765.4	-1030.09	-803.08	-23521.93
g552X	43	0	1277.5	-672.27	1277.5	-672.27	1340.38	-705.36	23281.15
g553P	44	0	-1030.83	-1380.19	-1030.83	-1380.19	-1289.45	-1726.47	-38503.64
g553X	44	0	1632.12	-1220.58	1632.12	-1220.58	2041.6	-1526.81	39420.38
g554P	44	0	-2196.01	-2269.61	-2196.01	-2269.61	-5577.1	-5764	-9140.13
g554X	44	0	2813.19	-2020.42	2813.19	-2020.42	7144.51	-5131.14	9503.24
g555P	44	0	-1386.76	-2993.62	-1386.76	-2993.62	-4167.09	-8995.55	-7631.43
g555X	44	0	2153.19	-2704.42	2153.19	-2704.42	6470.15	-8126.52	6923.13
g556P	44	0	1768.29	-3338.84	1768.29	-3338.84	6338.79	-11968.76	2231.55
g556X	44	0	-844.95	-3640.79	-844.95	-3640.79	-3028.89	-13051.17	78.18
g557P	45	0	555.54	-1211.09	555.54	-1211.09	469.82	-1024.23	-24854.58
g557X	45	0	-140.61	-1269.64	-140.61	-1269.64	-118.91	-1073.74	16792.8
g558P	46	0	242.83	961.93	242.83	961.93	311.51	1234.02	6554.61
g558X	46	0	118.38	939.07	118.38	939.07	151.86	1204.69	-5722.7
g560P	46	0	397.95	164.65	397.95	164.65	491.43	203.33	17242.6
g560X	46	0	-40.46	188.4	-40.46	188.4	-49.96	232.66	-10536.29
g559P	46	0	-398.58	857.4	-398.58	857.4	-639.14	1374.89	-492.57
g559X	46	0	-81.76	818.47	-81.76	818.47	-131.11	1312.46	79.22
g561P	46	0	430.56	-695.17	430.56	-695.17	464.07	-749.28	-20593.44
g561X	46	0	-84.05	-727.11	-84.05	-727.11	-90.59	-783.7	10070.87
g562P	46	0	579.79	797.18	579.79	797.18	1239.63	1704.43	2708.01
g562X	46	0	76.03	717.96	76.03	717.96	162.57	1535.06	-1779.36
g563P	46	0	548.5	-773.63	548.5	-773.63	851.09	-1200.41	22927.04
g563X	46	0	-48.69	-788.11	-48.69	-788.11	-75.56	-1222.87	-11253.19
g564P	46	0	-975.13	849.05	-975.13	849.05	-3127.37	2723	-12893.08
g564X	46	0	-24.84	700.04	-24.84	700.04	-79.68	2245.11	6092.71
g565P	47	0	722.97	-1085.2	722.97	-1085.2	1191.69	-1788.76	45222.45
g565X	47	0	-156.1	-1116.71	-156.1	-1116.71	-257.31	-1840.71	-22150.53
g566P	47	0	-1712.92	344.79	-1712.92	344.79	-10987.09	2211.54	2057.77
g566X	47	0	149.93	58.85	149.93	58.85	961.67	377.47	-317.33

g567P	48	0	-587.59	478.95	-587.59	478.95	-1179.1	961.08	-26433.1
g567X	48	0	300.49	530.13	300.49	530.13	602.99	1063.79	1102.59
Fg567P	48	0	-486.17	497.34	-486.17	497.34	-975.58	998	-9131.76
Fg567X	48	0	243.45	569.6	243.45	569.6	488.52	1142.99	-14344.53
Fg567463P	48	0	-595	479.14	-595	479.14	-1193.96	961.46	-30078.12
Fg567463X	48	0	343.53	525.61	343.53	525.61	689.34	1054.73	4007.01
Fg567464P	48	0	-454.79	500.83	-454.79	500.83	-912.62	1004.99	4835.04
Fg567464X	48	0	288.1	550.97	288.1	550.97	578.13	1105.61	-26064.93
Fg567465P	48	0	-2581.49	1091.52	-2581.49	1091.52	-15540.53	6570.93	18319.82
Fg567465X	48	0	2176.69	1248.01	2176.69	1248.01	13103.66	7513.02	-33509.49
FFg567465P	48	0	-990.84	1388	-990.84	1388	-5964.87	8355.76	16682.78
FFg567465X	48	0	645.15	1423.64	645.15	1423.64	3883.79	8570.31	-31807.57
FFg5674P	48	0	-243.05	1386.59	-243.05	1386.59	-1463.17	8347.28	8390.28
FFg5674X	48	0	16.97	1485.61	16.97	1485.61	102.17	8943.33	-21138.93
g568P	49	0	-1310.45	-1872.29	-1310.45	-1872.29	-3153.01	-4504.84	-61439.53
g568X	49	0	684.8	-1960.63	684.8	-1960.63	1647.68	-4717.37	60671.43
Fg568P	49	0	-1160.39	147.36	-1160.39	147.36	-2791.97	354.55	-37139.64
Fg568X	49	0	618.33	202.46	618.33	202.46	1487.73	487.14	38438.57
Fg568467P	49	0	-1368.42	949.37	-1368.42	949.37	-3292.49	2284.24	-40255.91
Fg568467X	49	0	812.36	1040.47	812.36	1040.47	1954.58	2503.43	40294.96
Fg568468P	49	0	-1086.09	935.15	-1086.09	935.15	-2613.18	2250.02	14363.66
Fg568468X	49	0	723.18	1021.3	723.18	1021.3	1740.01	2457.31	-9273.66
Fg568469P	49	0	-1073.6	1256.96	-1073.6	1256.96	-2583.14	3024.3	-8873.63
Fg568469X	49	0	825.42	1348.54	825.42	1348.54	1986	3244.65	5751.28
g569P	50	0	-5672.43	-690.67	-5672.43	-690.67	-3909.38	-476	-18289.93
g569X	50	0	5286.93	-345.08	5286.93	-345.08	3643.7	-237.83	18280.95
g570P	51	0	-3048.87	-253.69	-3048.87	-253.69	-2526.18	-210.19	-20950.25
g570X	51	0	2829.31	-46.72	2829.31	-46.72	2344.26	-38.71	20455.95
g571P	51	0	3180.83	275.82	3180.83	275.82	3271.72	283.7	20764.29
g571X	51	0	-3535.57	-31.2	-3535.57	-31.2	-3636.6	-32.09	-20916.8
g572P	51	0	-3773.37	661.09	-3773.37	661.09	-4993.27	874.81	-26249.63
g572X	51	0	3376.66	1012.67	3376.66	1012.67	4468.3	1340.06	25289.14
g573P	51	0	-5204.77	1203.02	-5204.77	1203.02	-11865.14	2742.48	-24352.65
g573X	51	0	4896.03	1516.85	4896.03	1516.85	11161.33	3457.91	24412.71
g574P	51	0	3305.11	3530.99	3305.11	3530.99	9211.91	9841.48	22795.64
g574X	51	0	-3695.01	3184.38	-3695.01	3184.38	-10298.63	8875.4	-22312.34
g575P	51	0	-3798.92	4135.48	-3798.92	4135.48	-13407.18	14594.96	-16798.04
g575X	51	0	3392.49	4556.34	3392.49	4556.34	11972.82	16080.29	14545.05
g576P	52	0	835.26	1905.3	835.26	1905.3	746.85	1703.63	-30168.83
g576X	52	0	-1652.56	1697.49	-1652.56	1697.49	-1477.64	1517.82	34870.79
g577P	53	0	78.71	-1827.23	78.71	-1827.23	105.18	-2441.73	6560.8
g577X	53	0	-815.87	-1903.71	-815.87	-1903.71	-1090.24	-2543.93	-7154.98
g578P	53	0	866.19	-882.12	866.19	-882.12	1431.9	-1458.23	20272.52
g578X	53	0	-1696.24	-845.76	-1696.24	-845.76	-2804.07	-1398.13	-24320.95
g579P	53	0	-537.37	-1524.28	-537.37	-1524.28	-957.46	-2715.87	-60.86
g579X	53	0	1412.57	-1703.05	1412.57	-1703.05	2516.82	-3034.39	-464.23
g580P	53	0	871.65	1308.41	871.65	1308.41	1116.45	1675.87	-37312.75
g580X	53	0	-1519.03	1180.38	-1519.03	1180.38	-1945.64	1511.88	43773.12
g581P	53	0	820.92	-1929.1	820.92	-1929.1	2194	-5155.73	9151.37
g581X	53	0	-1873.47	-2128.04	-1873.47	-2128.04	-5007.04	-5687.4	-11465.91
g582P	53	0	1626.5	2301.81	1626.5	2301.81	3978.51	5630.35	34938.96
g582X	53	0	-2451.44	2110.19	-2451.44	2110.19	-5996.36	5161.63	-40298.56
g584P	53	0	2492.53	-1063.58	2492.53	-1063.58	13323.07	-5685.06	3578.55
g584X	53	0	-3952.38	-1540.64	-3952.38	-1540.64	-21126.3	-8235.01	-6218.6
g583P	108	0	548.28	-45.22	548.28	-45.22	7668.28	-632.42	33955.84
Fg583P	108	0	95.03	-1166.91	95.03	-1166.91	1329.04	-16320.48	-33773.6
g585P	108	0	643.86	991.97	643.86	991.97	6777.49	10441.82	32724.99
Fg585P	108	0	41.63	-498.39	41.63	-498.39	438.22	-5246.25	-35004.51
g589P	28-Jan	0	-4310.85	156.31	-4310.85	156.31	-13905.97	504.21	122514.54
g586P	28-Jan	0	-4572.59	118.59	-4572.59	118.59	-14750.29	382.54	121755.19
g587P	28-Jan	0	-4890.75	43.43	-4890.75	43.43	-15776.6	140.09	121521.32

g588P	101	0	5865.01	-5176.78	5865.01	-5176.78	12629.9	-11147.85	402267.44
g588X	101	0	4506.44	-3868.89	4506.44	-3868.89	9704.31	-8331.4	-457699
Fg588P	101	0	3996.38	-4518.14	3996.38	-4518.14	8605.93	-9729.5	415134.06
Fg588X	101	0	5762.71	-4410.79	5762.71	-4410.79	12409.61	-9498.35	-472173.51
g590P	102	0	869.55	-141.94	869.55	-141.94	1159.39	-189.25	10742.67
g590Y	102	0	956.6	-84.06	956.6	-84.06	1275.46	-112.08	1441.48
Fg590P	102	0	832.73	-146.26	832.73	-146.26	1110.31	-195.02	-10823.55
Fg590Y	102	0	740.76	-81.39	740.76	-81.39	987.67	-108.52	21650.91
g591P	103	0	1620.61	-227.41	1620.61	-227.41	1837.16	-257.8	-11591.05
g591X	103	0	-1347.39	-226.74	-1347.39	-226.74	-1527.44	-257.04	13870.54
g591XY	103	0	-1404.09	-228.76	-1404.09	-228.76	-1591.71	-259.33	-12026.55
g591Y	103	0	1563.91	-225.77	1563.91	-225.77	1772.89	-255.94	12785.23
g592P	104	0	51.16	-197.58	51.16	-197.58	55.08	-212.74	-802.59
g593P	109	0	369.76	-107.43	369.76	-107.43	408.43	-118.67	-4430.61
g594P	109	0	495.52	-163.6	495.52	-163.6	547.53	-180.77	-7077.15
g596P	109	0	497.42	-197.76	497.42	-197.76	549.64	-218.52	-7046.8
g595P	110	0	-765.79	-288.35	-765.79	-288.35	-668.77	-251.81	18421.09
g597P	110	0	-754.98	-260.96	-754.98	-260.96	-652.61	-225.57	18699.82
g598P	110	0	-565.55	-207.34	-565.55	-207.34	-488.82	-179.2	11814.08
g600P	12	0	-10879.5	-3318.31	-10879.5	-3318.31	-9689.56	-2955.37	-167757.7
g600X	12	0	11053.07	-1197.88	11053.07	-1197.88	9845.74	-1067.03	173663.28
g600XY	12	0	11101.53	1651.97	11101.53	1651.97	9888.9	1471.52	228748.62
g600Y	12	0	-10932.36	-158.24	-10932.36	-158.24	-9736.63	-140.93	-245016.78
ig600PP	12	0	-14577.44	-2349.75	-14577.44	-2349.75	-15194.48	-2449.21	-141427.2
ig600PX	12	0	14850.26	-759.64	14850.26	-759.64	15475.92	-791.64	148125.56
ig600PXY	12	0	14746.07	-427.44	14746.07	-427.44	15367.33	-445.45	206490.87
ig600PY	12	0	-14792.72	-1816.2	-14792.72	-1816.2	-15418.87	-1893.07	-221739.97
g599P	73	0	817.13	-120.34	817.13	-120.34	1001.39	-147.47	16586.21
g599X	73	0	-816.74	-70.46	-816.74	-70.46	-1001.2	-86.37	-17114.38
g599XY	73	0	-812.06	-53.77	-812.06	-53.77	-995.46	-65.91	-11557.48
g599Y	73	0	805.04	-98.05	805.04	-98.05	986.58	-120.16	17400.12
g601P	12	0	3029.27	-14243.45	3029.27	-14243.45	2988.46	-14051.56	134576.93
g601X	12	0	-167.28	-14359.61	-167.28	-14359.61	-165.03	-14166.15	-121599.62
g601XY	12	0	-2787.52	12241.39	-2787.52	12241.39	-2749.96	12076.47	-88092.56
g601Y	12	0	-15.87	12466.69	-15.87	12466.69	-15.66	12298.73	36949.9
g602P	5	0	11016.81	-77263.32	11016.81	-77263.32	15294.27	-107262.08	860457.01
g602X	5	0	3962.74	-77042.8	3962.74	-77042.8	5501.33	-106955.94	-805477.26
g602XY	5	0	-8517.05	76936.93	-8517.05	76936.93	-11823.93	106808.96	-1006176.28
g602Y	5	0	-8279.33	77637.61	-8279.33	77637.61	-11493.91	107781.69	666625.26
g603P	5	0	-7247.77	84236.33	-7247.77	84236.33	-10061.83	116942.48	585914.79
g603X	5	0	-12401.34	85520.51	-12401.34	85520.51	-17216.37	118725.26	-898782.15
g603XY	5	0	1811.83	-84349.92	1811.83	-84349.92	2515.31	-117100.17	-714265.5
g603Y	5	0	13873.2	-84909.93	13873.2	-84909.93	19259.7	-117877.6	753143.21
g604P	5	0	-11736.84	116816.49	-11736.84	116816.49	-21725.15	216229.89	677702.11
g604X	5	0	-11044.5	115300.89	-11044.5	115300.89	-20443.62	213424.48	-1004078.35
g604XY	5	0	14684.11	-116236.35	14684.11	-116236.35	27180.61	-215156.04	-765975.3
g604Y	5	0	14343.88	-114983.61	14343.88	-114983.61	26550.83	-212837.18	826147.72
g605P	5	0	-9386.13	122216.32	-9386.13	122216.32	-17373.93	226225.1	679093.71
g605X	5	0	-16286.79	122878.52	-16286.79	122878.52	-30147.21	227450.84	-1004827.73
g605XY	5	0	11307.59	-122107.16	11307.59	-122107.16	20930.59	-226023.04	-766381.32
g605Y	5	0	17865.88	-121332.19	17865.88	-121332.19	33070.13	-224588.54	827849.01
g606P	5	0	-14694.81	126735.01	-14694.81	126735.01	-27200.41	234589.29	597741.56
g606X	5	0	-15480.96	125839.68	-15480.96	125839.68	-28655.59	232932.02	-890213.59
g606XY	5	0	12780.93	-124976.64	12780.93	-124976.64	23657.77	-231334.51	-732702.83
g606Y	5	0	13808.43	-125281.6	13808.43	-125281.6	25559.71	-231898.99	747145.97
g607P	5	0	-4461.68	131032.1	-4461.68	131032.1	-8258.67	242543.29	599676.79
g607X	5	0	-28948.12	132888.98	-28948.12	132888.98	-53583.6	245980.41	-891632.48
g607XY	5	0	533.33	-130416.98	533.33	-130416.98	987.21	-241404.69	-733754.76
g607Y	5	0	25272.22	-131050.36	25272.22	-131050.36	46779.44	-242577.09	749441.1
g498P	13	0	2504.3	-23291.23	2504.3	-23291.23	5002.76	-46528.08	357575.08
g498X	13	0	7527.05	-23334.54	7527.05	-23334.54	15036.52	-46614.61	-349880.33

g498XY	13	0	138.53	21420.29	138.53	21420.29	276.74	42790.56	-268828.01
g498Y	13	0	-9709.22	21536.84	-9709.22	21536.84	-19395.77	43023.41	217983.77
g499P	13	0	4429.12	-33845.5	4429.12	-33845.5	4423.95	-33805.99	340958.03
g499X	13	0	1921.1	-34018.44	1921.1	-34018.44	1918.86	-33978.73	-336667.76
g499XY	13	0	-4122.03	29896.4	-4122.03	29896.4	-4117.22	29861.5	-246967.32
g499Y	13	0	-2268.11	30098.6	-2268.11	30098.6	-2265.47	30063.46	208555.36
g500P	13	0	2170.63	-23069.98	2170.63	-23069.98	4336.18	-46086.09	351543.11
g500X	13	0	13209.94	-23251.83	13209.94	-23251.83	26389.03	-46449.38	-354551.99
g500XY	13	0	2260.41	21206.57	2260.41	21206.57	4515.54	42363.63	-259259.68
g500Y	13	0	-13373.5	21360.56	-13373.5	21360.56	-26715.77	42671.25	222956.9
g501P	13	0	46948.82	-183.47	46948.82	-183.47	90270.96	-352.77	272081.56
g501X	13	0	-46888.74	-4375.95	-46888.74	-4375.95	-90155.44	-8413.87	-266107.63
g501XY	13	0	-46007.06	-3752.12	-46007.06	-3752.12	-88460.2	-7214.4	-345136.74
g501Y	13	0	48079.26	1163.27	48079.26	1163.27	92444.51	2236.67	279566.4
g608P	13	0	28151.89	-897.38	28151.89	-897.38	27064.56	-862.72	239606.51
g608X	13	0	-28006.22	-6486.73	-28006.22	-6486.73	-26924.52	-6236.19	-233983.43
g608XY	13	0	-28088.67	-7903.31	-28088.67	-7903.31	-27003.78	-7598.06	-309219.61
g608Y	13	0	27807.61	-1262.54	27807.61	-1262.54	26733.58	-1213.77	251092.81
g609P	13	0	60028.08	-1533.51	60028.08	-1533.51	115419.13	-2948.56	232006.07
g609X	13	0	-60614.06	-5272.75	-60614.06	-5272.75	-116545.83	-10138.19	-224701.16
g609XY	13	0	-59351.12	-3116.05	-59351.12	-3116.05	-114117.51	-5991.39	-303714.39
g609Y	13	0	61825.67	1496.6	61825.67	1496.6	118875.45	2877.58	239830.55
g611P	14	0	1715.61	-14156.66	1715.61	-14156.66	1960.46	-16177.04	98785.27
g611X	14	0	3059.08	-14361.19	3059.08	-14361.19	3495.66	-16410.76	-47633.2
g611XY	14	0	-1024.43	12450.22	-1024.43	12450.22	-1170.63	14227.06	-105270.86
g611Y	14	0	-2551.77	12595.63	-2551.77	12595.63	-2915.94	14393.22	56725.62
g610P	14	0	1231.6	-13855.06	1231.6	-13855.06	1449.76	-16309.37	95749.28
g610X	14	0	3334.1	-13953.68	3334.1	-13953.68	3924.71	-16425.47	-50617.28
g610XY	14	0	-1496.75	11900.19	-1496.75	11900.19	-1761.88	14008.22	-101384.61
g610Y	14	0	-3550.61	11935.95	-3550.61	11935.95	-4179.57	14050.31	58106.54
g612P	14	0	17890.25	-434.77	17890.25	-434.77	19351.28	-470.28	209318.44
g612X	14	0	-17553.58	-2925.68	-17553.58	-2925.68	-18984.62	-3164.19	-219196.18
g612XY	14	0	-17800.07	-3844.87	-17800.07	-3844.87	-19251.21	-4158.32	-182257.28
g612Y	14	0	17674.02	-876.6	17674.02	-876.6	19117.39	-948.19	182241.15
g613P	14	0	19731.88	-414.95	19731.88	-414.95	21343.31	-448.84	192752.92
g613X	14	0	-19478.3	-2608.75	-19478.3	-2608.75	-21071.8	-2822.17	-201830.71
g613XY	14	0	-19461.03	-3851.79	-19461.03	-3851.79	-21053.11	-4166.9	-165433.03
g613Y	14	0	19578.07	-1208.09	19578.07	-1208.09	21176.95	-1306.75	166710.09
g614P	14	0	1954.03	-15928.46	1954.03	-15928.46	2272.64	-18525.69	-43754.16
g614X	14	0	2524.15	-15995.07	2524.15	-15995.07	2935.73	-18603.15	94552.32
g614XY	14	0	-2213.25	13989.83	-2213.25	13989.83	-2574.13	16270.95	56574.99
g614Y	14	0	-2802.93	14054.49	-2802.93	14054.49	-3259.97	16346.15	-89608.92
g615P	14	0	673.79	-15512.81	673.79	-15512.81	808	-18602.69	-48432.36
g615X	14	0	5388.04	-15751.75	5388.04	-15751.75	6461.25	-18889.23	96629.12
g615XY	14	0	73.9	13176.16	73.9	13176.16	88.62	15800.63	63938.35
g615Y	14	0	-4636.91	13404.32	-4636.91	13404.32	-5560.5	16074.23	-89603.43
g616P	14	0	19661.02	95.29	19661.02	95.29	21266.67	103.07	190979.91
g616X	14	0	-19502.51	-3120.19	-19502.51	-3120.19	-21097.99	-3375.45	-186044.8
g616XY	14	0	-19411.51	-3870.25	-19411.51	-3870.25	-20999.55	-4186.87	-154220.32
g616Y	14	0	19554.84	-1187.98	19554.84	-1187.98	21151.81	-1285	150546.32
g617P	14	0	21429.88	1020.15	21429.88	1020.15	23186.09	1103.75	176512.32
g617X	14	0	-21027.72	-1907.57	-21027.72	-1907.57	-22747.97	-2063.62	-170368.95
g617XY	14	0	-21160.53	-4807.09	-21160.53	-4807.09	-22891.65	-5200.35	-138866.76
g617Y	14	0	21079.88	-2439.89	21079.88	-2439.89	22807.41	-2639.84	135690.24
g494P	74	0	384.53	-3678.58	384.53	-3678.58	533.56	-5104.24	21602.35
g494X	74	0	100.74	-3652.5	100.74	-3652.5	139.78	-5068.05	-17905.13
g494XY	74	0	-364.58	3685.91	-364.58	3685.91	-505.88	5114.41	-27662.81
g494Y	74	0	-218.71	3663.56	-218.71	3663.56	-303.48	5083.39	13914.54
g495P	74	0	-454.91	-3949.76	-454.91	-3949.76	-892.13	-7745.94	8327.2
g495X	74	0	-194.15	-3917.29	-194.15	-3917.29	-380.75	-7682.27	3966.87
g495XY	74	0	415.17	3874.62	415.17	3874.62	814.2	7598.6	-4731.35

g495Y	74	0	339.34	3797.53	339.34	3797.53	665.48	7447.42	-10250.7
g496P	74	0	-569.92	3620.32	-569.92	3620.32	-1159.7	7366.77	-14027.36
g496X	74	0	-120.99	3595.57	-120.99	3595.57	-246.2	7316.41	-490.01
g496XY	74	0	561.25	-3716.67	561.25	-3716.67	1142.05	-7562.83	13854.12
g496Y	74	0	289.15	-3747.09	289.15	-3747.09	588.37	-7624.73	7769.33
g497P	74	0	333.21	2499.27	333.21	2499.27	462.58	3469.65	23762.66
g497X	74	0	490.81	2504.28	490.81	2504.28	681.37	3476.6	-33116.08
g497XY	74	0	-76.27	-2507.12	-76.27	-2507.12	-105.89	-3480.55	-27823.6
g497Y	74	0	-617.03	-2514.11	-617.03	-2514.11	-856.61	-3490.26	29262.43
g502P	74	0	-3360.09	-441.09	-3360.09	-441.09	-6461.51	-848.23	-80290.46
g502X	74	0	3384.79	253.29	3384.79	253.29	6509.02	487.09	83460.92
g502XY	74	0	3373.68	-12.78	3373.68	-12.78	6487.64	-24.58	81459.49
g502Y	74	0	-3385.18	-640.13	-3385.18	-640.13	-6509.77	-1230.98	-81635.84
g503P	74	0	3231.94	263.88	3231.94	263.88	6213.36	507.32	67683.49
g503X	74	0	-3255.51	-615.4	-3255.51	-615.4	-6258.68	-1183.09	-66773.57
g503XY	74	0	-3239.52	-226.98	-3239.52	-226.98	-6227.92	-436.36	-66754.54
g503Y	74	0	3278.44	468.94	3278.44	468.94	6302.76	901.52	66259.94
g504P	75	0	67.95	2.7	67.95	2.7	101.09	4.02	-4059.02
g504X	75	0	75.55	2.67	75.55	2.67	112.39	3.97	10076.29
g504XY	75	0	-81.34	-91.39	-81.34	-91.39	-121	-135.95	5701.2
g504Y	75	0	-93.2	-86.88	-93.2	-86.88	-138.64	-129.24	-6689.18
g505P	75	0	638.85	-77.51	638.85	-77.51	851.63	-103.33	-10375.94
g505X	75	0	637.43	-89.95	637.43	-89.95	849.57	-119.89	14447.05
g505XY	75	0	-641.95	-96.06	-641.95	-96.06	-855.59	-128.03	11393.77
g505Y	75	0	-637.74	-88.76	-637.74	-88.76	-850.16	-118.32	-12273.6
g618P	75	0	62.83	-1.55	62.83	-1.55	96.33	-2.38	-18660.28
g618X	75	0	137.47	-1.05	137.47	-1.05	210.75	-1.61	25307.96
g618XY	75	0	-44.57	-104.52	-44.57	-104.52	-68.33	-160.24	22127.28
g618Y	75	0	-118.51	-98.44	-118.51	-98.44	-181.69	-150.91	-21393.86
g619P	75	0	699.94	-67.82	699.94	-67.82	933.06	-90.4	-8438.09
g619X	75	0	704.35	-80.86	704.35	-80.86	939.13	-107.81	13578.01
g619XY	75	0	-699.95	-104.32	-699.95	-104.32	-933.26	-139.09	10744.72
g619Y	75	0	-703.81	-99.07	-703.81	-99.07	-938.23	-132.06	-11332.57
g621P	1	0	-46455.58	-28137.58	-46455.58	-28137.58	-91555.84	-55454.25	2385204.67
g621X	1	0	36174.41	-37575.59	36174.41	-37575.59	71293.46	-74054.93	-2115639.51
g621XY	1	0	47337.77	31374.19	47337.77	31374.19	93294.48	61833.06	-2639647.73
g621Y	1	0	-35540.15	40749.66	-35540.15	40749.66	-70043.44	80310.48	1852658.1
g488P	2	0	36291.77	-53667.08	36291.77	-53667.08	76298.53	-112827.74	2135575.4
g488X	2	0	-24115.4	-69679.82	-24115.4	-69679.82	-50699.35	-146492.36	-1918065.54
g488XY	2	0	-32585.78	57323.72	-32585.78	57323.72	-68507.17	120515.34	-2377421.7
g488Y	2	0	28143.66	73400.39	28143.66	73400.39	59168.22	154314.36	1663904.13
g489P	2	0	49905.86	-47371.83	49905.86	-47371.83	104920.29	-99592.84	2140657.25
g489X	2	0	-37998.03	-61032.52	-37998.03	-61032.52	-79885.69	-128312.59	-1921708.62
g489XY	2	0	-48977.72	49823.27	-48977.72	49823.27	-102969.01	104746.65	-2381886.13
g489Y	2	0	38958.62	63526.95	38958.62	63526.95	81905.22	133556.79	1668077.54
g491P	2	0	58543.81	-48022.27	58543.81	-48022.27	123080.41	-100960.31	2131800.45
g491X	2	0	-45865.82	-61792.08	-45865.82	-61792.08	-96426.65	-129909.46	-1912879.21
g491XY	2	0	-58660.33	50593.24	-58660.33	50593.24	-123325.38	106365.41	-2370220.7
g491Y	2	0	45750.29	64398.52	45750.29	64398.52	96183.77	135389.15	1661783.04
g493P	2	0	87857.81	-52344.12	87857.81	-52344.12	184709.11	-110046.39	2142036.04
g493X	2	0	-71046.19	-67604.56	-71046.19	-67604.56	-149364.97	-142129.4	-1920342.03
g493XY	2	0	-90298.68	55916.14	-90298.68	55916.14	-189840.71	117556.09	-2379780.78
g493Y	2	0	68608.26	71190.09	68608.26	71190.09	144239.55	149667.49	1669917.29
g620P	2	0	62312.55	-66621.09	62312.55	-66621.09	131003.67	-140061.79	1896750.99
g620X	2	0	-45421.1	-85541.47	-45421.1	-85541.47	-95491.7	-179839.33	-1726061.64
g620XY	2	0	-58904.98	70294.71	-58904.98	70294.71	-123839.72	147785.09	-2122083.81
g620Y	2	0	48946.96	89183.48	48946.96	89183.48	102904.33	187496.16	1482791.65
g622P	2	0	75507.65	-62451.55	75507.65	-62451.55	158744.59	-131295.9	1901867.21
g622X	2	0	-58782.34	-79691.21	-58782.34	-79691.21	-123581.88	-167539.94	-1729698.41
g622XY	2	0	-74592.38	64980.13	-74592.38	64980.13	-156820.35	136611.91	-2126514.44
g622Y	2	0	59462.7	82176.14	59462.7	82176.14	125012.24	172764.17	1487005.36

g623P	2	0	84279.22	-62994.2	84279.22	-62994.2	177185.61	-132436.75	1900345.58
g623X	2	0	-66328.84	-80281.67	-66328.84	-80281.67	-139447.38	-168781.3	-1726138.12
g623XY	2	0	-83978.35	65648.19	-83978.35	65648.19	-176553.09	138016.4	-2121551.52
g623Y	2	0	66338.98	82899.08	66338.98	82899.08	139468.7	174284.05	1486427.12
g624P	2	0	108482.55	-66129.17	108482.55	-66129.17	228069.83	-139027.6	1908928.57
g624X	2	0	-87635.73	-84438.77	-87635.73	-84438.77	-184242.21	-177521.06	-1732340.57
g624XY	2	0	-110426.31	69704.95	-110426.31	69704.95	-232156.33	146545.2	-2129423.59
g624Y	2	0	85391.09	87973.93	85391.09	87973.93	179523.17	184953.24	1493330.37
g625P	3	0	70467.27	-75062.83	70467.27	-75062.83	148147.87	-157809.4	1664765.11
g625X	3	0	-52246.15	-95559.91	-52246.15	-95559.91	-109840.43	-200901.74	-1536490.89
g625XY	3	0	-67133.37	79142.43	-67133.37	79142.43	-141138.8	166386.21	-1870210.32
g625Y	3	0	55693.44	99672.01	55693.44	99672.01	117087.89	209546.86	1303358.09
g626P	3	0	87344.59	-71293.83	87344.59	-71293.83	183630.13	-149885.59	1671250.07
g626X	3	0	-69081.25	-90210.09	-69081.25	-90210.09	-145233.95	-189654.47	-1541686
g626XY	3	0	-86830.69	73765.15	-86830.69	73765.15	-182549.74	155081.2	-1876449.39
g626Y	3	0	68976.53	92674.76	68976.53	92674.76	145013.79	194836.09	1308571.45
g627P	3	0	94804.98	-72010.21	94804.98	-72010.21	199314.6	-151391.69	1662516.28
g627X	3	0	-76020.51	-91033.06	-76020.51	-91033.06	-159822.8	-191384.66	-1534042.24
g627XY	3	0	-95214.23	74648.16	-95214.23	74648.16	-200175	156937.62	-1865965.77
g627Y	3	0	74907.12	93652.46	74907.12	93652.46	157482.04	196891.58	1301945.74
g628P	3	0	121463.05	-74667.32	121463.05	-74667.32	255359.57	-156977.9	1672231.61
g628X	3	0	-99817.96	-94651.93	-99817.96	-94651.93	-209853.71	-198992.84	-1541645.11
g628XY	3	0	-124568.61	78609.56	-124568.61	78609.56	-261888.58	165265.92	-1875474.89
g628Y	3	0	95900.12	98538.01	95900.12	98538.01	201616.99	207162.79	1309704.48
g629P	3	0	90768.22	-93690.21	90768.22	-93690.21	190827.86	-196970.93	1445516.4
g629X	3	0	-67888.27	-118416.59	-67888.27	-118416.59	-142725.86	-248954.8	-1358635.15
g629XY	3	0	-86038.99	98056.24	-86038.99	98056.24	-180885.29	206149.93	-1629501.93
g629Y	3	0	72107.8	122868.45	72107.8	122868.45	151596.85	258314.24	1130925.06
g630P	3	0	108839.24	-91256.85	108839.24	-91256.85	228819.72	-191855.13	1452823.42
g630X	3	0	-86035.96	-114739.35	-86035.96	-114739.35	-180878.93	-241223.9	-1364580.97
g630XY	3	0	-106861.99	93691.66	-106861.99	93691.66	-224662.82	196974	-1636511.08
g630Y	3	0	86247.51	117305.22	86247.51	117305.22	181323.67	246618.3	1136768.54
g631P	3	0	114273	-91989.68	114273	-91989.68	240243.46	-193395.82	1456149.11
g631X	3	0	-90612.42	-115551.6	-90612.42	-115551.6	-190500.3	-242931.55	-1366537.93
g631XY	3	0	-112322.28	94638.19	-112322.28	94638.19	-236142.35	198963.94	-1637548.54
g631Y	3	0	90632.54	118358.23	90632.54	118358.23	190542.62	248832.1	1139537.1
g632P	3	0	140232.37	-94309.23	140232.37	-94309.23	294819.52	-198272.34	1465881.45
g632X	3	0	-114428.25	-118675.62	-114428.25	-118675.62	-240569.86	-249499.38	-1374318.55
g632XY	3	0	-141088.82	98436.7	-141088.82	98436.7	-296620.09	206949.78	-1647080.81
g632Y	3	0	111110.59	123016.6	111110.59	123016.6	233594.93	258625.7	1147326.03

Appendix C

Angles size - staggered bracing tower

C.1 Bottom section

This subsection contains annotations for the various members of the bottom section (see Figures C.1 and C.2), as well as the angles to be chosen for each of these members depending on the grade of steel used (see Table C.1). for this section, the two face have the same geometry.

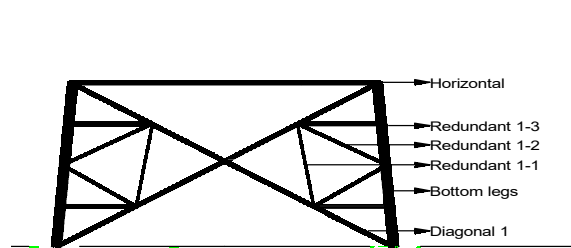


Figure C.1: Annotations of the bottom section of the tower.

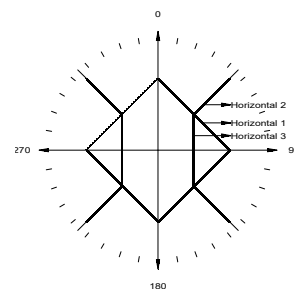


Figure C.2: Annotations of the horizontal bracing in the bottom section

Group	Angle type	Angle size
Bottom legs	SAE	AM 250x250x34
Diagonal	SAE	AM 120x120x8
Redundant 1	SAE	AM 75x75x4
Redundant 2	SAE	AM 90x90x5
Redundant 3	SAE	AM 100x100x6
Horizontal 1	SAE	AM 110x110x6
Horizontal 2	SAE	AM 75x75x4
Horizontal 3	SAE	AM 90x90x5

Table C.1: Angle profiles for the different parts of the bottom section

C.2 Section 1

This subsection contains annotations for the various members of the section 1 (see Figures C.3 and C.4), as well as the angles to be chosen for each of these members depending on the grade of steel used (see Tables C.2 and C.3).

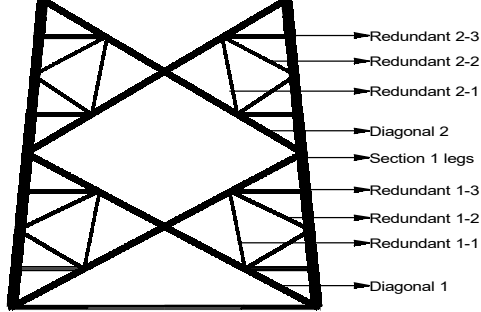


Figure C.3: Annotations of the faces of the section 1 of the tower.

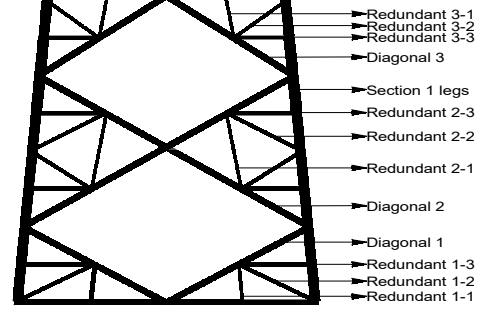


Figure C.4: Annotations of the sides of the section 1 of the tower.

Group	Angle type	Angle size
Section 1 legs	SAE	AM 250x250x34
Diagonal 1	SAE	AM 150x150x10-/+
Diagonal 2	SAE	AM 150x150x10-/+
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 90x90x5
Redundant 1-3	SAE	AM 100x100x6
Redundant 2-1	SAE	AM 76x76x4,8
Redundant 2-2	SAE	AM 80x80x5
Redundant 2-3	SAE	AM 90x90x6

Table C.2: Angle profiles for the different parts of the faces of the section 1

Group	Angle type	Angle size
Section 1 legs	SAE	AM 250x250x34
Diagonal 1	SAE	AM 150x150x10-/+
Diagonal 2	SAE	AM 150x150x10-/+
Diagonal 3	SAE	AM 150x150x10-/+
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 90x90x5
Redundant 1-3	SAE	AM 100x100x6
Redundant 2-1	SAE	AM 75x75x4
Redundant 2-2	SAE	AM 90x90x5
Redundant 2-3	SAE	AM 100x100x6
Redundant 3-1	SAE	AM 75x75x6-
Redundant 3-2	SAE	AM 75x75x5
Redundant 3-3	SAE	AM 80x80x6

Table C.3: Angle profiles for the different parts of the sides of the section 1

C.3 Section 2

This subsection contains annotations for the various members of the section 2 (see Figures C.5 and C.6), as well as the angles to be chosen for each of these members depending on the grade of steel used (see Tables C.4 and C.5).

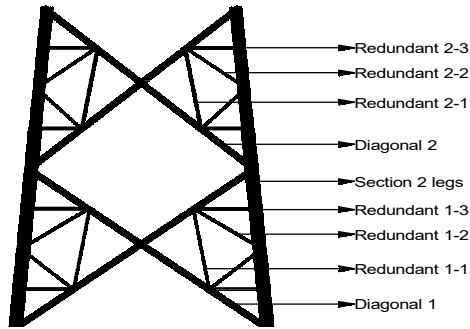


Figure C.5: Annotations of the faces of the section 2 of the tower.

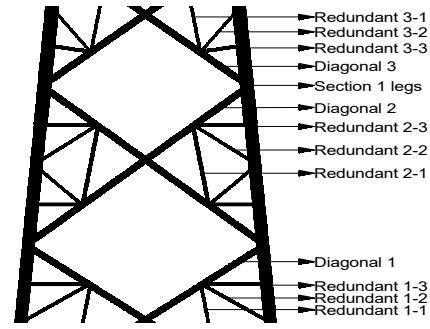


Figure C.6: Annotations of the sides of the section 2 of the tower.

Group	Angle type	Angle size
Section 2 legs	SAE	AM 300x300x27
Diagonal 1	SAE	AM 150x150x10-/+
Diagonal 2	SAE	AM 150x150x10-/+
Redundant 1-1	SAE	AM 75x75x6-
Redundant 1-2	SAE	AM 75x75x5
Redundant 1-3	SAE	AM 80x80x6
Redundant 2-1	SAE	AM 90x90x6
Redundant 2-2	SAE	AM 70x70x5
Redundant 2-3	SAE	AM 75x75x7

Table C.4: Angle profiles for the different parts of the faces of the section 2

Group	Angle type	Angle size
Section 2 legs	SAE	AM 300x300x27
Diagonal 1	SAE	AM 150x150x10-/+
Diagonal 2	SAE	AM 150x150x10-/
Diagonal 3	SAE	AM 150x150x10-/
Redundant 1-1	SAE	AM 75x75x6-
Redundant 1-2	SAE	AM 75x75x5
Redundant 1-3	SAE	AM 80x80x6
Redundant 2-1	SAE	AM 90x90x6
Redundant 2-2	SAE	AM 70x70x5
Redundant 2-3	SAE	AM 75x75x7
Redundant 3-1	SAE	AM 70x70x5
Redundant 3-2	SAE	AM 60x60x5
Redundant 3-3	SAE	AM 80x80x5

Table C.5: Angle profiles for the different parts of the sides of the section 2

C.4 Section 3

This subsection contains annotations for the various members of the section 3 (see Figures C.7 and C.8), as well as the angles to be chosen for each of these members depending on the grade of steel used (see Tables C.6 and C.7).

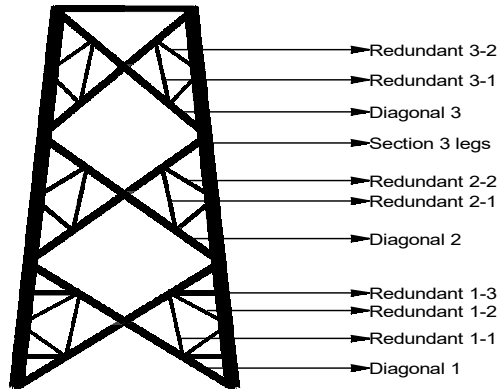


Figure C.7: Annotations of the faces of the section 3 of the tower.

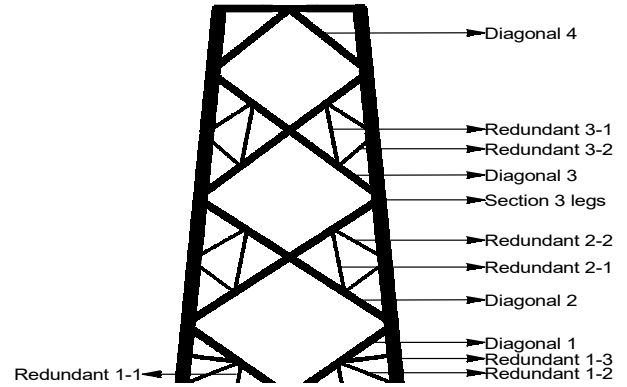


Figure C.8: Annotations of the sides of the section 3 of the tower.

Group	Angle type	Angle size
Section 3 legs	SAE	AM 300x300x26
Diagonal 1	SAE	AM 150x150x10-/+
Diagonal 2	SAE	AM 150x150x10-/+
Diagonal 3	SAE	AM 140x140x11
Redundant 1-1	SAE	AM 70x70x5
Redundant 1-2	SAE	AM 60x60x5
Redundant 1-3	SAE	AM 80x80x5
Redundant 2-1	SAE	AM 80x80x5
Redundant 2-2	SAE	AM 80x80x5
Redundant 3-1	SAE	AM 75x75x4
Redundant 3-2	SAE	AM 65x65x4

Table C.6: Angle profiles for the different parts of the faces of the section 3

Group	Angle type	Angle size
Section 3 legs	SAE	AM 300x300x26
Diagonal 1	SAE	AM 150x150x10-/+
Diagonal 2	SAE	AM 150x150x10-/+
Diagonal 3	SAE	AM 140x140x11
Diagonal 4	SAE	AM 140x140x11
Redundant 1-1	SAE	AM 70x70x5
Redundant 1-2	SAE	AM 60x60x5
Redundant 1-3	SAE	AM 80x80x5
Redundant 2-1	SAE	AM 60x60x5
Redundant 2-2	SAE	AM 80x80x5
Redundant 3-1	SAE	AM 75x75x4
Redundant 3-2	SAE	AM 65x65x4

Table C.7: Angle profiles for the different parts of the sides of the section 3

C.5 Section 4

This subsection contains annotations (see Figures C.9 to C.12) for the various members of the section 4, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Tables C.8 to C.10).

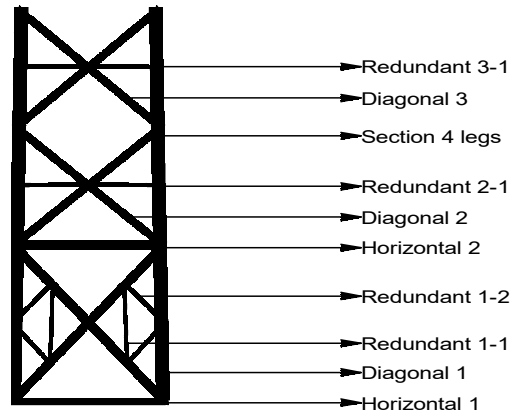


Figure C.9: Annotations of the faces of the section 4 of the tower.

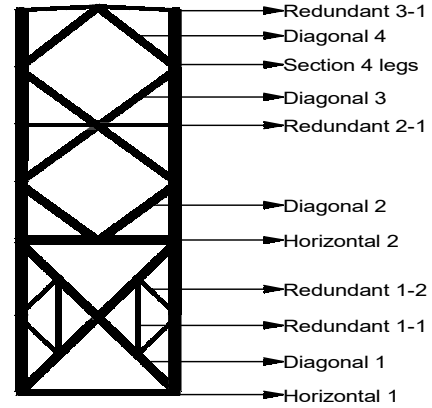


Figure C.10: Annotations of the sides of the section 4 of the tower.

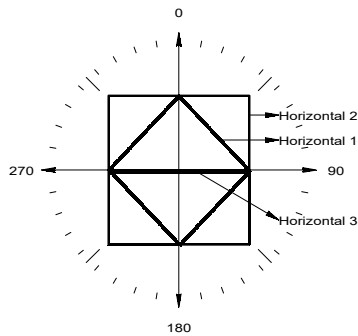


Figure C.11: Annotations of the horizontal bracing in the section 4

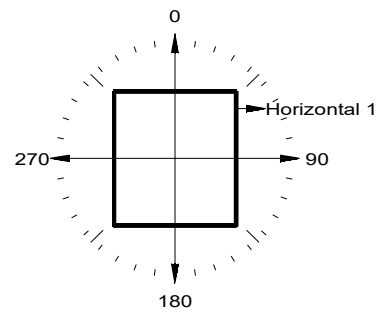


Figure C.12: Annotations of the horizontal bracing in the section 4

Group	Angle type	Angle size
Section 4 legs	SAE	AM 250x250x22
Diagonal 1	SAE	AM 160x160x16-/+
Diagonal 2	SAE	AM 140x140x14
Diagonal 3	SAE	AM 140x140x14
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 75x75x4
Redundant 2-1	SAE	AM 75x75x5
Redundant 3-1	SAE	AM 75x75x5

Table C.8: Angle profiles for the different parts of the faces of the section 4

Group	Angle type	Angle size
Section 4 legs	SAE	AM 250x250x22
Diagonal 1	SAE	AM 160x160x16-/+
Diagonal 2	SAE	AM 160x160x16-/+
Diagonal 3	SAE	AM 140x140x14
Diagonal 4	SAE	AM 140x140x14
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 75x75x4
Redundant 2-1	SAE	AM 75x75x5
Redundant 3-1	SAE	AM 75x75x5

Table C.9: Angle profiles for the different parts of the sides of the section 4

Group	Angle type	Angle size
Horizontal 1-1	SAE	AM 110x110x11
Horizontal 1-2	SAE	AM 100x100x6
Horizontal 1-3	SAE	AM 75x75x5
Horizontal 2-1	SAE	AM 150x150x12-/+

Table C.10: Angle profiles for the different parts of the horizontal bracing of the section 4

C.6 Section 5

This subsection contains annotations (see Figures C.13 to C.16) for the various members of the section 4, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Tables C.11 to C.13).

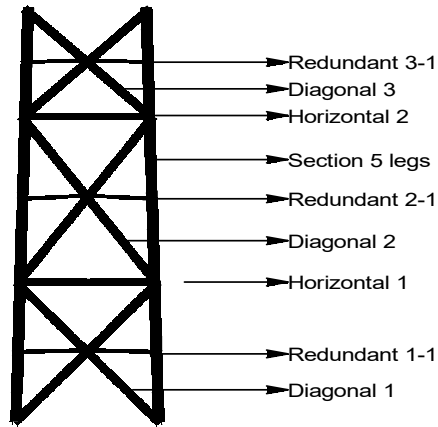


Figure C.13: Annotations of the faces of the section 5 of the tower.

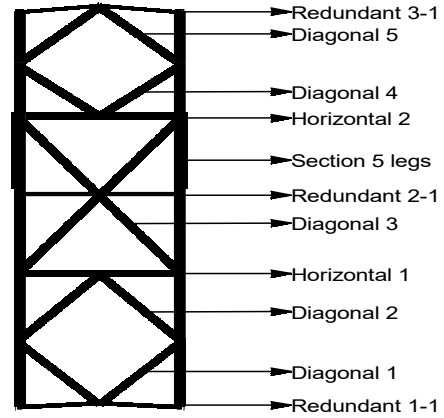


Figure C.14: Annotations of the sides of the section 5 of the tower.

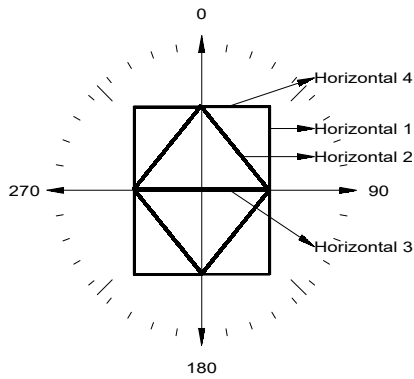


Figure C.15: Annotations of the horizontal 1 bracing in the section 5

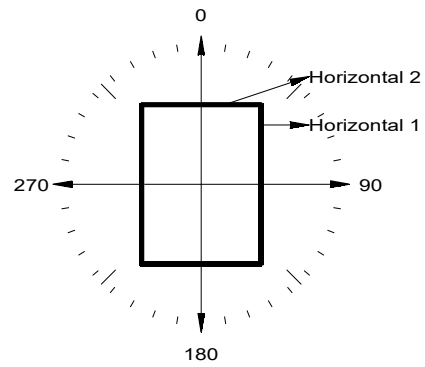


Figure C.16: Annotations of the horizontal 2 bracing in the section 5

Group	Angle type	Angle size
Section 5 legs	SAE	AM 200x200x19
Diagonal 1	SAE	AM 150x150x12-/+
Diagonal 2	SAE	AM 150x150x12-/+
Diagonal 3	SAE	AM 150x150x12-/+
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4

Table C.11: Angle profiles for the different parts of the faces of the section 5

Group	Angle type	Angle size
Section 5 legs	SAE	AM 200x200x19
Diagonal 1	SAE	AM 140x140x14
Diagonal 2	SAE	AM 150x150x12-/+
Diagonal 3	SAE	AM 150x150x12-/+
Diagonal 4	SAE	AM 150x150x12-/+
Diagonal 5	SAE	AM 150x150x12-/+
Redundant 1-1	SAE	AM 75x75x5
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4

Table C.12: Angle profiles for the different parts of the sides of the section 5

Group	Angle type	Angle size
Horizontal 1-1	SAE	AM 120x120x10-
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x4
Horizontal 1-4	SAE	AM 120x120x9
Horizontal 2-1	SAE	AM 110x110x8
Horizontal 2-2	SAE	AM 110x110x8

Table C.13: Angle profiles for the different parts of the horizontal bracing of the section 5

C.7 Top section

This subsection contains annotations (see Figures C.17 to C.21) for the various members of the top section, as well as the angles to be chosen for each of these members depending on the grade of steel used (see Tables C.14 to C.16).

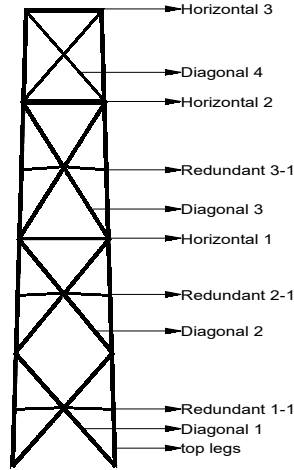


Figure C.17: Annotations of the faces of the top of the tower

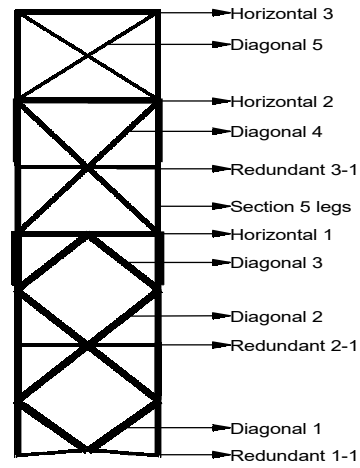


Figure C.18: Annotations of the sides of the top of the tower

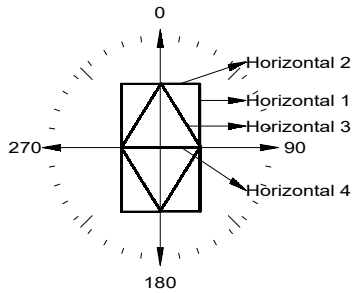


Figure C.19: Annotations of the horizontal 1 bracing in the top section

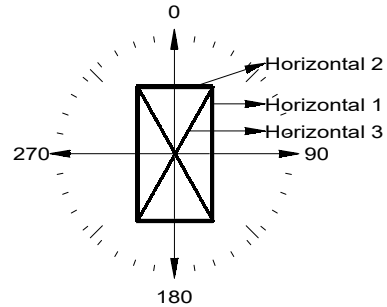


Figure C.20: Annotations of the horizontal 2 bracing in the top section

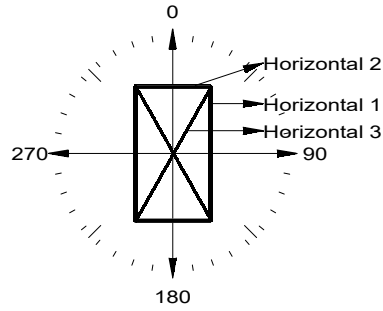


Figure C.21: Annotations of the horizontal 3 bracing in the top section

Group	Angle type	Angle size
Top legs	SAE	AM 130x130x14
Diagonal 1	SAE	AM 140x140x9
Diagonal 2	SAE	AM 140x140x9
Diagonal 3	SAE	AM 100x100x6
Diagonal 4	SAE	AM 65x65x4
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4

Table C.14: Angle profiles for the different parts of the faces of the top section

Group	Angle type	Angle size
Top legs	SAE	AM 130x130x14
Diagonal 1	SAE	AM 140x140x9
Diagonal 2	SAE	AM 140x140x9
Diagonal 3	SAE	AM 100x100x6
Diagonal 4	SAE	AM 65x65x4
Diagonal 5	SAE	AM 65x65x4
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4

Table C.15: Angle profiles for the different parts of the sides of the top section

Group	Angle type	Angle size
Horizontal 1-1	SAE	AM 100x100x7
Horizontal 1-2	SAE	AM 120x120x13
Horizontal 1-3	SAE	AM 90x90x6
Horizontal 1-4	SAE	AM 55x55x4
Horizontal 2-1	SAE	AM 90x90x5
Horizontal 2-2	SAE	AM 90x90x5
Horizontal 2-3	SAE	AM 100x100x6
Horizontal 3-1	SAE	AM 75x75x6-
Horizontal 3-2	SAE	AM 75x75x6-
Horizontal 3-3	SAE	AM 100x100x6

Table C.16: Angle profiles for the different parts of the horizontal bracing of the top section

C.8 Cross arms

This subsection contains the angles to be chosen for each of these members, depending on the grade of steel used (see Tables C.17 to C.20). As the geometry of the arms has not changed for this section, the annotations are also identical. The tables will therefore follow the annotations of the figures for the basic dead-end towers.

Group	Angle type	Angle size
Bottom	SAE	AM 140x140x16
Top	SAE	AM 90x90x5
Diagonal 1	SAE	AM 60x60x4
Diagonal 2	SAE	AM 50x50x4
Diagonal 3	SAE	AM 45x45x4
Vertical 1	SAE	AM 65x65x4
Vertical 2	SAE	AM 45x45x4
Base 1 to 6	SAE	AM 90x90x6
Base 7	SAE	AM 80x80x6
Base 8	SAE	AM 70x70x6-
End	SAE	AM 35x35x5
H top	SAE	AM 40x40x4
Bracing	SAE	AM 50x50x4

Table C.17: Angle profiles for the different parts of the three first big cross arms

Group	Angle type	Angle size
Bottom	SAE	AM 130x130x11
Top	SAE	AM 75x75x4
Diagonal 1	SAE	AM 50x50x4
Diagonal 2	SAE	AM 45x45x3
Vertical	SAE	AM 50x50x4
Base 1 to 5	SAE	AM 90x90x6
Base 6	SAE	AM 75x75x5
End	SAE	AM 35x35x4

Table C.18: Angle profiles for the different parts of the three first small cross arms

Group	Angle type	Angle size
Bottom	SAE	AM 75x75x7
Top	SAE	AM 50x50x4
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Diagonal 3	SAE	AM 30x30x3
Vertical 1 to 5	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2	SAE	AM 90x90x5
Base 3	SAE	AM 65x65x4
Base 4	SAE	AM 55x55x4
Base 5 to 8	SAE	AM 50x50x4
End	SAE	AM 30x30x4

Table C.19: Angle profiles for the different parts of the big top cross arm

Group	Angle type	Angle size
Bottom	SAE	AM 65x65x5
Top	SAE	AM 45x45x3
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Vertical 1 to 4	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2 to 7	SAE	AM 75x75x4
End	SAE	AM 30x30x4

Table C.20: Angle profiles for the different parts of the small top cross arm

Appendix D

Angles size according to leg inclination

D.1 7 metres between legs

Group	Angle type	Angle size
Bottom section		
Bottom legs	SAE	AM 300x300x33
Diagonal	SAE	AM 110x110x9
Redundant 1	SAE	AM 75x75x6-
Redundant 2	SAE	AM 90x90x5
Redundant 3	SAE	AM 100x100x6
Horizontal 1	SAE	AM 75x75x4
Horizontal 2	SAE	AM 75x75x4
Horizontal 3	SAE	AM 90x90x5
Section 1		
Section 1 legs	SAE	AM 300x300x32
Diagonal 1	SAE	AM 130x130x9
Diagonal 2	SAE	AM 130x130x9
Redundant 1-1	SAE	AM 75x75x6-
Redundant 1-2	SAE	AM 90x90x5
Redundant 1-3	SAE	AM 100x100x6
Redundant 2-1	SAE	AM 90x90x5
Redundant 2-2	SAE	AM 80x80x5
Redundant 2-3	SAE	AM 90x90x6
Horizontal 1	SAE	AM 60x60x4
Horizontal 2	SAE	AM 60x60x4

Horizontal 3	SAE	AM 70x70x5
Section 2		
Section 2 legs	SAE	AM 300x300x29
Diagonal 1	SAE	AM 130x130x10
Diagonal 2	SAE	AM 130x130x10
Redundant 1-1	SAE	AM 90x90x6
Redundant 1-2	SAE	AM 75x75x5
Redundant 1-3	SAE	AM 90x90x6
Redundant 2-1	SAE	AM 100x100x6
Redundant 2-2	SAE	AM 70x70x5
Redundant 2-3	SAE	AM 90x90x6
Horizontal 1	SAE	AM 45x45x3
Horizontal 2	SAE	AM 45x45x3
Horizontal 3	SAE	AM 60x60x4
Section 3		
Section 3 legs	SAE	AM 300x300x26
Diagonal 1	SAE	AM 130x130x11
Diagonal 2	SAE	AM 130x130x11
Diagonal 3	SAE	AM 140x140x12
Redundant 1-1	SAE	AM 76x76x4,8
Redundant 1-2	SAE	AM 60x60x5
Redundant 1-3	SAE	AM 70x70x6-
Redundant 2-1	SAE	AM 75x75x6-
Redundant 2-2	SAE	AM 75x75x6-
Redundant 3-1	SAE	AM 70x70x5
Redundant 3-2	SAE	AM 65x65x4
Horizontal 1	SAE	AM 45x45x3
Horizontal 2	SAE	AM 45x45x3
Horizontal 3	SAE	AM 50x50x4
Section 4		
Section 4 legs	SAE	AM 250x250x22
Diagonal 1	SAE	AM 180x180x13+
Diagonal 2	SAE	AM 150x150x12-/+
Diagonal 3	SAE	AM 150x150x12-/+
Redundant 1-1	SAE	AM 70x70x5
Redundant 1-2	SAE	AM 70x70x5
Redundant 2-1	SAE	AM 75x75x5
Redundant 3-1	SAE	AM 75x75x5

Horizontal 1-1	SAE	AM 120x120x9
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x5
Horizontal 2-1	SAE	AM 140x140x12
Section 5		
Section 5 legs	SAE	AM 200x200x16-/+
Diagonal 1	SAE	AM 150x150x13-/+
Diagonal 2	SAE	AM 150x150x13-/+
Diagonal 3	SAE	AM 150x150x13-/+
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 76x76x4,8
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x4
Horizontal 1-4	SAE	AM 110x110x9
Horizontal 2-1	SAE	AM 110x110x7
Horizontal 2-2	SAE	AM 110x110x7
Top section		
Top legs	SAE	AM 130x130x11
Diagonal 1	SAE	AM 140x140x9
Diagonal 2	SAE	AM 140x140x9
Diagonal 3	SAE	AM 100x100x6
Diagonal 4	SAE	AM 65x65x4
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 80x80x5
Horizontal 1-2	SAE	AM 120x120x13
Horizontal 1-3	SAE	AM 90x90x6
Horizontal 1-4	SAE	AM 55x55x4
Horizontal 2-1	SAE	AM 90x90x5
Horizontal 2-2	SAE	AM 90x90x5
Horizontal 2-3	SAE	AM 100x100x6
Horizontal 3-1	SAE	AM 75x75x6-
Horizontal 3-2	SAE	AM 75x75x6-
Horizontal 3-3	SAE	AM 100x100x6
Three first big cross arms		

Bottom	SAE	AM 140x140x16
Top	SAE	AM 90x90x5
Diagonal 1	SAE	AM 60x60x4
Diagonal 2	SAE	AM 50x50x4
Diagonal 3	SAE	AM 45x45x4
Vertical 1	SAE	AM 65x65x4
Vertical 2	SAE	AM 45x45x4
Base 1 to 6	SAE	AM 90x90x6
Base 7	SAE	AM 80x80x6
Base 8	SAE	AM 70x70x6-
End	SAE	AM 35x35x5
H top	SAE	AM 40x40x4
Bracing	SAE	AM 50x50x4
Three first small cross arms		
Bottom	SAE	AM 130x130x11
Top	SAE	AM 75x75x4
Diagonal 1	SAE	AM 50x50x4
Diagonal 2	SAE	AM 45x45x3
Vertical	SAE	AM 50x50x4
Base 1 to 5	SAE	AM 90x90x6
Base 6	SAE	AM 75x75x5
End	SAE	AM 35x35x5
Big top cross arms		
Bottom	SAE	AM 75x75x7
Top	SAE	AM 50x50x4
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Diagonal 3	SAE	AM 30x30x3
Vertical 1 to 5	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2	SAE	AM 90x90x5
Base 3	SAE	AM 65x65x4
Base 4	SAE	AM 55x55x4
Base 5 to 8	SAE	AM 50x50x4
End	SAE	AM 30x30x4
Big small cross arms		
Bottom	SAE	AM 70x70x5
Top	SAE	AM 45x45x3

Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Vertical 1 to 4	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2 to 7	SAE	AM 75x75x4
End	SAE	AM 30x30x4

D.2 8 metres between legs

Group	Angle type	Angle size
Bottom section		
Bottom legs	SAE	AM 300x300x29
Diagonal	SAE	AM 110x110x8
Redundant 1	SAE	AM 76x76x4,8
Redundant 2	SAE	AM 90x90x5
Redundant 3	SAE	AM 100x100x6
Horizontal 1	SAE	AM 75x75x4
Horizontal 2	SAE	AM 75x75x4
Horizontal 3	SAE	AM 90x90x5
Section 1		
Section 1 legs	SAE	AM 300x300x28
Diagonal 1	SAE	AM 130x130x8
Diagonal 2	SAE	AM 130x130x8
Redundant 1-1	SAE	AM 76x76x4,8
Redundant 1-2	SAE	AM 90x90x5
Redundant 1-3	SAE	AM 100x100x6
Redundant 2-1	SAE	AM 80x80x5
Redundant 2-2	SAE	AM 80x80x5
Redundant 2-3	SAE	AM 90x90x6
Horizontal 1	SAE	AM 60x60x4
Horizontal 2	SAE	AM 60x60x4
Horizontal 3	SAE	AM 70x70x5
Section 2		
Section 2 legs	SAE	AM 300x300x27
Diagonal 1	SAE	AM 130x130x9
Diagonal 2	SAE	AM 130x130x9
Redundant 1-1	SAE	AM 90x90x5

Redundant 1-2	SAE	AM 75x75x5
Redundant 1-3	SAE	AM 90x90x6
Redundant 2-1	SAE	AM 90x90x6
Redundant 2-2	SAE	AM 70x70x5
Redundant 2-3	SAE	AM 75x75x7
Horizontal 1	SAE	AM 45x45x3
Horizontal 2	SAE	AM 45x45x3
Horizontal 3	SAE	AM 60x60x4
Section 3		
Section 3 legs	SAE	AM 300x300x25
Diagonal 1	SAE	AM 130x130x10
Diagonal 2	SAE	AM 130x130x10
Diagonal 3	SAE	AM 130x130x13
Redundant 1-1	SAE	AM 70x70x5
Redundant 1-2	SAE	AM 60x60x5
Redundant 1-3	SAE	AM 75x75x5
Redundant 2-1	SAE	AM 75x75x6-
Redundant 2-2	SAE	AM 75x75x6-
Redundant 3-1	SAE	AM 65x65x5
Redundant 3-2	SAE	AM 65x65x4
Horizontal 1	SAE	AM 45x45x3
Horizontal 2	SAE	AM 45x45x3
Horizontal 3	SAE	AM 50x50x4
Section 4		
Section 4 legs	SAE	AM 250x250x22
Diagonal 1	SAE	AM 180x180x13+
Diagonal 2	SAE	AM 150x150x12-/+
Diagonal 3	SAE	AM 150x150x12-/+
Redundant 1-1	SAE	AM 70x70x5
Redundant 1-2	SAE	AM 70x70x5
Redundant 2-1	SAE	AM 75x75x5
Redundant 3-1	SAE	AM 75x75x5
Horizontal 1-1	SAE	AM 130x130x9
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x5
Horizontal 2-1	SAE	AM 140x140x12
Section 5		
Section 5 legs	SAE	AM 200x200x16-/+

Diagonal 1	SAE	AM 150x150x13-/+
Diagonal 2	SAE	AM 150x150x13-/+
Diagonal 3	SAE	AM 150x150x13-/+
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 76x76x4,8
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x4
Horizontal 1-4	SAE	AM 110x110x9
Horizontal 2-1	SAE	AM 110x110x7
Horizontal 2-2	SAE	AM 110x110x7
Top section		
Top legs	SAE	AM 130x130x11
Diagonal 1	SAE	AM 140x140x9
Diagonal 2	SAE	AM 140x140x9
Diagonal 3	SAE	AM 100x100x6
Diagonal 4	SAE	AM 65x65x4
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 80x80x5
Horizontal 1-2	SAE	AM 120x120x13
Horizontal 1-3	SAE	AM 90x90x6
Horizontal 1-4	SAE	AM 55x55x4
Horizontal 2-1	SAE	AM 90x90x5
Horizontal 2-2	SAE	AM 90x90x5
Horizontal 2-3	SAE	AM 100x100x6
Horizontal 3-1	SAE	AM 75x75x6-
Horizontal 3-2	SAE	AM 75x75x6-
Horizontal 3-3	SAE	AM 100x100x6
Three first big cross arms		
Bottom	SAE	AM 140x140x16
Top	SAE	AM 90x90x5
Diagonal 1	SAE	AM 60x60x4
Diagonal 2	SAE	AM 50x50x4
Diagonal 3	SAE	AM 45x45x4
Vertical 1	SAE	AM 65x65x4

Vertical 2	SAE	AM 45x45x4
Base 1 to 6	SAE	AM 90x90x6
Base 7	SAE	AM 80x80x6
Base 8	SAE	AM 70x70x6-
End	SAE	AM 35x35x5
H top	SAE	AM 40x40x4
Bracing	SAE	AM 50x50x4
Three first small cross arms		
Bottom	SAE	AM 130x130x11
Top	SAE	AM 75x75x4
Diagonal 1	SAE	AM 50x50x4
Diagonal 2	SAE	AM 45x45x3
Vertical	SAE	AM 50x50x4
Base 1 to 5	SAE	AM 90x90x6
Base 6	SAE	AM 75x75x5
End	SAE	AM 35x35x5
Big top cross arms		
Bottom	SAE	AM 75x75x7
Top	SAE	AM 50x50x4
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Diagonal 3	SAE	AM 30x30x3
Vertical 1 to 5	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2	SAE	AM 90x90x5
Base 3	SAE	AM 65x65x4
Base 4	SAE	AM 55x55x4
Base 5 to 8	SAE	AM 50x50x4
End	SAE	AM 30x30x4
Big small cross arms		
Bottom	SAE	AM 70x70x5
Top	SAE	AM 45x45x3
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Vertical 1 to 4	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2 to 7	SAE	AM 75x75x4
End	SAE	AM 30x30x4

D.3 9 metres between legs

Group	Angle type	Angle size
Bottom section		
Bottom legs	SAE	AM 300x300x26
Diagonal	SAE	AM 120x120x7
Redundant 1	SAE	AM 75x75x4
Redundant 2	SAE	AM 90x90x5
Redundant 3	SAE	AM 100x100x6
Horizontal 1	SAE	AM 75x75x4
Horizontal 2	SAE	AM 75x75x4
Horizontal 3	SAE	AM 90x90x5
Section 1		
Section 1 legs	SAE	AM 300x300x26
Diagonal 1	SAE	AM 120x120x8
Diagonal 2	SAE	AM 120x120x8
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 90x90x5
Redundant 1-3	SAE	AM 100x100x6
Redundant 2-1	SAE	AM 70x70x5
Redundant 2-2	SAE	AM 80x80x5
Redundant 2-3	SAE	AM 90x90x6
Horizontal 1	SAE	AM 60x60x4
Horizontal 2	SAE	AM 60x60x4
Horizontal 3	SAE	AM 70x70x5
Section 2		
Section 2 legs	SAE	AM 300x300x25
Diagonal 1	SAE	AM 120x120x8
Diagonal 2	SAE	AM 120x120x8
Redundant 1-1	SAE	AM 80x80x5
Redundant 1-2	SAE	AM 76x76x4,8
Redundant 1-3	SAE	AM 80x80x6
Redundant 2-1	SAE	AM 90x90x5
Redundant 2-2	SAE	AM 70x70x5
Redundant 2-3	SAE	AM 80x80x6
Horizontal 1	SAE	AM 45x45x3
Horizontal 2	SAE	AM 45x45x3
Horizontal 3	SAE	AM 60x60x4
Section 3		

Section 3 legs	SAE	AM 250x250x30
Diagonal 1	SAE	AM 140x140x9
Diagonal 2	SAE	AM 140x140x9
Diagonal 3	SAE	AM 130x130x13
Redundant 1-1	SAE	AM 60x60x5
Redundant 1-2	SAE	AM 60x60x5
Redundant 1-3	SAE	AM 75x75x5
Redundant 2-1	SAE	AM 75x75x5
Redundant 2-2	SAE	AM 75x75x5
Redundant 3-1	SAE	AM 75x75x4
Redundant 3-2	SAE	AM 65x65x4
Horizontal 1	SAE	AM 45x45x3
Horizontal 2	SAE	AM 45x45x3
Horizontal 3	SAE	AM 50x50x4
Section 4		
Section 4 legs	SAE	AM 250x250x22
Diagonal 1	SAE	AM 180x180x13+
Diagonal 2	SAE	AM 150x150x12-/+
Diagonal 3	SAE	AM 150x150x12-/+
Redundant 1-1	SAE	AM 70x70x5
Redundant 1-2	SAE	AM 70x70x5
Redundant 2-1	SAE	AM 75x75x5
Redundant 3-1	SAE	AM 75x75x5
Horizontal 1-1	SAE	AM 130x130x10
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x5
Horizontal 2-1	SAE	AM 140x140x12
Section 5		
Section 5 legs	SAE	AM 200x200x16-/+
Diagonal 1	SAE	AM 150x150x13-/+
Diagonal 2	SAE	AM 150x150x13-/+
Diagonal 3	SAE	AM 150x150x13-/+
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 76x76x4,8
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x4

Horizontal 1-4	SAE	AM 110x110x9
Horizontal 2-1	SAE	AM 110x110x7
Horizontal 2-2	SAE	AM 110x110x7
Top section		
Top legs	SAE	AM 130x130x11
Diagonal 1	SAE	AM 140x140x9
Diagonal 2	SAE	AM 140x140x9
Diagonal 3	SAE	AM 100x100x6
Diagonal 4	SAE	AM 65x65x4
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 80x80x5
Horizontal 1-2	SAE	AM 120x120x13
Horizontal 1-3	SAE	AM 90x90x6
Horizontal 1-4	SAE	AM 55x55x4
Horizontal 2-1	SAE	AM 90x90x5
Horizontal 2-2	SAE	AM 90x90x5
Horizontal 2-3	SAE	AM 100x100x6
Horizontal 3-1	SAE	AM 75x75x6-
Horizontal 3-2	SAE	AM 75x75x6-
Horizontal 3-3	SAE	AM 100x100x6
Three first big cross arms		
Bottom	SAE	AM 140x140x16
Top	SAE	AM 90x90x5
Diagonal 1	SAE	AM 60x60x4
Diagonal 2	SAE	AM 50x50x4
Diagonal 3	SAE	AM 45x45x4
Vertical 1	SAE	AM 65x65x4
Vertical 2	SAE	AM 45x45x4
Base 1 to 6	SAE	AM 90x90x6
Base 7	SAE	AM 80x80x6
Base 8	SAE	AM 70x70x6-
End	SAE	AM 35x35x5
H top	SAE	AM 40x40x4
Bracing	SAE	AM 50x50x4
Three first small cross arms		
Bottom	SAE	AM 130x130x11

Top	SAE	AM 75x75x4
Diagonal 1	SAE	AM 50x50x4
Diagonal 2	SAE	AM 45x45x3
Vertical	SAE	AM 50x50x4
Base 1 to 5	SAE	AM 90x90x6
Base 6	SAE	AM 75x75x5
End	SAE	AM 35x35x5
Big top cross arms		
Bottom	SAE	AM 75x75x7
Top	SAE	AM 50x50x4
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Diagonal 3	SAE	AM 30x30x3
Vertical 1 to 5	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2	SAE	AM 90x90x5
Base 3	SAE	AM 65x65x4
Base 4	SAE	AM 55x55x4
Base 5 to 8	SAE	AM 50x50x4
End	SAE	AM 30x30x4
Big small cross arms		
Bottom	SAE	AM 65x65x6
Top	SAE	AM 45x45x3
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Vertical 1 to 4	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2 to 7	SAE	AM 75x75x4
End	SAE	AM 30x30x4

D.4 10 metres between legs

Group	Angle type	Angle size
Bottom section		
Bottom legs	SAE	AM 250x250x29
Diagonal	SAE	AM 110x110x7
Redundant 1	SAE	AM 75x75x4

Redundant 2	SAE	AM 90x90x5
Redundant 3	SAE	AM 100x100x6
Horizontal 1	SAE	AM 70x70x5
Horizontal 2	SAE	AM 70x70x5
Horizontal 3	SAE	AM 90x90x5
Section 1		
Section 1 legs	SAE	AM 250x250x29
Diagonal 1	SAE	AM 110x110x7
Diagonal 2	SAE	AM 110x110x7
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 90x90x5
Redundant 1-3	SAE	AM 100x100x6
Redundant 2-1	SAE	AM 60x60x5
Redundant 2-2	SAE	AM 80x80x5
Redundant 2-3	SAE	AM 90x90x6
Horizontal 1	SAE	AM 65x65x4
Horizontal 2	SAE	AM 65x65x4
Horizontal 3	SAE	AM 70x70x5
Section 2		
Section 2 legs	SAE	AM 250x250x28
Diagonal 1	SAE	AM 110x110x8
Diagonal 2	SAE	AM 110x110x8
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 76x76x4,8
Redundant 1-3	SAE	AM 80x80x6
Redundant 2-1	SAE	AM 80x80x5
Redundant 2-2	SAE	AM 70x70x5
Redundant 2-3	SAE	AM 75x75x6-
Horizontal 1	SAE	AM 50x50x4
Horizontal 2	SAE	AM 45x45x5
Horizontal 3	SAE	AM 60x60x4
Section 3		
Section 3 legs	SAE	AM 250x250x29
Diagonal 1	SAE	AM 140x140x9
Diagonal 2	SAE	AM 140x140x9
Diagonal 3	SAE	AM 130x130x13
Redundant 1-1	SAE	AM 65x65x4
Redundant 1-2	SAE	AM 60x60x5

Redundant 1-3	SAE	AM 80x80x5
Redundant 2-1	SAE	AM 70x70x5
Redundant 2-2	SAE	AM 70x70x5
Redundant 3-1	SAE	AM 60x60x5
Redundant 3-2	SAE	AM 65x65x4
Horizontal 1	SAE	AM 45x45x3
Horizontal 2	SAE	AM 45x45x3
Horizontal 3	SAE	AM 50x50x4
Section 4		
Section 4 legs	SAE	AM 250x250x22
Diagonal 1	SAE	AM 160x160x16-/+
Diagonal 2	SAE	AM 150x150x12-/+
Diagonal 3	SAE	AM 150x150x12-/+
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 75x75x4
Redundant 2-1	SAE	AM 75x75x5
Redundant 3-1	SAE	AM 75x75x5
Horizontal 1-1	SAE	AM 140x140x10
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x5
Horizontal 2-1	SAE	AM 150x150x12-/+
Section 5		
Section 5 legs	SAE	AM 200x200x16-/+
Diagonal 1	SAE	AM 150x150x13-/+
Diagonal 2	SAE	AM 150x150x13-/+
Diagonal 3	SAE	AM 150x150x13-/+
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 76x76x4,8
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x4
Horizontal 1-4	SAE	AM 110x110x9
Horizontal 2-1	SAE	AM 110x110x7
Horizontal 2-2	SAE	AM 110x110x7
Top section		
Top legs	SAE	AM 130x130x11
Diagonal 1	SAE	AM 140x140x9

Diagonal 2	SAE	AM 140x140x9
Diagonal 3	SAE	AM 100x100x6
Diagonal 4	SAE	AM 65x65x4
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 80x80x5
Horizontal 1-2	SAE	AM 120x120x13
Horizontal 1-3	SAE	AM 90x90x6
Horizontal 1-4	SAE	AM 55x55x4
Horizontal 2-1	SAE	AM 90x90x5
Horizontal 2-2	SAE	AM 90x90x5
Horizontal 2-3	SAE	AM 100x100x6
Horizontal 3-1	SAE	AM 75x75x6-
Horizontal 3-2	SAE	AM 75x75x6-
Horizontal 3-3	SAE	AM 100x100x6
Three first big cross arms		
Bottom	SAE	AM 140x140x16
Top	SAE	AM 90x90x5
Diagonal 1	SAE	AM 60x60x4
Diagonal 2	SAE	AM 50x50x4
Diagonal 3	SAE	AM 45x45x4
Vertical 1	SAE	AM 65x65x4
Vertical 2	SAE	AM 45x45x4
Base 1 to 6	SAE	AM 90x90x6
Base 7	SAE	AM 80x80x6
Base 8	SAE	AM 70x70x6-
End	SAE	AM 35x35x5
H top	SAE	AM 40x40x4
Bracing	SAE	AM 50x50x4
Three first small cross arms		
Bottom	SAE	AM 130x130x11
Top	SAE	AM 75x75x4
Diagonal 1	SAE	AM 50x50x4
Diagonal 2	SAE	AM 45x45x3
Vertical	SAE	AM 50x50x4
Base 1 to 5	SAE	AM 90x90x6
Base 6	SAE	AM 75x75x5

End	SAE	AM 35x35x5
Big top cross arms		
Bottom	SAE	AM 75x75x7
Top	SAE	AM 50x50x4
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Diagonal 3	SAE	AM 30x30x3
Vertical 1 to 5	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2	SAE	AM 90x90x5
Base 3	SAE	AM 65x65x4
Base 4	SAE	AM 55x55x4
Base 5 to 8	SAE	AM 50x50x4
End	SAE	AM 30x30x4
Big small cross arms		
Bottom	SAE	AM 65x65x6
Top	SAE	AM 45x45x3
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Vertical 1 to 4	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2 to 7	SAE	AM 75x75x4
End	SAE	AM 30x30x4

D.5 10,2 metres between legs

Group	Angle type	Angle size
Bottom section		
Bottom legs	SAE	AM 250x250x29
Diagonal	SAE	AM 110x110x7
Redundant 1	SAE	AM 75x75x4
Redundant 2	SAE	AM 90x90x5
Redundant 3	SAE	AM 100x100x6
Horizontal 1	SAE	AM 70x70x5
Horizontal 2	SAE	AM 70x70x5
Horizontal 3	SAE	AM 90x90x5
Section 1		

Section 1 legs	SAE	AM 250x250x28
Diagonal 1	SAE	AM 110x110x7
Diagonal 2	SAE	AM 110x110x7
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 90x90x5
Redundant 1-3	SAE	AM 100x100x6
Redundant 2-1	SAE	AM 60x60x5
Redundant 2-2	SAE	AM 80x80x5
Redundant 2-3	SAE	AM 90x90x6
Horizontal 1	SAE	AM 65x65x4
Horizontal 2	SAE	AM 65x65x4
Horizontal 3	SAE	AM 70x70x5
Section 2		
Section 2 legs	SAE	AM 250x250x28
Diagonal 1	SAE	AM 110x110x8
Diagonal 2	SAE	AM 110x110x8
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 76x76x4,8
Redundant 1-3	SAE	AM 80x80x6
Redundant 2-1	SAE	AM 80x80x5
Redundant 2-2	SAE	AM 70x70x5
Redundant 2-3	SAE	AM 75x75x6-
Horizontal 1	SAE	AM 50x50x4
Horizontal 2	SAE	AM 45x45x5
Horizontal 3	SAE	AM 60x60x4
Section 3		
Section 3 legs	SAE	AM 250x250x29
Diagonal 1	SAE	AM 140x140x9
Diagonal 2	SAE	AM 140x140x9
Diagonal 3	SAE	AM 140x140x12
Redundant 1-1	SAE	AM 65x65x4
Redundant 1-2	SAE	AM 60x60x5
Redundant 1-3	SAE	AM 75x75x5
Redundant 2-1	SAE	AM 70x70x5
Redundant 2-2	SAE	AM 70x70x5
Redundant 3-1	SAE	AM 60x60x5
Redundant 3-2	SAE	AM 65x65x4
Horizontal 1	SAE	AM 45x45x3

Horizontal 2	SAE	AM 45x45x3
Horizontal 3	SAE	AM 50x50x4
Section 4		
Section 4 legs	SAE	AM 250x250x22
Diagonal 1	SAE	AM 180x180x13+
Diagonal 2	SAE	AM 150x150x12-/+
Diagonal 3	SAE	AM 150x150x12-/+
Redundant 1-1	SAE	AM 70x70x5
Redundant 1-2	SAE	AM 70x70x5
Redundant 2-1	SAE	AM 75x75x5
Redundant 3-1	SAE	AM 75x75x5
Horizontal 1-1	SAE	AM 140x140x10
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x5
Horizontal 2-1	SAE	AM 140x140x12
Section 5		
Section 5 legs	SAE	AM 200x200x16-/+
Diagonal 1	SAE	AM 150x150x13-/+
Diagonal 2	SAE	AM 150x150x13-/+
Diagonal 3	SAE	AM 150x150x13-/+
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 76x76x4,8
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x4
Horizontal 1-4	SAE	AM 110x110x9
Horizontal 2-1	SAE	AM 110x110x7
Horizontal 2-2	SAE	AM 110x110x7
Top section		
Top legs	SAE	AM 130x130x11
Diagonal 1	SAE	AM 140x140x9
Diagonal 2	SAE	AM 140x140x9
Diagonal 3	SAE	AM 100x100x6
Diagonal 4	SAE	AM 65x65x4
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4

Horizontal 1-1	SAE	AM 80x80x5
Horizontal 1-2	SAE	AM 120x120x13
Horizontal 1-3	SAE	AM 90x90x6
Horizontal 1-4	SAE	AM 55x55x4
Horizontal 2-1	SAE	AM 90x90x5
Horizontal 2-2	SAE	AM 90x90x5
Horizontal 2-3	SAE	AM 100x100x6
Horizontal 3-1	SAE	AM 75x75x6-
Horizontal 3-2	SAE	AM 75x75x6-
Horizontal 3-3	SAE	AM 100x100x6
Three first big cross arms		
Bottom	SAE	AM 140x140x16
Top	SAE	AM 90x90x5
Diagonal 1	SAE	AM 60x60x4
Diagonal 2	SAE	AM 50x50x4
Diagonal 3	SAE	AM 45x45x4
Vertical 1	SAE	AM 65x65x4
Vertical 2	SAE	AM 45x45x4
Base 1 to 6	SAE	AM 90x90x6
Base 7	SAE	AM 80x80x6
Base 8	SAE	AM 70x70x6-
End	SAE	AM 35x35x5
H top	SAE	AM 40x40x4
Bracing	SAE	AM 50x50x4
Three first small cross arms		
Bottom	SAE	AM 130x130x11
Top	SAE	AM 75x75x4
Diagonal 1	SAE	AM 50x50x4
Diagonal 2	SAE	AM 45x45x3
Vertical	SAE	AM 50x50x4
Base 1 to 5	SAE	AM 90x90x6
Base 6	SAE	AM 75x75x5
End	SAE	AM 35x35x5
Big top cross arms		
Bottom	SAE	AM 75x75x7
Top	SAE	AM 50x50x4
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3

Diagonal 3	SAE	AM 30x30x3
Vertical 1 to 5	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2	SAE	AM 90x90x5
Base 3	SAE	AM 65x65x4
Base 4	SAE	AM 55x55x4
Base 5 to 8	SAE	AM 50x50x4
End	SAE	AM 30x30x4
Big small cross arms		
Bottom	SAE	AM 65x65x6
Top	SAE	AM 45x45x3
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Vertical 1 to 4	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2 to 7	SAE	AM 75x75x4
End	SAE	AM 30x30x4

D.6 11 metres between legs

Group	Angle type	Angle size
Bottom section		
Bottom legs	SAE	AM 250x250x27
Diagonal	SAE	AM 110x110x7
Redundant 1	SAE	AM 75x75x4
Redundant 2	SAE	AM 90x90x5
Redundant 3	SAE	AM 100x100x6
Horizontal 1	SAE	AM 70x70x5
Horizontal 2	SAE	AM 70x70x5
Horizontal 3	SAE	AM 90x90x5
Section 1		
Section 1 legs	SAE	AM 250x250x27
Diagonal 1	SAE	AM 120x120x7
Diagonal 2	SAE	AM 120x120x7
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 90x90x5
Redundant 1-3	SAE	AM 100x100x6

Redundant 2-1	SAE	AM 60x60x5
Redundant 2-2	SAE	AM 80x80x5
Redundant 2-3	SAE	AM 90x90x6
Horizontal 1	SAE	AM 65x65x4
Horizontal 2	SAE	AM 65x65x4
Horizontal 3	SAE	AM 70x70x5
Section 2		
Section 2 legs	SAE	AM 250x250x27
Diagonal 1	SAE	AM 120x120x7
Diagonal 2	SAE	AM 120x120x7
Redundant 1-1	SAE	AM 60x60x5
Redundant 1-2	SAE	AM 76x76x4,8
Redundant 1-3	SAE	AM 80x80x6
Redundant 2-1	SAE	AM 76x76x4,8
Redundant 2-2	SAE	AM 70x70x5
Redundant 2-3	SAE	AM 75x75x6-
Horizontal 1	SAE	AM 50x50x4
Horizontal 2	SAE	AM 45x45x5
Horizontal 3	SAE	AM 60x60x4
Section 3		
Section 3 legs	SAE	AM 250x250x28
Diagonal 1	SAE	AM 140x140x9
Diagonal 2	SAE	AM 140x140x9
Diagonal 3	SAE	AM 140x140x12
Redundant 1-1	SAE	AM 65x65x4
Redundant 1-2	SAE	AM 60x60x5
Redundant 1-3	SAE	AM 80x80x5
Redundant 2-1	SAE	AM 70x70x5
Redundant 2-2	SAE	AM 70x70x5
Redundant 3-1	SAE	AM 60x60x5
Redundant 3-2	SAE	AM 65x65x4
Horizontal 1	SAE	AM 45x45x3
Horizontal 2	SAE	AM 45x45x3
Horizontal 3	SAE	AM 50x50x4
Section 4		
Section 4 legs	SAE	AM 250x250x22
Diagonal 1	SAE	AM 160x160x16-/+
Diagonal 2	SAE	AM 150x150x12-/+

Diagonal 3	SAE	AM 150x150x12-/+
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 75x75x4
Redundant 2-1	SAE	AM 75x75x5
Redundant 3-1	SAE	AM 75x75x5
Horizontal 1-1	SAE	AM 130x130x11
Horizontal 1-2	SAE	AM 100x100x6
Horizontal 1-3	SAE	AM 75x75x5
Horizontal 2-1	SAE	AM 150x150x12-/+
Section 5		
Section 5 legs	SAE	AM 200x200x16-/+
Diagonal 1	SAE	AM 150x150x13-/+
Diagonal 2	SAE	AM 150x150x13-/+
Diagonal 3	SAE	AM 150x150x13-/+
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 76x76x4,8
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x4
Horizontal 1-4	SAE	AM 110x110x9
Horizontal 2-1	SAE	AM 110x110x7
Horizontal 2-2	SAE	AM 110x110x7
Top section		
Top legs	SAE	AM 130x130x11
Diagonal 1	SAE	AM 130x130x10
Diagonal 2	SAE	AM 130x130x10
Diagonal 3	SAE	AM 100x100x6
Diagonal 4	SAE	AM 65x65x4
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 80x80x5
Horizontal 1-2	SAE	AM 120x120x13
Horizontal 1-3	SAE	AM 90x90x6
Horizontal 1-4	SAE	AM 55x55x4
Horizontal 2-1	SAE	AM 90x90x5
Horizontal 2-2	SAE	AM 90x90x5

Horizontal 2-3	SAE	AM 100x100x6
Horizontal 3-1	SAE	AM 75x75x6-
Horizontal 3-2	SAE	AM 75x75x6-
Horizontal 3-3	SAE	AM 100x100x6
Three first big cross arms		
Bottom	SAE	AM 140x140x16
Top	SAE	AM 90x90x5
Diagonal 1	SAE	AM 60x60x4
Diagonal 2	SAE	AM 50x50x4
Diagonal 3	SAE	AM 45x45x4
Vertical 1	SAE	AM 65x65x4
Vertical 2	SAE	AM 45x45x4
Base 1 to 6	SAE	AM 90x90x6
Base 7	SAE	AM 80x80x6
Base 8	SAE	AM 70x70x6-
End	SAE	AM 35x35x5
H top	SAE	AM 40x40x4
Bracing	SAE	AM 50x50x4
Three first small cross arms		
Bottom	SAE	AM 130x130x11
Top	SAE	AM 75x75x4
Diagonal 1	SAE	AM 50x50x4
Diagonal 2	SAE	AM 45x45x3
Vertical	SAE	AM 50x50x4
Base 1 to 5	SAE	AM 90x90x6
Base 6	SAE	AM 75x75x5
End	SAE	AM 35x35x5
Big top cross arms		
Bottom	SAE	AM 75x75x7
Top	SAE	AM 50x50x4
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Diagonal 3	SAE	AM 30x30x3
Vertical 1 to 5	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2	SAE	AM 90x90x5
Base 3	SAE	AM 65x65x4
Base 4	SAE	AM 55x55x4

Base 5 to 8	SAE	AM 50x50x4
End	SAE	AM 30x30x4
Big small cross arms		
Bottom	SAE	AM 70x70x5
Top	SAE	AM 45x45x3
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Vertical 1 to 4	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2 to 7	SAE	AM 75x75x4
End	SAE	AM 30x30x4

D.7 12 metres between legs

Group	Angle type	Angle size
Bottom section		
Bottom legs	SAE	AM 250x250x25
Diagonal	SAE	AM 120x120x7
Redundant 1	SAE	AM 75x75x4
Redundant 2	SAE	AM 90x90x5
Redundant 3	SAE	AM 110x110x6
Horizontal 1	SAE	AM 70x70x5
Horizontal 2	SAE	AM 70x70x5
Horizontal 3	SAE	AM 90x90x5
Section 1		
Section 1 legs	SAE	AM 250x250x25
Diagonal 1	SAE	AM 120x120x8
Diagonal 2	SAE	AM 120x120x8
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 90x90x5
Redundant 1-3	SAE	AM 110x110x6
Redundant 2-1	SAE	AM 60x60x5
Redundant 2-2	SAE	AM 80x80x5
Redundant 2-3	SAE	AM 90x90x6
Horizontal 1	SAE	AM 65x65x4
Horizontal 2	SAE	AM 65x65x4
Horizontal 3	SAE	AM 70x70x5

Section 2		
Section 2 legs	SAE	AM 250x250x25
Diagonal 1	SAE	AM 120x120x8
Diagonal 2	SAE	AM 120x120x8
Redundant 1-1	SAE	AM 65x65x4
Redundant 1-2	SAE	AM 76x76x4,8
Redundant 1-3	SAE	AM 80x80x6
Redundant 2-1	SAE	AM 76x76x4,8
Redundant 2-2	SAE	AM 70x70x5
Redundant 2-3	SAE	AM 75x75x6-
Horizontal 1	SAE	AM 50x50x4
Horizontal 2	SAE	AM 45x45x5
Horizontal 3	SAE	AM 60x60x4
Section 3		
Section 3 legs	SAE	AM 250x250x28
Diagonal 1	SAE	AM 140x140x9
Diagonal 2	SAE	AM 140x140x9
Diagonal 3	SAE	AM 150x150x12-/+
Redundant 1-1	SAE	AM 60x60x4
Redundant 1-2	SAE	AM 60x60x5
Redundant 1-3	SAE	AM 80x80x5
Redundant 2-1	SAE	AM 70x70x5
Redundant 2-2	SAE	AM 70x70x5
Redundant 3-1	SAE	AM 75x75x4
Redundant 3-2	SAE	AM 65x65x4
Horizontal 1	SAE	AM 45x45x3
Horizontal 2	SAE	AM 45x45x3
Horizontal 3	SAE	AM 50x50x4
Section 4		
Section 4 legs	SAE	AM 250x250x22
Diagonal 1	SAE	AM 160x160x16-/+
Diagonal 2	SAE	AM 150x150x12-/+
Diagonal 3	SAE	AM 150x150x12-/+
Redundant 1-1	SAE	AM 75x75x4
Redundant 1-2	SAE	AM 75x75x4
Redundant 2-1	SAE	AM 75x75x5
Redundant 3-1	SAE	AM 75x75x5
Horizontal 1-1	SAE	AM 140x140x11

Horizontal 1-2	SAE	AM 100x100x6
Horizontal 1-3	SAE	AM 75x75x5
Horizontal 2-1	SAE	AM 150x150x12-/+
Section 5		
Section 5 legs	SAE	AM 200x200x16-/+
Diagonal 1	SAE	AM 150x150x13-/+
Diagonal 2	SAE	AM 150x150x13-/+
Diagonal 3	SAE	AM 150x150x13-/+
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 76x76x4,8
Horizontal 1-2	SAE	AM 90x90x6
Horizontal 1-3	SAE	AM 75x75x4
Horizontal 1-4	SAE	AM 110x110x9
Horizontal 2-1	SAE	AM 110x110x7
Horizontal 2-2	SAE	AM 110x110x7
Top section		
Top legs	SAE	AM 130x130x11
Diagonal 1	SAE	AM 130x130x10
Diagonal 2	SAE	AM 130x130x10
Diagonal 3	SAE	AM 100x100x6
Diagonal 4	SAE	AM 65x65x4
Redundant 1-1	SAE	AM 65x65x4
Redundant 2-1	SAE	AM 65x65x4
Redundant 3-1	SAE	AM 65x65x4
Horizontal 1-1	SAE	AM 80x80x5
Horizontal 1-2	SAE	AM 120x120x13
Horizontal 1-3	SAE	AM 90x90x6
Horizontal 1-4	SAE	AM 55x55x4
Horizontal 2-1	SAE	AM 90x90x5
Horizontal 2-2	SAE	AM 90x90x5
Horizontal 2-3	SAE	AM 100x100x6
Horizontal 3-1	SAE	AM 75x75x6-
Horizontal 3-2	SAE	AM 75x75x6-
Horizontal 3-3	SAE	AM 100x100x6
Three first big cross arms		
Bottom	SAE	AM 140x140x16

Top	SAE	AM 90x90x5
Diagonal 1	SAE	AM 60x60x4
Diagonal 2	SAE	AM 50x50x4
Diagonal 3	SAE	AM 45x45x4
Vertical 1	SAE	AM 65x65x4
Vertical 2	SAE	AM 45x45x4
Base 1 to 6	SAE	AM 90x90x6
Base 7	SAE	AM 80x80x6
Base 8	SAE	AM 70x70x6-
End	SAE	AM 35x35x5
H top	SAE	AM 40x40x4
Bracing	SAE	AM 50x50x4
Three first small cross arms		
Bottom	SAE	AM 130x130x11
Top	SAE	AM 75x75x4
Diagonal 1	SAE	AM 50x50x4
Diagonal 2	SAE	AM 45x45x3
Vertical	SAE	AM 50x50x4
Base 1 to 5	SAE	AM 90x90x6
Base 6	SAE	AM 75x75x5
End	SAE	AM 35x35x5
Big top cross arms		
Bottom	SAE	AM 75x75x7
Top	SAE	AM 50x50x4
Diagonal 1	SAE	AM 45x45x4
Diagonal 2	SAE	AM 45x45x3
Diagonal 3	SAE	AM 30x30x3
Vertical 1 to 5	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2	SAE	AM 90x90x5
Base 3	SAE	AM 65x65x4
Base 4	SAE	AM 55x55x4
Base 5 to 8	SAE	AM 50x50x4
End	SAE	AM 30x30x4
Big small cross arms		
Bottom	SAE	AM 65x65x6
Top	SAE	AM 45x45x3
Diagonal 1	SAE	AM 45x45x4

Diagonal 2	SAE	AM 45x45x3
Vertical 1 to 4	SAE	AM 45x45x3
Base 1	SAE	AM 90x90x5
Base 2 to 7	SAE	AM 75x75x4
End	SAE	AM 30x30x4

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