Concept development, floating bridge
E39 Bjørnafjorden

Appendix L – Enclosure 3

Analysis of construction stages

ENCLOSURE L3

PROJECT	Concept development, floating bridge E39 Bjørnafjorden	DOCUMENT CODE	SBJ-33-C5-AMC-22-RE-112
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SUBJECT	Analysis of construction stages	PROJECT MANAGER	Svein Erik Jakobsen
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SUMMARY

This Enclosure to Appendix L deals with construction stages of the cable stayed bridge. Four stages are considered critical and evaluated herein:

- A1. The last stage of casting the column in axis 1E
- A2. The last stage of casting the tower in axis 2
- B. The last stage of symmetric cantilevered situation of cable stayed bridge before continuity in axis 1E is established.
- C. The last stage of assembling main span before before continuity in axis 3 is established.

Buffeting response for all wind directions as well as permanent loads during construction is calculated.

This Enclosure describes the models and analyzes in detail, and section forces, both ULS max/min and characteristic forces, are presented. Capcacity and stability checks due to forces resulting from this Enclosure are included in Enclosure L1 and Enclosure L2 respectively.

A summary of the most important results is presented in the following:

Tower

Capacity checks of critical sections and foundation stability are performed. Constructions stages are governing for the tower.

Stay cables

Constructions stages will not be governing for the cables as the maximum ULS force in the longest cable in main span is ca. 8MN.

Back columns

Capacity checks of critical sections and foundation stability are performed. Constructions stages are governing for the axis 1E column.

Bridge girder (steel)

Maximum bending moment about strong axis is 1700MNm at axis 2 for stage C, and maximum bending moment about weak axis is 55MNm. Thus, construction stages are not governing for the steel bridge girder.

Bridge girder (concrete)

Capacity checks of critical sections are performed, but the construction stages are not governing.

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1 Introduction

This Enclosure lists the assumptions that the global analysis of the Bjørnafjorden Bridge rely on for the assumed most critical conditions during the constructional stages of the cable stayed bridge:

Included impact on these stages:

- Dead loads and pre-stressing of stay cables
- Static wind loads
- Dynamic buffeting wind loads

Deformation loads and secondary forces from previous construction stages are neglected. Imperfections are also neglected.

Loads and load factors are in accordance with the Design basis.

This Enclosure is structured as follows:

Chapter 2: Considered critical construction stages described.

Chapter 3-6: Analysis description (calc. method, models, loads and load combinations etc.).

Chapter 7: Section forces:

- Chapter 7.1: Tabulated max/min ULS forces for all considered critical sections.
- Chapter 7.2: Plotted characteristic forces from static and dynamic wind for the various wind directions and for all considered critical sections. Characteristic forces from permanent load are also shown.

Chapter 8: Natural modes of vibration for each stage.

Chapter 9: Modal response for each modes listed for each stage for selected wind directions.

Capcacity and stability checks due to forces resulting from this Enclosure are included in Enclosure L1 and Enclosure L2 respectively.

2 Construction stages

The construction of the cable stayed bridge is described with the following stages:

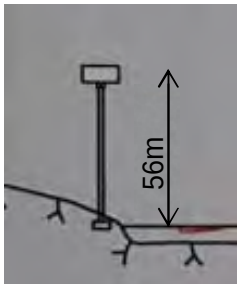
- Construction of the approach bridge
- Construction of abutment and piers
- Construction of the tower
- Construction of the bridge girder
- Construction of the cable stayed bridge girder
  - Erection of the pier table
  - Balanced cantilever construction
  - Closing at the side span
  - Completion of the main span girder
- Installation of stay cables

The piers and the tower of the cable stayed bridge will be constructed using climbing formwork. The concrete bridge girder is cast in sections and is launched, section by section, towards the tower on temporary sliding equipment located at the abutment and on each pier. The cable stayed bridge girder (steel) is installed using the balanced cantilever method, working out from the tower towards the side span and the main span respectively. The girders are lifted from barges by derrick cranes.

The four stages shown in the following chapters are considered critical and evaluated herein.

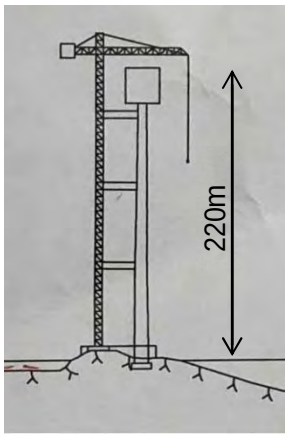
2.1 A1. The last stage of casting the column in axis 1E

The axis 1E column with a total height of 56m casted. Climbing formwork at the top.



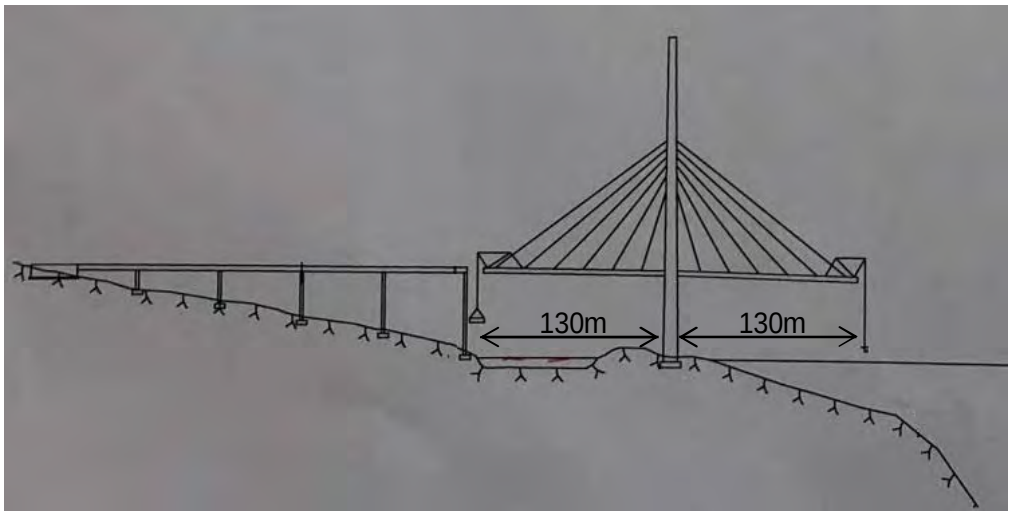
2.2 A2: The last stage of casting the tower in axis 2

Tower fully casted up to elevation z=220m. Climbing formwork at the tower top. Crane and lift mounted to the tower.



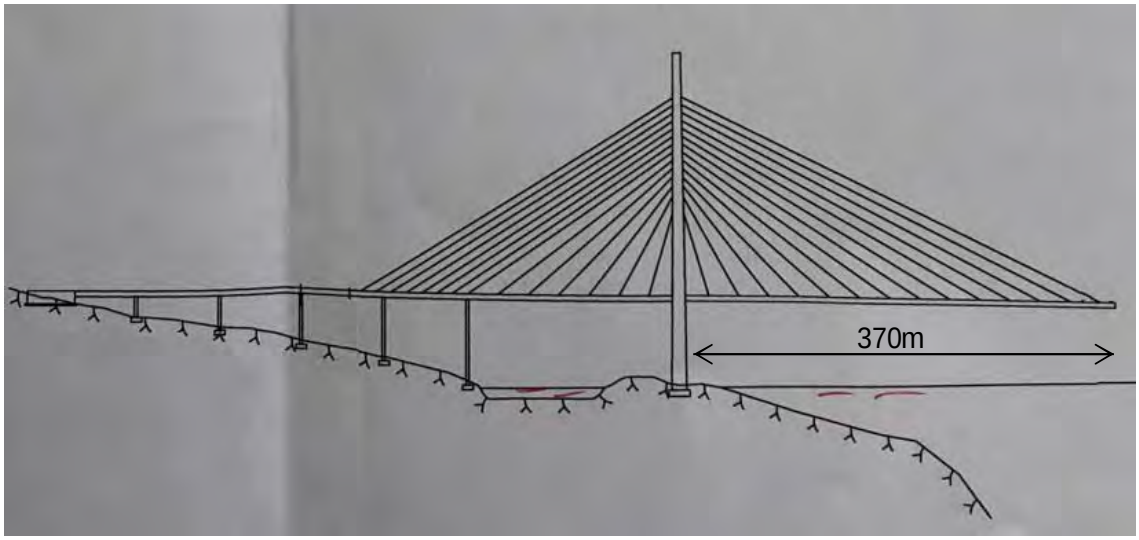
2.3 B: Cantilevered situation of cable stayed bridge before closing at the side span

Derrick cranes at the end of both 130m cantilevers. Crane and lift mounted to the tower is also assumed, but this is not shown in the figure below.



2.4 C. Cantilevered bridge girder in main span before before closing in axis 3

Main span cantilever 370m. No special equipment included. Instead it is chosen to include 100 year return period wind loads due to the assumption that this stage may last for a considerable longer period of time compared to the other stages. 10 year return period is used in general for construction stages.



3 Method of calculation

3.1 Analysis tool

The analyses are carried out with the general beam element program NovaFrame version 6. The program has modules that treat buffeting wind loads as well as combination of loads to envelopes with max/min results.

3.2 Wind analysis

NovaFrame includes a module for stochastic dynamic wind analysis, or buffeting analysis. The response of the wind is divided into two parts;

- the static response from the mean flow of the wind (10 min. average), calculated in a straight forward ordinary static analysis,
- and the dynamic response of the unsteady flow of the wind, calculated by means of the stochastic wind analysis.

The stochastic analysis uses the structures natural frequencies and mode shapes to determine the dynamic response of each mode. In the stochastic analysis the contribution from each mode is assumed to be uncorrelated and is summed up using the RMS (root mean square) method.

In the stochastic analysis all components of the wind turbulence (horizontal in the wind direction, horizontal normal to the wind direction and vertical normal to the wind direction) are taken into account provided that the corresponding wind area and shape factors are defined. The aerodynamic damping is automatically calculated by the program.

3.3 Second order effects

Theoretically the effective stiffness including 2. order effects can be expressed as:

$$K_{eff} = K_E + K_G$$

Where K_E is the elastic stiffness matrix and K_G is the geometric and axial load dependent stiffness matrix. Introducing the geometric stiffness matrix, the possibility of calculating 2. order moments based on the load level given in the geometric stiffness is possible. This is a linear approximation of the 2. order effects stemming from P-Delta effects. This effect is of importance for the tower.

A decrease of geometric stiffness by increasing the axial (compression) load in the tower might result in larger 2.order moments in the tower legs.

Second order effects (P-Delta) are accounted for in the analyzes. Calculations are based on an axial force level calculated from non-factorized permanent loads and static wind loads. The permanent load condition at each construction stage is calculated in a simplified manner. It is assumed that the stiffness and loads of all components are activated in one step. A state of pre-stressing, at which general deformations and unbalanced forces in the tower are fairly low for stages “B” and “C”, is achieved. An unoptimized state of pre-stressing is considered to be conservative.

3.4 Geometric tolerances/imperfection

Geometric tolerances are not included in the model.

It is chosen to include an imbalance in the permanent load by increasing the selfweight of the bridge girder in main span by 5% for stages “B” and “C”. This gives horizontal displacements of 90mm and 120mm in top of the tower for the stages “B” and “C” respectively. This is considered a quite conservative approach taking into account that imbalanced displacements/forces will be measured continuously with current constructional practice for this kind of structure.

In stage A1 and stage A2 geometric tolerances/imperfections are assumed negligible. Imperfections of approximately 100mm are assumed to be of minor importance when compared to deformations due to static (max ca. 0.4m for stage A2) and dynamic (max ca. 0.9m for stage A2) wind response. Also, only the column/tower selfweight will contribute to the axial force level → low additional bending moments.

Thus, as imperfections are considered not decisive for concept design it is chosen to neglect it at this phase of the project.

3.5 Dynamic wind analysis

The eigenvalue analysis is performed on the basis of the linear elastic stiffness matrix, the geometric stiffness matrix as defined above and the mass matrix.

The total response of the wind impact is calculated as the sum of the static mean part and the fluctuating dynamic part.

Aerodynamic damping are accounted for, and calculated on basis of the quasi-static load coefficients.

Structural damping is assumed as:

- Stage A1, A2 and B: 0.8 % of critical for uncracked concrete and 1.6 % for cracked concrete according to N400 table 5.3.
- Stage C: 0.5 % of critical for cable stayed bridges according to Design basis 8.13.1.

Aerodynamic admittance is not included.

The natural modes of vibration are assumed uncorrelated; consequently a mode by mode analysis is used. The total response is gained from a square root of the sum of the squares (SRSS) of each mode contribution. In the load combining dynamic wind results is added with unfavorable sign for both governing force component and accompanying force components.

The dynamic analysis is performed for a wind state of 10 minutes duration.

The following amount of modes is used for each construction stage:

A1 → 10

A2 → 20

B → 35

C → 50

The natural frequencies and mode shapes for each stage are shown in chapter 8.

Response of mode by mode are shown in chapter 9 for the assumed most critical wind direction for each stage.

3.6 Cracking of concrete

Cracking of reinforced concrete will reduce the bending stiffness for elements along the tower legs/columns. This effect is studied by performing additional analyzes with a reduced E-modulus, $E_{cracked}$ = 0.4 x 30 000 MPa, for all tower elements in stages A2, B and C, and for all back column elements in stage A1. This is considered to be an achievable lower limit for the bending stiffness. According to N400 the damping ratio for cracked concrete (0.016) can be doubled compared to the uncracked state (0.008).

For the free-standing column or tower the reduction of stiffness alone (not taking into account P-Delta) the dynamic forces decreases (due to the significant increase of damping), but on the other hand the forces will increase due to the P-Delta effect (increased displacements).

Stability checks with cracked stiffness are performed for concept verification. However, section capacity checks with cracked stiffness are considered a matter of detail reinforcement design. Additionally, it is seen that the cracked stiffness of 40 % will not have a significant impact on the total forces due to the significantly increased level of structural damping. Reference is made to the stability checks. Thus, cracked stiffness is not considered for capacity checks in this phase.

3.7 Assessment of vortex shedding and galloping

The tower is of concrete and limited height. Based on experience with similar towers from previous projects it is not expected to show problems with vortex shedding or instabilities.

4 Analysis models

4.1 Model geometry, boundary conditions and joints

4.1.1 General

The NovaFrame models are comprised of beam elements, joints and master-slave connections. The master-slave connections are used to ensure the eccentricities of the connections between the cables and bridge elements, cables and tower elements as well as the eccentricities between the center of the bridge and top of the columns. Each element has a full set of element properties including mass, stiffness about all axes, modulus of elasticity and wind areas.

Reference is made to Appendix F chapter 2.3 for global and local coordinate systems.

The following chapters display the geometry, joints and boundary conditions for each stage. Currently, all the boundary conditions are fixed. The boundary conditions can be seen in green, the red lines in the model represent master-slave connections and the joints can be seen in blue.

4.1.2 Stage A1

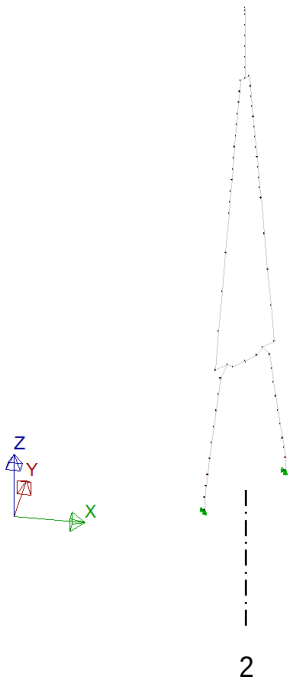
Element model:

Boundary conditions:

- All translations and rotations fixed in bottom column foundation (axis 1E).

4.1.3 Stage A2

Element model:

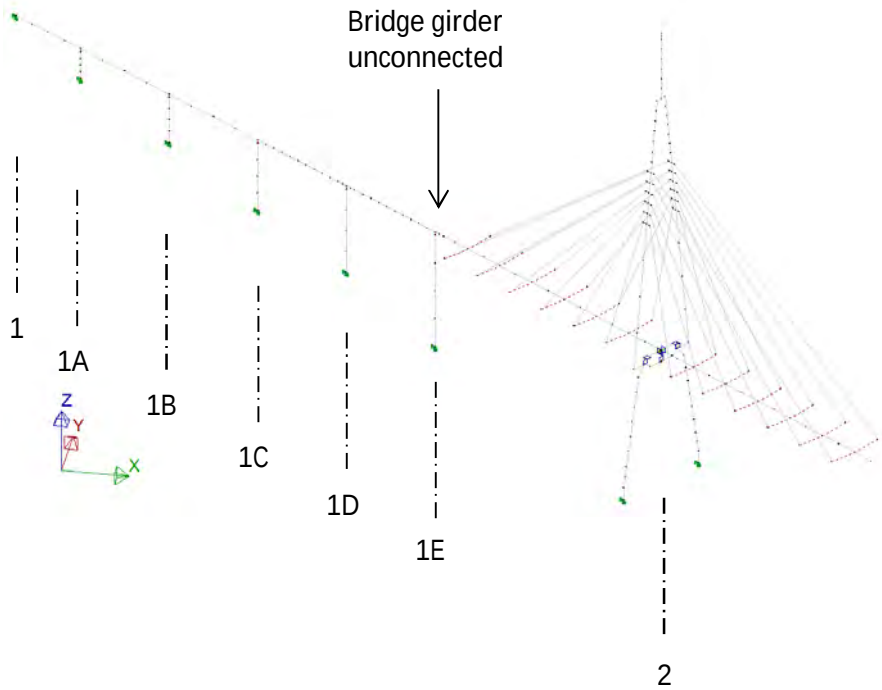


Boundary conditions:

- All translations and rotations fixed in bottom tower foundations (axis 2).

4.1.4 Stage B

Element model:



Boundary conditions:

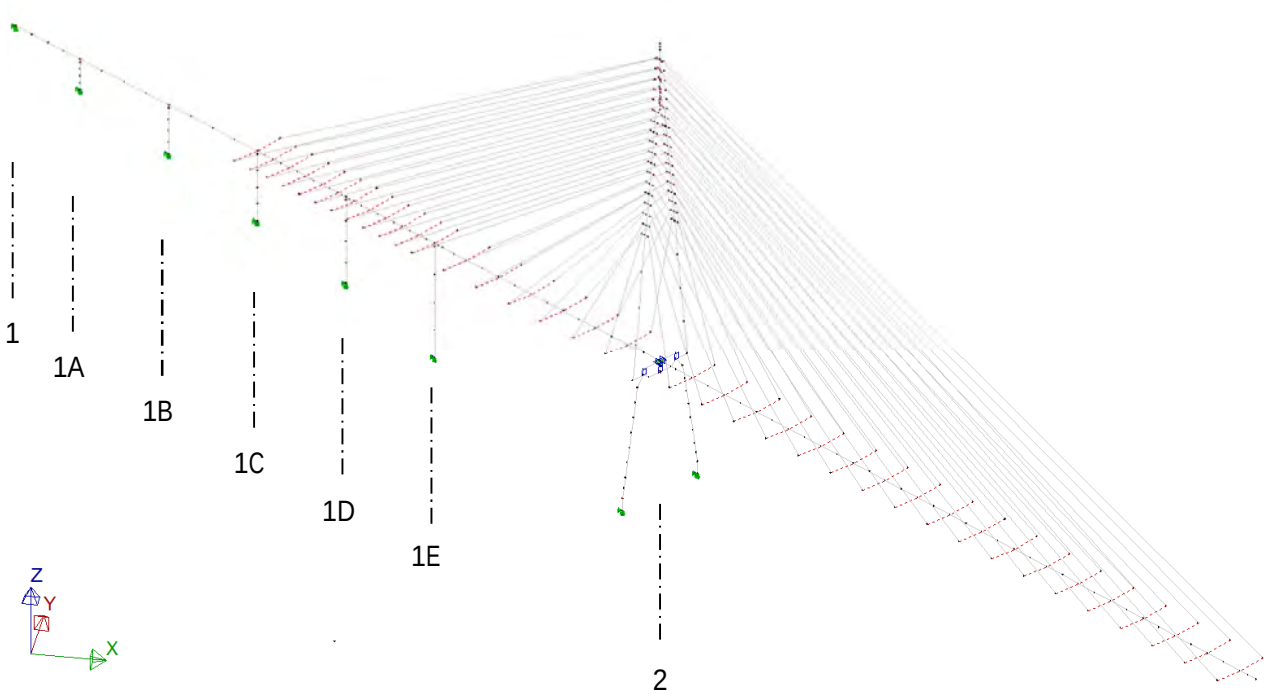
- All translations and rotations fixed at abutment (axis 1), in bottom columns (axis 1A-1E) and in bottom tower foundations (axis 2).

Joints:

- Temporary fixings between the tower and the bridge girder is assumed. The bridge girder is fixed to the tower for lentghwise, vertical and sidewise translations, and for rotations about the longitudinal and vertical axis. The bridge girder is free to rotate about the transverse axis of the bridge.

4.1.5 Stage C

Element model:



Boundary conditions:

- All translations and rotations fixed at abutment (axis 1), in bottom columns (axis 1A-1E) and in bottom tower foundations (axis 2).

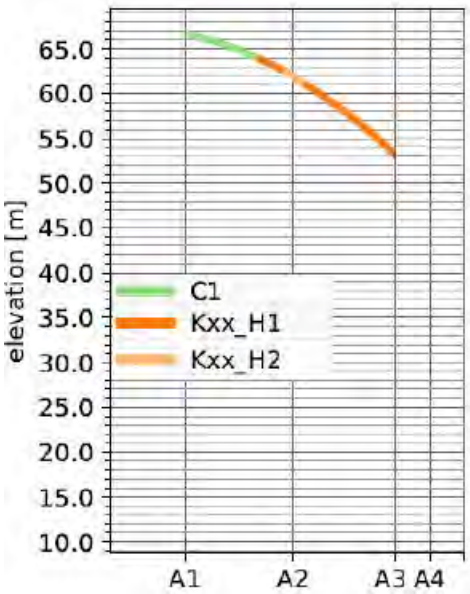
Joints:

- The bridge girder is only fixed to the tower for vertical and sidewise translations, and for rotations about the longitudinal axis. The bridge girder is free to translate in the longitudinal direction and is free to rotate about the vertical and transverse axis of the bridge. Thus, it is assumed that the temporary fixations included in stage "B" will be removed after connection in stage 1E. The removal of the temporary fixations from stage “B” will not generate any big changes in the forces. Thus, this is considered an OK approximation and should be conservative for wind response.

4.2 Cross sections

4.2.1 Bridge girder

Sectional property definition cable stayed bridge is shown on the following plot.



Key sectional properties of bridge girder (y = transverse/weak axis, z = vertical/strong axis) are shown in the following table.

	M	Iy	Iz	J	Ax	Ly	Lz
	[tonne/m]	[m^4]	[m^4]	[m^4]	[m^2]	[m]	[m]
Kxx_H1	14.4	2.6	97.9	6.4	1.35	27	3.5
Kxx_H2	14.4	3.5	126.7	9.7	1.75	27	3.5
C1	74.5	40.5	2138	135	28.0	29	3.5

E_{steel} = 210 000MPa for Kxx_h1 and Kxx_H2

$E_{concrete}$ = 29 764MPa for C1

4.2.2 Columns

10 500 mm x 2 100 mm constant cross section used for all columns.

A= 22.05m^2

$I_{transverse}$ = 8.10m^4

$I_{longitudinal}$ = 202.60m^4

J = 28.39m^4

$E_{concrete}$ = 29 764MPa

M = 55.1 tonne/m

4.2.3 Tower

Key sectional properties of tower (y = transverse axis, z = longitudinal axis) are shown in the following table.

Section	Ax [m^2]	Iy [m^4]	Iz [m^4]	J [m^4]	M [tonne/m]
Tower leg, bottom (z=0)	43.52	359.30	71.21	202.40	115.4
Tower leg, below cross beam (z=52)	34.58	302.10	541.70	582.30	91.7
Tower leg, above cross beam (z=57)	17.72	147.70	45.68	115.60	47.0
Tower leg, top (z=187)	10.72	49.66	36.31	66.56	28.4
Upper tower, bottom (z=187)	15.79	81.72	175.50	170.40	41.8
Upper tower, top (z=220)	7.57	23.19	9.83	22.55	20.1

$E_{concrete}$ = 29 764MPa

Cross beam:

$I_{vertical}$ = 40.95 m^4

$I_{longitudinal}$ = 40.95 m^4

J = 67.29m^4

$E_{concrete}$ = 29 764MPa

M = 35.6 tonne/m

4.2.4 Stay cables

Key sectional properties of stay cables are shown in the following table.

E_0 = 195 000MPa

E_{eff} is E_0 adjusted for sag:

$$E_{eff} = E_0 \frac{1}{1 + \frac{\gamma^2 L_h^2 E_0}{12 \sigma^3}} \qquad (2.6)$$

where:

E_{eff} = the effective elastic modulus in [N/mm^2]

E_0 = the elastic modulus of the stay cable material in the absence of the sag effect [N/mm^2]

γ = the specific weight of the stay cable material in [N/mm^3]

L_h = the projected stay cable length in plan in [mm]

σ = the axial stress of the cable in [N/mm^2]

Stay cable	Back span		Main span	
[No.]	A [m^2]	E_{eff} [MPa]	A [m^2]	E_{eff} [MPa]
1	3.90E-03	194970.9	3.90E-03	194971.0
2	4.20E-03	194811.9	4.20E-03	194846.2
3	4.50E-03	194577.9	4.50E-03	194525.3
4	5.10E-03	194121.3	5.10E-03	194176.5
5	5.70E-03	193314.6	5.70E-03	193641.3
6	6.15E-03	192487.6	6.15E-03	193059.0
7	7.05E-03	192108.2	7.05E-03	191906.1
8	7.20E-03	192100.6	7.20E-03	191052.5
9	7.65E-03	191798.2	7.65E-03	189978.4
10	8.10E-03	191230.2	8.10E-03	189213.7
11	8.55E-03	190737.5	8.55E-03	187833.3
12	9.00E-03	190121.3	9.00E-03	186196.3
13	9.00E-03	189524.4	9.00E-03	185341.0
14	9.45E-03	189376.4	9.45E-03	183465.1
15	1.01E-02	188917.0	1.01E-02	181946.3
16	1.04E-02	188417.6	1.04E-02	180351.4
17	1.04E-02	187390.6	1.04E-02	178908.0
18	1.04E-02	186937.3	1.04E-02	177508.5

5 Loads and masses

5.1 Selfweight

Reference is made to Appendix G chapter 2.1.1. Selfweight and masses of the following elements are applied to the static system and calculated acc. to Design basis 6.2.1.1:

- Bridge girder (super dead load weight is not included)
- Cables stays
- Tower
- Columns

It is chosen to include an imbalance in the permanent load by increasing the selfweight of the bridge girder in main span by 5% for stages “B” and “C”.

5.2 Permanent forces stay cables

Cable stay forces from permanent loads (imbalanced selfweight of the bridge girder not included) in stages “B” and “C” are shown in the following table. Stay cable numbering is in accordance with the drawings. It should be noted that the pre-stressing of the stay cables is simplified and not fully optimized. Thus, the forces will deviate from the more comprehensive analyzes performed in RM Bridge. However, the simplified methodology is considered satisfactory for the purpose of analyzes performed in this Enclosure.

Stay cable	Axial force from permanent loads (dead load + pre-stressing) [MN]			
	Back span		Main span	
[No.]	Stage “B”	Stage “C”	Stage “B”	Stage “C”
1	1.1	1.4	1.1	1.1
2	1.4	1.9	1.4	2.6
3	1.7	2.1	1.7	2.0
4	1.9	1.9	1.9	1.8
5	2.3	2.2	2.3	2.2
6	2.5	2.4	2.5	2.4
7	-	2.6	-	2.6
8	-	2.8	-	2.8
9	-	3.1	-	3.0
10	-	3.3	-	3.2
11	-	3.5	-	3.4
12	-	3.7	-	3.6
13	-	3.8	-	3.7
14	-	4.0	-	3.9
15	-	4.2	-	4.0
16	-	4.2	-	4.0
17	-	3.5	-	2.9

18	-	3.7	-	3.8

5.3 Special equipment during construction

Climbing formwork at top of tower in stage A1

The assumed mass of the formwork at the column top is 50 tonne.

Climbing formwork at top of tower in stage A2

The assumed mass of the formwork at the tower top is 100 tonne.

Crane in stage A2 and B

The mass of the crane mast is neglected. It is chosen to include 100 tonne in top of the tower from the crane top.

Derrick lifts in stage B

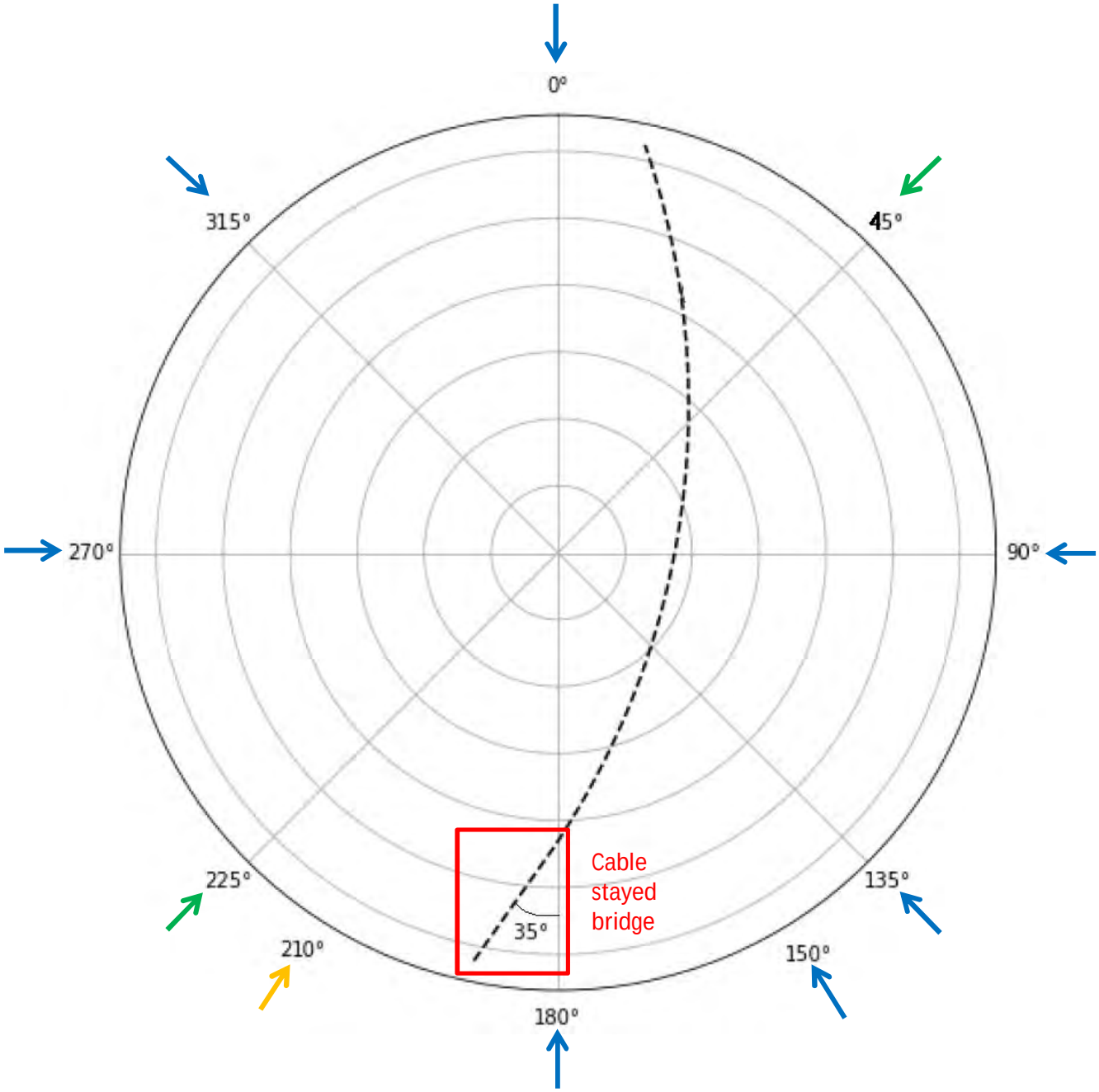
The mass of the Derrick cranes at the end of both cantilevers in stage “B” are assumed to be 50 tonne each.

5.4 Wind loads

5.4.1 Wind directions

Wind analyses are performed with the wind directions (shown with arrows) shown in the figure below. Alignment for K12 is shown with dotted line. 0 degrees is wind from north. Reference is made to Design basis. Wind directions shown with:

- Blue arrows is performed for stages A2, B and C.
- Green arrows is only performed for stage A2.
- Orange arrows is performed for stages A1 and A2.



5.4.2 Wind climate

Wind speeds in construction stages have in general a return period (R) of 10 years.

For stage "C" it is chosen to include 100 year return period wind loads due to the assumption that this stage may last for a considerable longer period of time compared to other stages.

Evaluated wind climate are acc. to the Appendix E.

In the following table mean wind input are summarized for the different stages and wind directions. The values shown are calculated for 10 min mean and z=10m height, roughness length z_0= 0.01 and terrain factor k_t = 0.17.

Stage	Wind dir.	Basic wind speed	Sector red. coeff.	Wind speed
[-]	[deg]	[m/s]	[-]	[m/s]
A1	210	23.5	0.85	23.46
A2	0	23.5	0.7	19.32
	45	23.5	0.7	19.32
	90	23.5	0.85	23.46
	135	23.5	0.85	23.46
	150	23.5	0.85	23.46
	180	23.5	0.85	23.46
	210	23.5	0.85	23.46
	225	23.5	0.9	24.84
	270	23.5	1.0	27.60
	315	23.5	1.0	27.60
B	0	23.5	0.7	19.32
	90	23.5	0.85	23.46
	135	23.5	0.85	23.46
	150	23.5	0.85	23.46
	180	23.5	0.85	23.46
	270	23.5	1.0	27.60
	315	23.5	1.0	27.60
C	0	27.0	0.7	22.19
	90	27.0	0.85	26.95
	135	27.0	0.85	26.95
	150	27.0	0.85	26.95
	180	27.0	0.85	26.95
	270	27.0	1.0	31.71
	315	27.0	1.0	31.71

Wind length scales, turbulence intensities and coherence factors are defined for each wind analysis (direction). These are calculated based on a defined reference height. It is chosen to perform analyzes for reference heights of both 50m and 200m for stage A2, B and C. Only reference height 50m is used for stage A1. The most unfavorable reference height will further be calculated and governing due to the load combining routine.

In the following table wind parameters are summarized for the different wind directions and chosen reference heights.

Parameter	Sector 150 deg – 210 deg		Else	
	z_{ref}=50m	z_{ref}=200m	z_{ref}=50m	z_{ref}=200m
I_u	0.3000	0.1500	0.1174	0.1010
I_v	0.2520	0.1260	0.0986	0.0848
I_w	0.1800	0.0900	0.0704	0.0606
${}^xL_u$ [m]	162.1	398.1	162.1	398.1
${}^xL_v$ [m]	40.5	99.5	40.5	99.5
${}^xL_w$ [m]	13.5	33.2	13.5	33.2
A_u	6.8	6.8	6.8	6.8
A_v	9.4	9.4	9.4	9.4
A_w	9.4	9.4	9.4	9.4
C_{ux}*	8.0	8.0	8.0	8.0
C_{uy}	10.0	10.0	10.0	10.0
C_{uz}*	8.0	8.0	8.0	8.0
C_{vx}*	8.0	8.0	8.0	8.0
C_{vy}*	8.0	8.0	8.0	8.0
C_{vz}*	8.0	8.0	8.0	8.0
C_{wx}*	8.0	8.0	8.0	8.0
C_{wy}	6.5	6.5	6.5	6.5
C_{wz}*	8.0	8.0	8.0	8.0

*) Not in accordance with Appendix E. These values are not adjustable in NovaFrame, but this is not expected to have significant impact.

The fluctuating wind spectrum is in accordance with Eurocode NS-EN 1991-1-4:2005 / NS3491-4:2002 and N400:

$$\frac{nS_i}{\sigma_i^2} = \frac{A_i \hat{n}_i}{(1 + 1.5 A_i \hat{n}_i)^{5/3}}, \qquad \hat{n}_i = \frac{n\, {}^xL_i(z_{ref})}{U(z_{ref})}$$

The coherence function is an exponential decay function defined as:

$$\sqrt{coh(n, \Delta s_j)} = \exp\left(-C_{ij} \frac{n \Delta s_j}{(U(z)}\right), \qquad i = u, v, w$$

5.4.3 Wind areas and coefficients

Wind factors are properties of all elements in NovaFrame. The following chapters summarize the wind factors and corresponding wind areas used in analyzes.

The wind direction is transformed to the local NovaFrame coordinate system meaning skew winds will reduce to decomposition and be analyzed accordingly.

Tower legs, upper tower and cross beam

The coefficients are calculated from NS-EN-1991-1-4:2005 section 7.6 and is based on an approximated corner cut of r=0.6m. This is not in direct accordance with chamfering shown on drawings. The general function of a rectangular cross section given with square corners with a cross wind dimension D, and along wind dimension B is shown below.

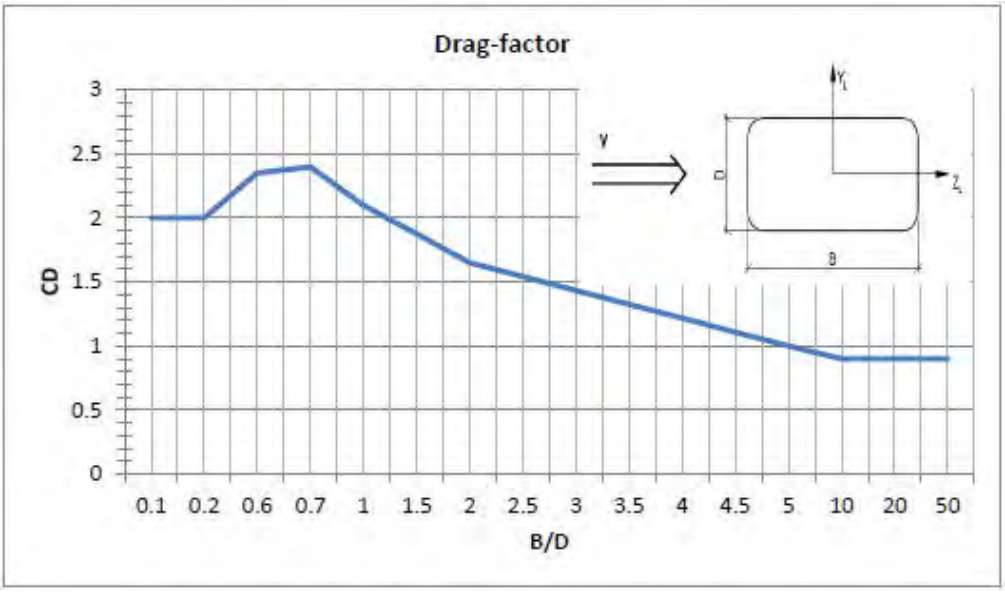


Figure 1: Basis for drag factors tower legs, upper tower and cross beam in both directions

Further assumptions:

- Rectangular cross-sections.
- Wind perpendicular to one side of the cross section.
- No end effects included.
- Lift based on the worst of a +/- 10 deg range around the transverse and longitudinal direction.
- Shielding effects are neglected.
- Derivatives from Chacao vind tunnel tests.

Calculated drag factors varies along the tower sections in the range 1.1 – 2.1 for wind in the longitudinal direction and 1.5 – 2.0 in the transverse direction.

Calculated lift factors varies along the tower sections in the range 0.3 - 0.6 for both winds in the longitudinal and transverse direction.

Calculated derivative lift factors varies along the tower sections in the range 0.7 - 3.5 rad^{-1} for both winds in the longitudinal and transverse direction.

The same coefficients are used for all skew wind cases. It has been sought to achieve the most unfavorable sign for lift for each wind direction. However, lift and derivatives does not seem to have significant impact on the response.

Columns

The columns are modelled with a drag coefficient of 2.0 in the longitudinal direction of the bridge (B/D=0.2) and conservatively 1.5 in the transverse direction (B/D=5). Reference is made to document 10205546-08-RAP-160 chapter 2.7

Cables

Drag factors for cables are defined as 1.2 and 0.8 below and above 20 m/s wind. Reference is made to document 10205546-08-RAP-160 chapter 2.6

Bridge girder

Wind coefficients included in accordance with document 10205546-08-RAP-160 chapter 2.5.

Special equipment during construction

This chapter lists the assumptions that the analysis of the construction stages rely on regarding effective wind areas of cranes, lifts and formwork.

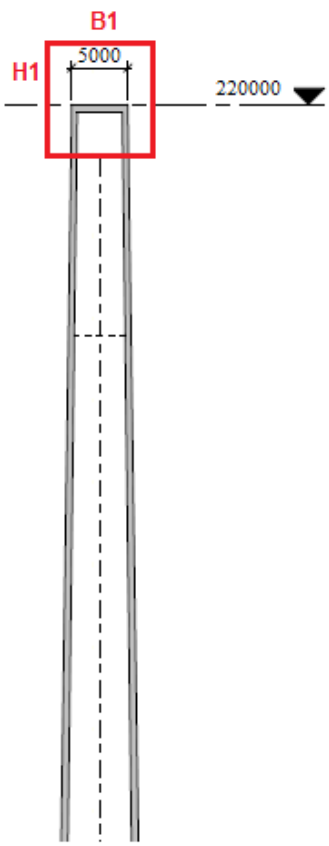
Climbing formwork at top of tower in stage A1

In the following effective areas and effective wind areas (including drag factors) are calculated for the climbing formwork at the top of the axis 1E column. These parameters apply for wind in longitudinal direction of the bridge axis. Wind in the transverse direction will not be critical and is not considered.

Assumed exposed area:	A_{ref} = 12 m x 6 m = 72 m^2
Drag-factors:	$C_{d,formwork}$ = 2.4
(acc. to NS-EN 1991-1-4)	
Effective wind area:	$C_{d,\ formwork}$ x A_{ref} = 173m^2

Climbing formwork at top of tower in stage A2

The assumed exposed areas / wind areas for the formwork at the tower top are illustrated to the right.



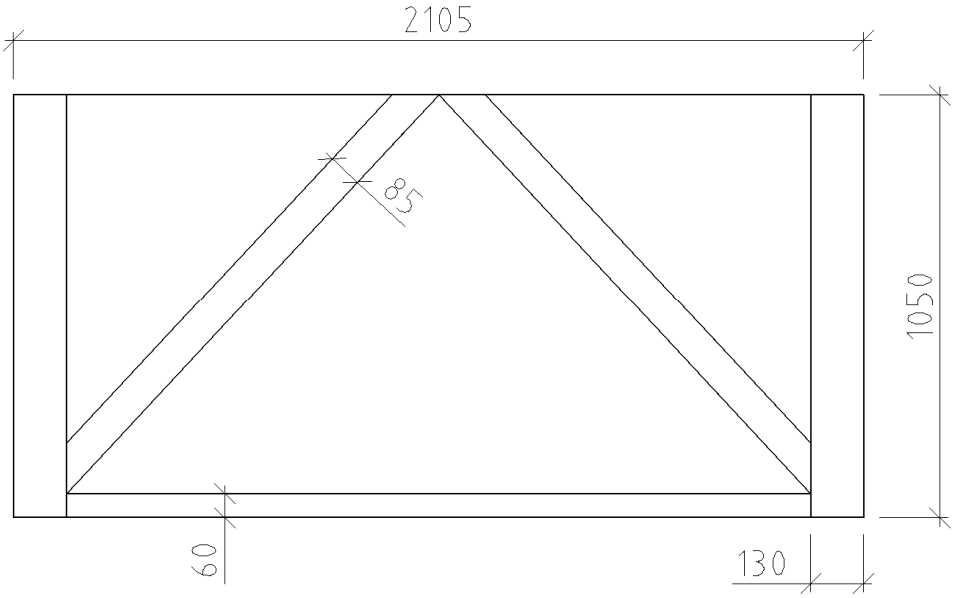
In the following effective areas and effective wind areas (including drag factors) are calculated. These parameters apply for both wind in transversal and longitudinal direction of the bridge axis.

Assumed height of formwork:	H1 = 7m (~3.5m above tower top)
Assumed width of formwork:	B1= 5m + 2x1m = 7m
Exposed area:	A_{ref} = 7m x 7m = 50m^2
Drag-factors:	$C_{d,formwork}$ = 2.4
(acc. to NS-EN 1991-1-4)	
Effective wind area:	$C_{d,formwork}$ x A_{ref} = 120m^2

Crane and lifts in stage A2 and B

In the following effective areas and effective wind areas (including drag factors) are calculated for one crane. It is assumed that also a lift will be mounted to the tower. The same effective area as for the crane (calculated in the following) is used for the lift. The crane is assumed mounted to one tower leg, and the lift to the other.

The sketch below is taken from the Hardanger Bridge.



Including stair way (50000 mm^2/m) this gives a reference area of 645 260mm^2 / 1.05m

Outer dimensions, B x DH :	A = B x DH = 2105mm x 1050mm
	= 2 210 250mm^2 / 1.05m
Reference areas in longitudinal direction:	$A_{ref.y}$ = 645 260 mm^2
	$a_{ref.y}$ = 645 260 mm^2 / 1.05 m = 0.6145m^2/m
Reference area in transversal direction:	$A_{ref.z}$ = 0 m^2/m
Factor of compactness:	$\Phi = \frac{Aref}{A} = 0.29$
Drag-factors acc. to EN 1991-1-4 fig 7.34:	$C_{Dy} = C_{f0} = 2.5$
	$C_{Dz} = 0$
Check with NS3491-4 10.10.3:	$C_{Dy} = 4.4(1 - \Phi) = 3.1$
Chosen drag factor:	$C_{Dy} = 3.1$
Effective wind area:	$a_{crane} = C_{Dy} \cdot A_{ref}$
	$= 3.1 \cdot \frac{0.645m^2}{1.05m} = 1.9\text{m}^2/\text{m}$

Note! The above drag factor account for a crane mast with four sides of same compactness and with corner trusses. Thus the total wind force is expressed by a_{crane}.

The crane is assumed to have a height of 240m, which is 20m above tower top. The lower 30m of the crane is assumed to be transferred directly to the ground.

The crane is assumed to turn with the wind. Thus the wind area of the crane boom above the tower may be neglected. However, it is chosen to include some additional contribution from the crane top by multiplying the effective wind area of the climbing formwork in tower top by 2.

Forces from the crane are transferred as point loads at specific mounting points ending at certain distance below the tower top, in addition the crane mast itself will be transferring forces to the base. Thus, using the effective wind of the crane over the entire tower height and not accounting for the crane transferring the wind load to the ground (except the lower 30m) is a conservative approach.

For crane with a total height of approximately 240 m the total effective area is:

240*1.9 + 120 = 519 m^2

I.e. the total force to be transferred to the ground as portion of the total force: 30*1.9/519 = 0.11.

The tower is accounting for 89 % of the total wind force on the crane mast, and 11 % is transferred by the crane to the ground. Thus, the calculations above are assumed to be of good enough accuracy and on the conservative side.

The total wind load transferred from crane to tower will not be known until the fixation points of the crane are decided upon. Therefore, it is initially assumed uniformly distributed wind area from the crane for the upper 220m-30m = 190m of the tower in the analysis (except the additional wind area in top).

<u>Derrick lifts in stage B</u>

In the following effective areas and effective wind areas (including drag factors) are calculated for the Derrick cranes at the end of both cantilevers in stage “B”. These parameters are assumed to apply for both winds in transversal and longitudinal direction of the bridge axis.

Assumed exposed area:	A_{ref} = 20m^2
Drag-factors:	$C_{d,Derrick}$ = 2.4
(acc. to NS-EN 1991-1-4)	
Effective wind area:	$C_{d,Derrick}$ x A_{ref} = 48m^2

6 Load combinations

Load combinations are carried out in accordance with Design basis.

Actions to be considered for service limit state shall be cracking, deformations, concrete stresses and stability (check of eccentricities).

In the strength limit state both strength and stability (overturning, gliding and ground pressure) shall be considered.

Only load combinations with wind as the dominating load are considered relevant for analyzes performed in this Enclosure.

The most unfavorable load factor according to Design basis for each load case will be calculated by the program.

The program will calculate maximum/minimum force components amongst a large number of combinations. There are 6 components of element forces, and for each load combination the program will calculate 12 sets of forces, maximum and minimum of each load component with corresponding forces.

In general, the load combining will have the following form:

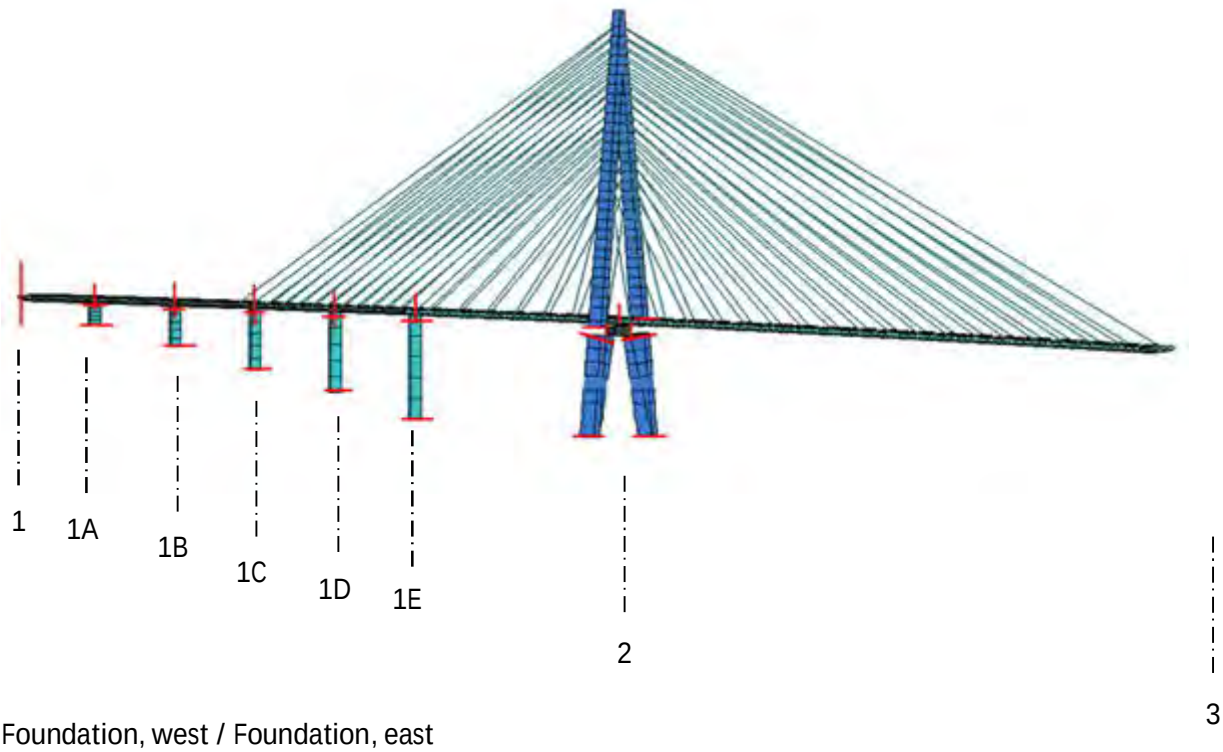
$F_{ULS/SLS} = (\gamma_{unfav,perm}$ or $\gamma_{fav,perm}) \times F_{perm} + \gamma_{unfav,SW} \times F_{SW} \pm \gamma_{unfav,DW} \times F_{DW}$

where static (SW) and dynamic (DW) wind forces only are included if they are unfavorable.

The forces from permanent load and static wind load will have a certain sign. The forces from the dynamic stochastic analysis will be without a sign as they are fluctuating and will be both positive and negative. Thus, all the dynamic forces in NovaFrame will initially be positive before the load combining routine. When combining the dynamic forces with the static forces (perm. load +static wind load) each dynamic force component will be assigned the most unfavorable sign. This will essentially be the same sign as the sum of the static forces for each component.

7 Section forces

Considered critical cross sections are shown on the figure below (foundations not shown) with red lines.



Foundation, west / Foundation, east

Tower leg bottom, west / Tower leg bottom, east

Tower leg below cross beam, west / Tower leg below cross beam, east

Tower leg above cross beam, west / Tower leg above cross beam, east

Cross beam, end west / Cross beam, end east

Bridge girder axis 1

Bridge girder axis 1A

Bridge girder axis 1B

Bridge girder axis 1C

Bridge girder axis 1D

Bridge girder axis 1E

Bridge girder axis 2

Bottom column axis 1A / Top column axis 1A

Bottom column axis 1B / Top column axis 1B

Bottom column axis 1C /Top column axis 1C

Bottom column axis 1D / Top column axis 1D

Bottom column axis 1E / Top column axis 1E'

7.1 ULS max/min forces

Tabulated max/min ULS forces, not necessarily coinciding, for each considered critical sections tabulated in the following.

Main object	Section	Stage	N [MN]	M_{longit} [MNm]	M_{transv} [MNm]	T [MNm]	V_{longit} [MN]	V_{transv} [MN]	Criteria
Tower leg west	Tower leg west, bottom, z=0	A2	-70	106	958	28	7	-5	Max
		A2	-160	24	-385	-63	-3	-10	Min
		B	-90	127	943	47	8	-5	Max
		B	-186	28	-552	-74	-5	-11	Min
		C	-104	243	473	49	7	-3	Max
		C	-289	-28	-276	-54	-5	-19	Min
Tower leg west	Tower leg west, section transition, z=10	A2	-58	22	889	28	7	-3	Max
		A2	-145	-16	-356	-63	-3	-7	Min
		B	-78	28	877	47	8	-3	Max
		B	-171	-17	-508	-74	-5	-9	Min
		C	-92	68	405	49	7	-1	Max
		C	-275	-52	-231	-54	-5	-16	Min
Tower leg west	Tower leg west, below cross beam, z=52	A2	-24	-23	604	28	6	3	Max
		A2	-103	-126	-269	-63	-3	0	Min
		B	-43	-44	625	47	7	2	Max
		B	-130	-173	-369	-74	-5	0	Min
		C	-57	11	157	49	5	4	Max
		C	-233	-459	-65	-54	-4	-8	Min
Tower leg west	Tower leg west, above cross beam, z=57	A2	-34	204	579	4	6	1	Max
		A2	-86	-64	-259	-9	-3	-7	Min
		B	-52	219	612	6	7	1	Max
		B	-106	-66	-362	-9	-4	-7	Min
		C	-82	312	152	17	5	4	Max
		C	-194	-188	-70	-15	-4	-10	Min

Main object	Section	Stage	N [MN]	M_{longit} [MNm]	M_{transv} [MNm]	T [MNm]	V_{longit} [MN]	V_{transv} [MN]	Criteria
Tower leg east	Tower leg east, bottom, z=0	A2	-68	-27	958	63	7	10	Max
		A2	-158	-110	-385	-28	-3	5	Min
		B	-86	-29	944	74	8	11	Max
		B	-183	-127	-549	-47	-5	5	Min
		C	-87	-2	482	60	7	21	Max
		C	-272	-274	-266	-42	-5	5	Min
Tower leg east	Tower leg east, section transition, z=10	A2	-56	15	889	63	7	8	Max
		A2	-143	-23	-356	-28	-3	3	Min
		B	-74	16	878	74	8	9	Max
		B	-168	-28	-507	-47	-5	3	Min
		C	-75	39	412	60	7	18	Max
		C	-257	-81	-223	-42	-5	3	Min
Tower leg east	Tower leg east, below cross beam, z=52	A2	-22	133	604	63	6	-1	Max
		A2	-101	31	-269	-28	-3	-3	Min
		B	-40	182	625	74	7	1	Max
		B	-126	54	-369	-47	-5	-2	Min
		C	-40	534	156	60	6	10	Max
		C	-215	60	-64	-42	-4	-2	Min
Tower leg east	Tower leg east, above cross beam, z=57	A2	-32	52	579	9	6	7	Max
		A2	-84	-215	-259	-4	-3	0	Min
		B	-49	51	612	9	7	8	Max
		B	-103	-234	-363	-6	-4	0	Min
		C	-70	124	156	19	5	11	Max
		C	-180	-376	-65	-13	-4	-2	Min

Main object	Section	Stage	N [MN]	M_{longit} [MNm]	M_{vert} [MNm]	T [MNm]	V_{longit} [MN]	V_{vert} [MN]	Criteria
Tower cross beam	End west	A2	-7	133	4	7	0	12	Max
		A2	-11	-67	-4	-7	0	-18	Min
		B	-8	152	31	24	4	14	Max
		B	-13	-71	-28	-24	-4	-19	Min
		C	-1	320	16	37	2	28	Max
		C	-22	-139	-17	-42	-2	-40	Min
Tower cross beam	End east	A2	-7	128	4	7	0	17	Max
		A2	-11	-71	-4	-7	0	-13	Min
		B	-8	147	31	24	4	19	Max
		B	-13	-77	-29	-24	-4	-14	Min
		C	2	275	16	37	2	33	Max
		C	-19	-183	-16	-42	-2	-34	Min

Analysis of construction stages

Main object	Section	Stage	N [MN]	M_{strong} [MNm]	M_{weak} [MNm]	T [MNm]	V_{vert} [MN]	V_{transv} [MN]	Criteria
Bridge deck	Abutment (axis 1)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	6	17	103	2	16	0	Max
		B	0	-13	79	-2	13	0	Min
		C	21	36	108	3	17	1	Max
		C	-11	-49	76	-3	13	-1	Min
Bridge deck	Back column 1 (axis 1A)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	3	8	202	3	24	1	Max
		B	-3	-13	153	-3	19	-1	Min
		C	18	43	210	8	25	3	Max
		C	-14	-61	140	-6	18	-2	Min
Bridge deck	Back column 2 (axis 1B)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	2	13	242	2	26	1	Max
		B	-3	-23	182	-2	20	0	Min
		C	18	147	266	12	28	5	Max
		C	-14	-104	184	-9	19	-3	Min
Bridge deck	Back column 3 (axis 1C)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	2	13	220	1	24	1	Max
		B	-2	-24	164	-2	18	0	Min
		C	11	360	161	20	16	3	Max
		C	-21	-239	70	-14	5	-2	Min
Bridge deck	Back column 4 (axis 1D)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	1	18	287	1	29	1	Max
		B	-2	-21	219	-1	23	0	Min
		C	-23	459	158	16	16	4	Max
		C	-68	-308	56	-12	6	-6	Min
Bridge deck	Back column 5 (axis 1E)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	-1	0	51	1	-16	0	Max
		B	-2	0	31	-1	-21	0	Min
		C	-47	184	111	29	-7	4	Max
		C	-111	-125	-53	-19	-18	-6	Min
Bridge deck	Axis 2	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	-10	85	78	14	5	1	Max
		B	-22	-108	9	-11	2	-1	Min
		C	-64	1170	31	30	3	7	Max
		C	-138	-1714	-54	-34	0	-5	Min

Main object	Section	Stage	N [MN]	M_{longit} [MNm]	M_{transv} [MNm]	T [MNm]	V_{longit} [MN]	V_{transv} [MN]	Criteria
Back columns	Back column 1, bottom (axis 1A)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	-39	11	19	0	4	1	Max
		B	-49	-11	12	0	2	-1	Min
		C	-38	47	22	1	4	2	Max
		C	-49	-33	6	-1	1	-3	Min
Back columns	Back column 1, top (axis 1A)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	-35	5	-21	0	4	1	Max
		B	-44	-5	-34	0	2	-1	Min
		C	-33	8	-14	1	4	2	Max
		C	-44	-10	-38	-1	2	-3	Min
Back columns	Back column 2, bottom (axis 1B)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	-47	19	1	0	0	1	Max
		B	-60	-12	-4	0	-1	-1	Min
		C	-47	87	9	1	1	3	Max
		C	-62	-64	-7	-1	-1	-4	Min
Back columns	Back column 2, top (axis 1B)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	-40	5	6	0	0	1	Max
		B	-51	-5	-3	0	0	-1	Min
		C	-40	12	9	1	1	3	Max
		C	-54	-15	-14	-1	-1	-4	Min
Back columns	Back column 3, bottom (axis 1C)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	-48	22	1	0	0	0	Max
		B	-61	-11	-4	0	0	-1	Min
		C	-29	104	-2	2	0	3	Max
		C	-49	-121	-20	-3	-2	-3	Min
Back columns	Back column 3, top (axis 1C)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	-38	2	5	0	0	0	Max
		B	-49	-2	-1	0	0	-1	Min
		C	-18	13	32	2	0	3	Max
		C	-36	-16	6	-3	-1	-3	Min
Back columns	Back column 4, bottom (axis 1D)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	-56	30	9	0	1	0	Max
		B	-71	-11	2	0	0	-1	Min
		C	-24	191	15	3	1	7	Max
		C	-47	-294	-3	-5	0	-5	Min
Back columns	Back column 4, top (axis 1D)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	-43	1	-9	0	1	0	Max
		B	-55	-1	-16	0	0	-1	Min
		C	-11	6	-3	3	1	7	Max
		C	-31	-7	-23	-5	0	-5	Min

Analysis of construction stages

Back columns	Back column 5, bottom (axis 1E)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	-35	28	-11	0	0	0	Max
		B	-44	-11	-30	0	-2	-1	Min
		C	-21	262	9	4	1	8	Max
		C	-43	-401	-28	-5	-2	-5	Min
Back columns	Back column 5, top (axis 1E)	A2	0	0	0	0	0	0	Max
		A2	0	0	0	0	0	0	Min
		B	-18	1	45	0	0	0	Max
		B	-23	-1	28	0	-1	0	Min
		C	-3	39	34	4	1	8	Max
		C	-22	-26	-1	-5	-1	-5	Min

7.2 Characteristic forces

This chapter includes the following.

Chapter 7.2.1 Stage A1:

Envelopes plotted (only for the critical wind direction from south, 210 degrees)

Chapter 7.2.2 Stage A2 to 7.2.4 Stage C:

Plotted characteristic forces from static and dynamic wind for the various wind directions and for each considered critical sections. Characteristic forces from permanent load are also shown.

Only the absolute values of the force components are shown.

7.2.1 Stage A1

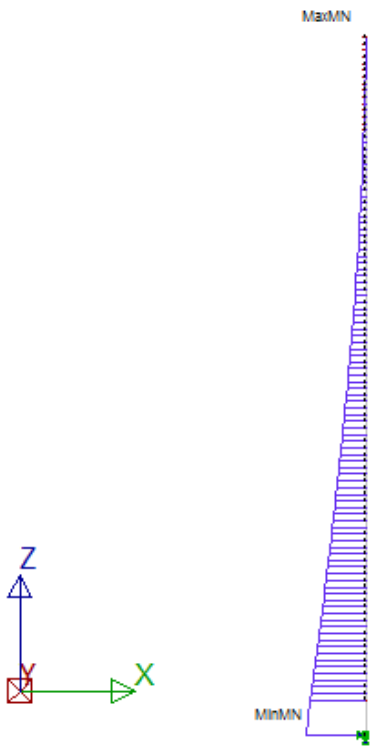
Axial forces from permanent load:

Max./min. sect.for. for all curves

Loadcases are plotted
Envelope curves are plotted

Type	Value [kN/ kNm]
MaxPM	-0.00
MinPM	-44300.33

Moment about transverse axis from static wind load:

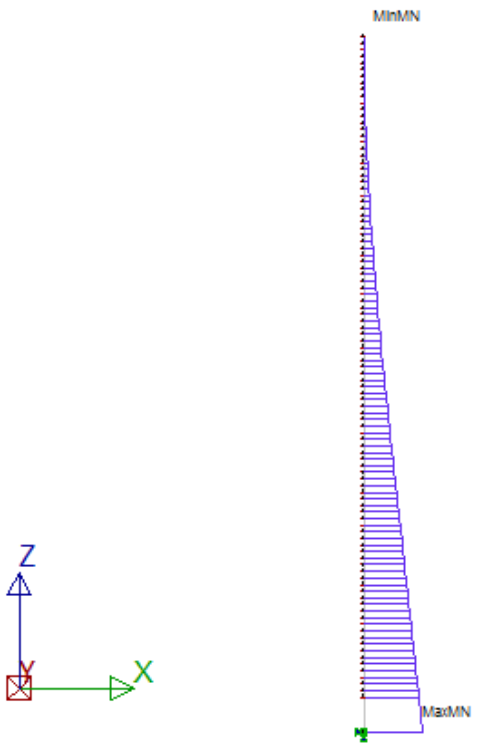


Max./min. sect.for. for all curves

Loadcases are plotted
Envelope curves are plotted

Type	Value [kN/ kNm]
MaxMN	-0.00
MinMN	-21373.51

Moment about transverse axis from dynamic wind load:

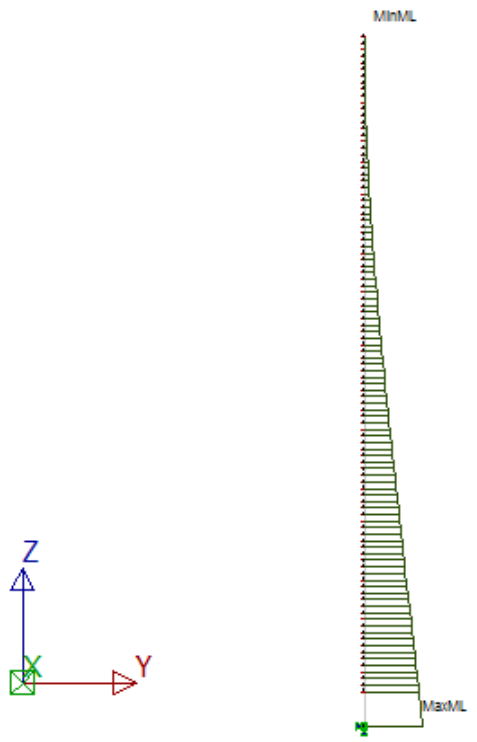


Max./min. sect.for. for all curves

Loadcases are plotted
Envelope curves are plotted

Type	Value [kN/ kNm]
MaxMN	73978.24
MinMN	0.00

Moment about longitudinal axis from dynamic wind load:



Max./min. sect.for. for all curves

Loadcases are plotted
Envelope curves are plotted

Type	Value [kN/ kNm]
MaxML	21858.16
MinML	0.00

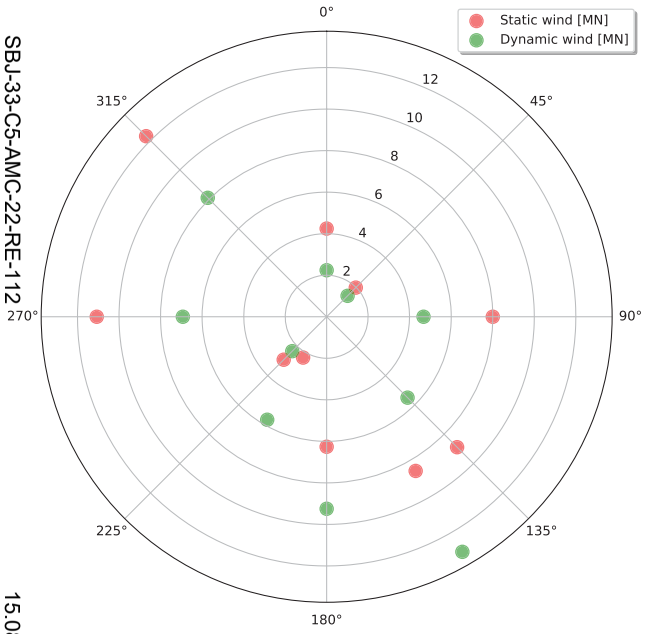
Analysis of construction stages

7.2.2 Stage A2

Analysis of construction stages

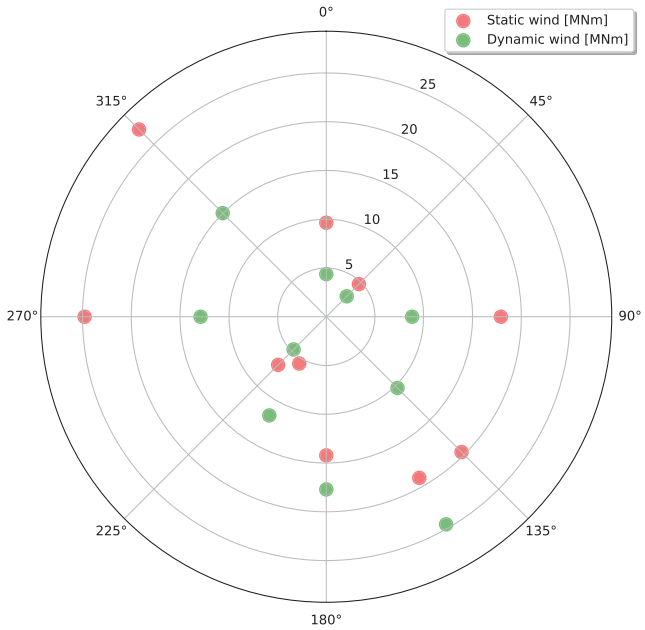
Stage A2 - Foundation, west - Axial force

132.2 [MN] from perm. loads



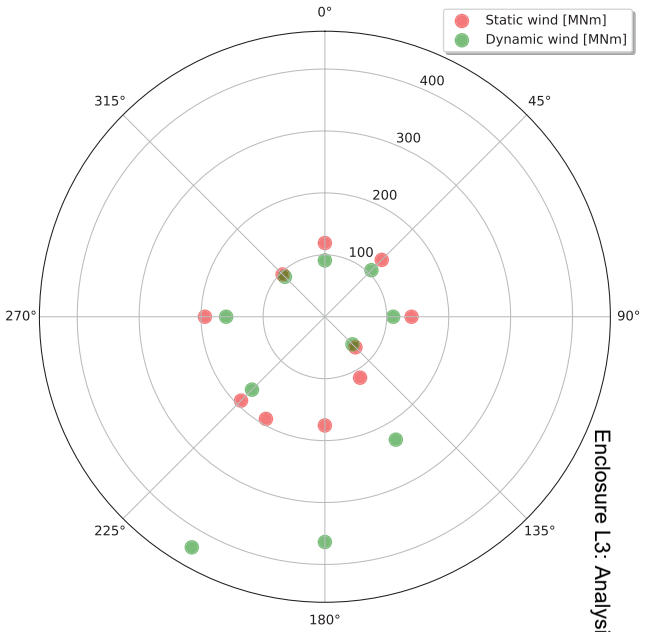
Stage A2 - Foundation, west - Moment about longitudinal axis

0.6 [MNm] from perm. loads



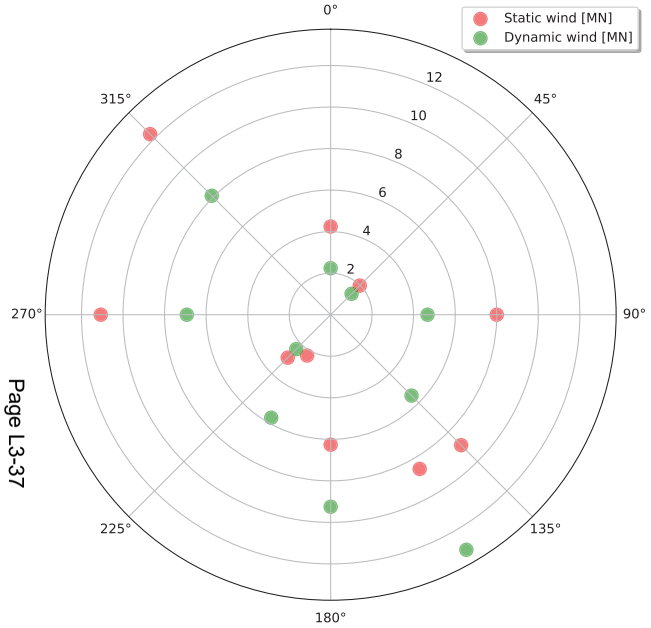
Stage A2 - Foundation, west - Moment about transverse axis

0.0 [MNm] from perm. loads



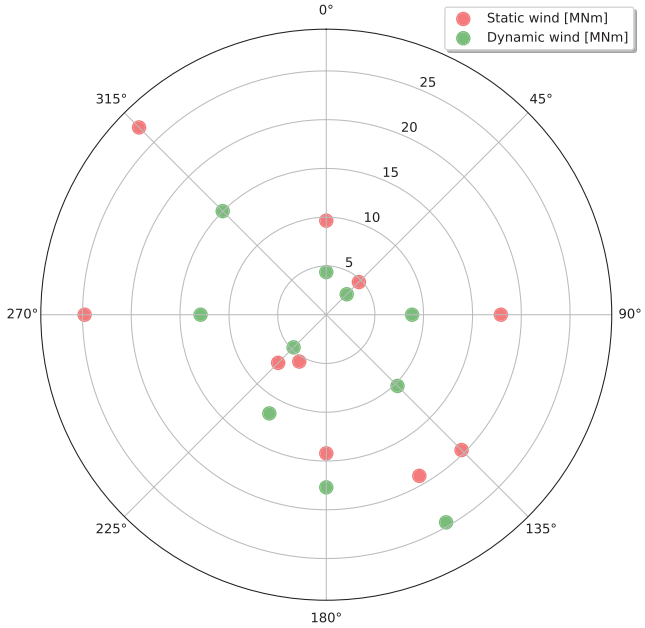
Stage A2 - Foundation, east - Axial force

132.2 [MN] from perm. loads



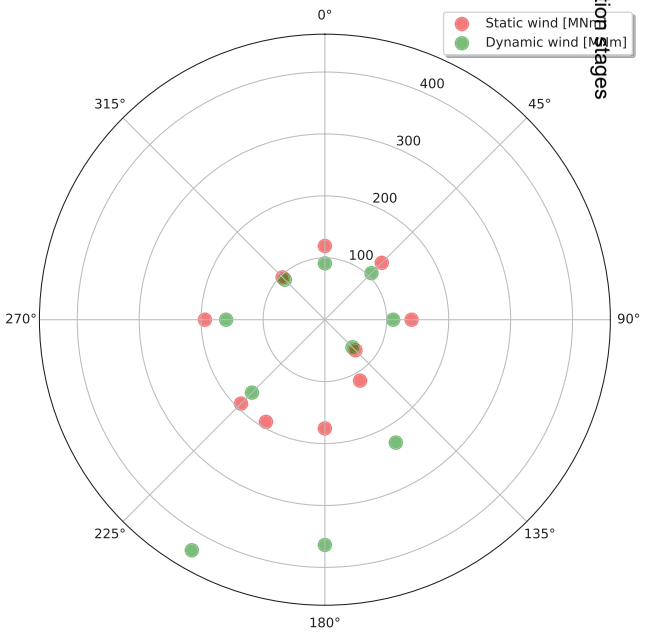
Stage A2 - Foundation, east - Moment about longitudinal axis

0.6 [MNm] from perm. loads



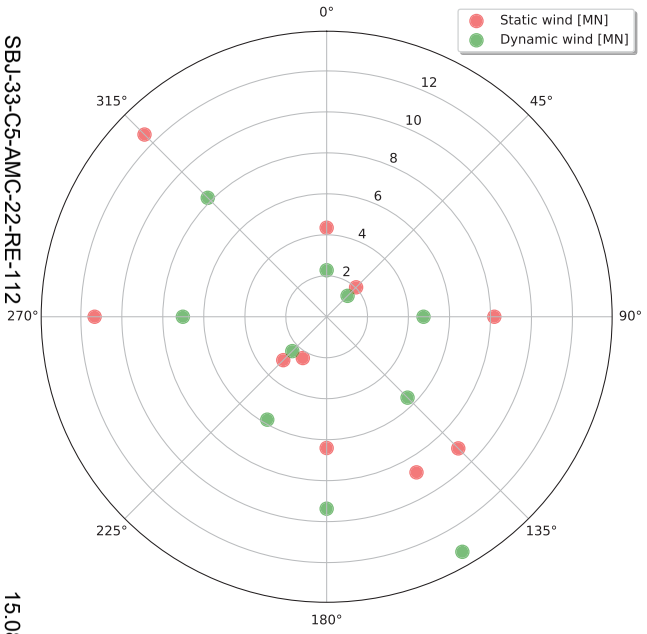
Stage A2 - Foundation, east - Moment about transverse axis

0.0 [MNm] from perm. loads



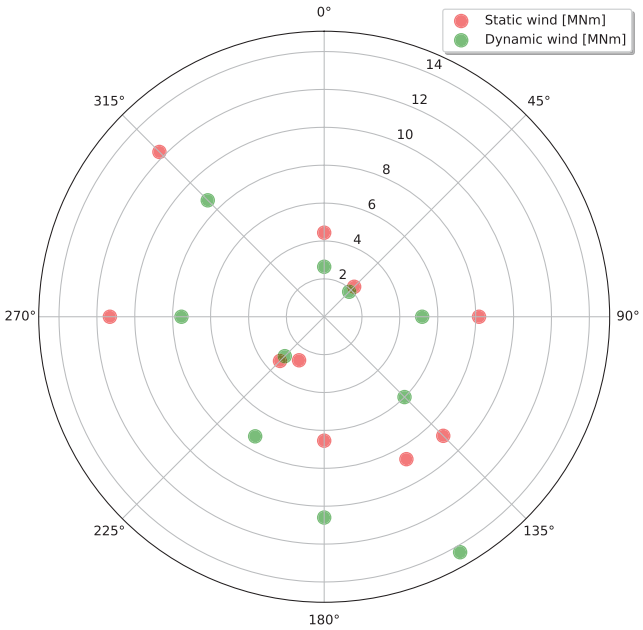
Stage A2 - Tower leg bottom, west - Axial force

103.7 [MN] from perm. loads



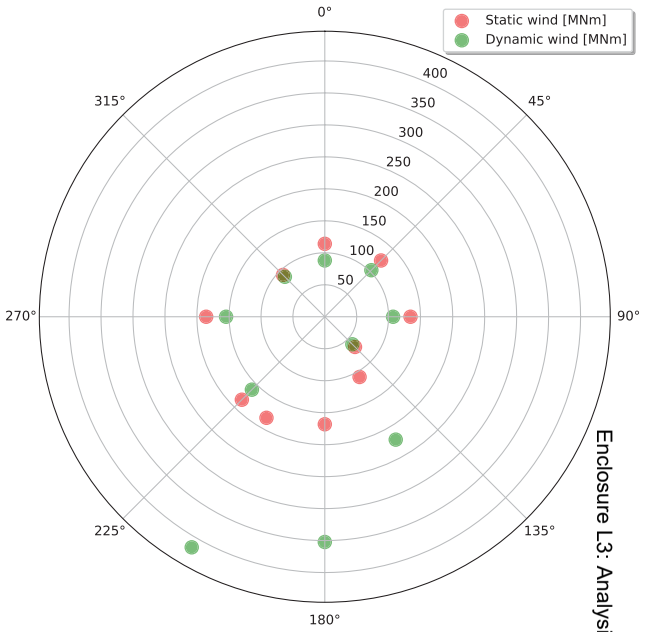
Stage A2 - Tower leg bottom, west - Moment about longitudinal axis

60.5 [MNm] from perm. loads



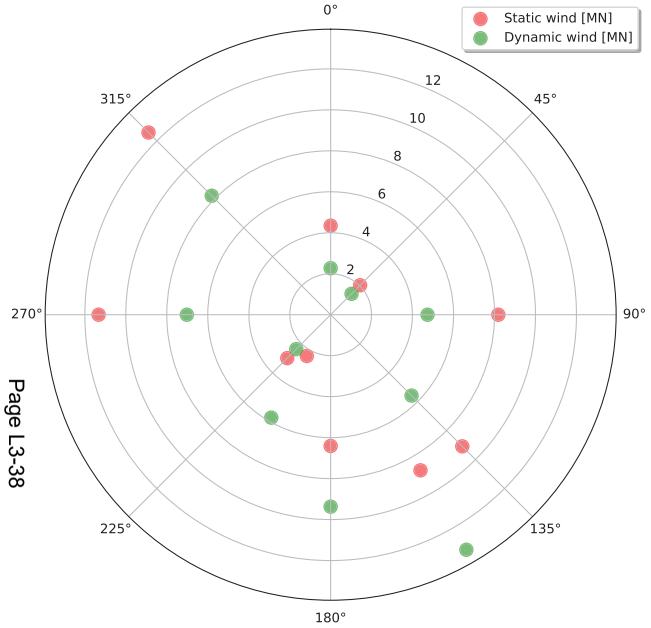
Stage A2 - Tower leg bottom, west - Moment about transverse axis

0.0 [MNm] from perm. loads



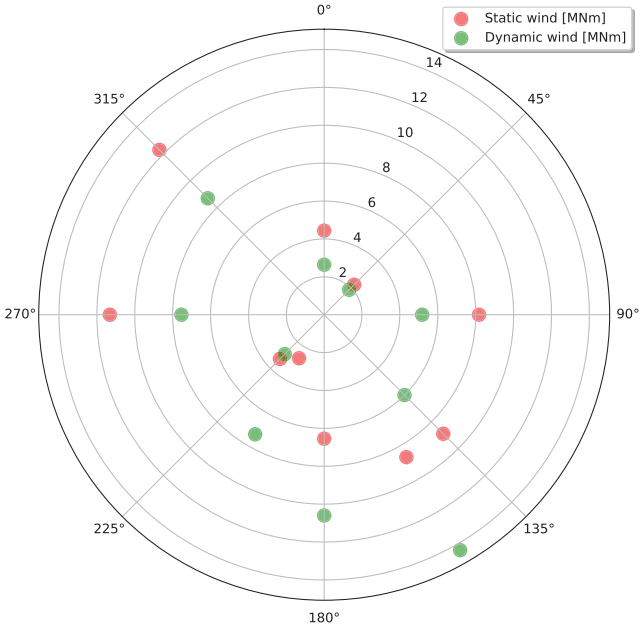
Stage A2 - Tower leg bottom, east - Axial force

103.7 [MN] from perm. loads



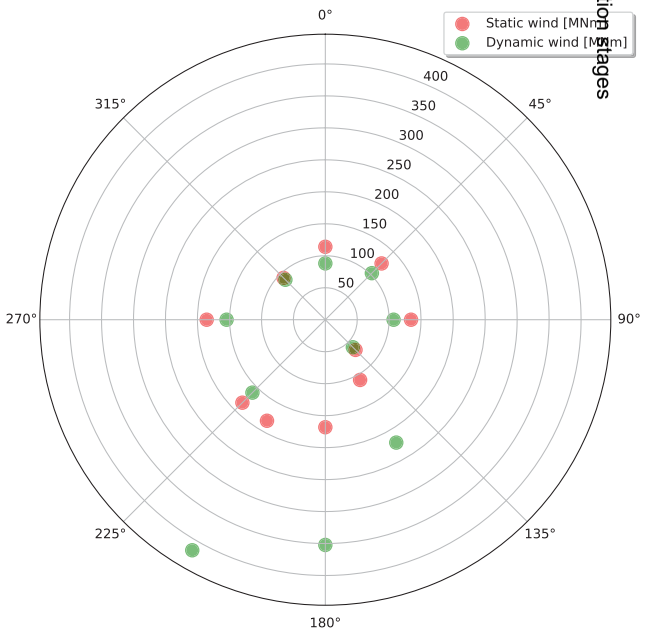
Stage A2 - Tower leg bottom, east - Moment about longitudinal axis

60.5 [MNm] from perm. loads



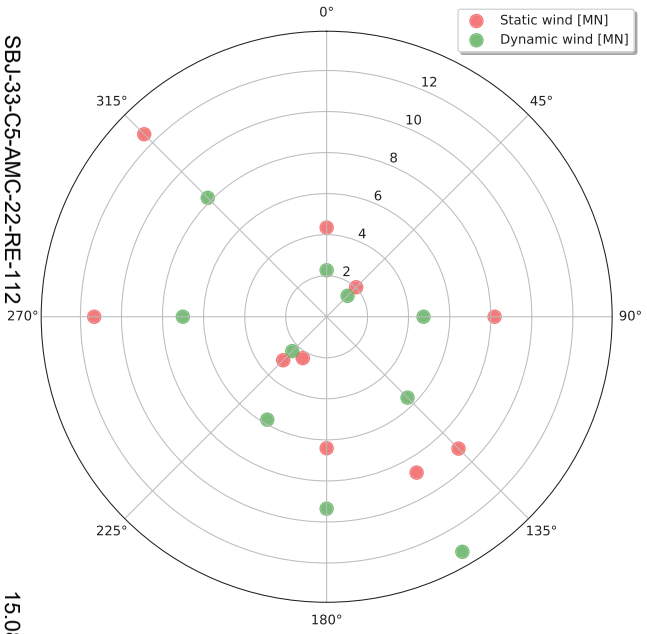
Stage A2 - Tower leg bottom, east - Moment about transverse axis

0.0 [MNm] from perm. loads



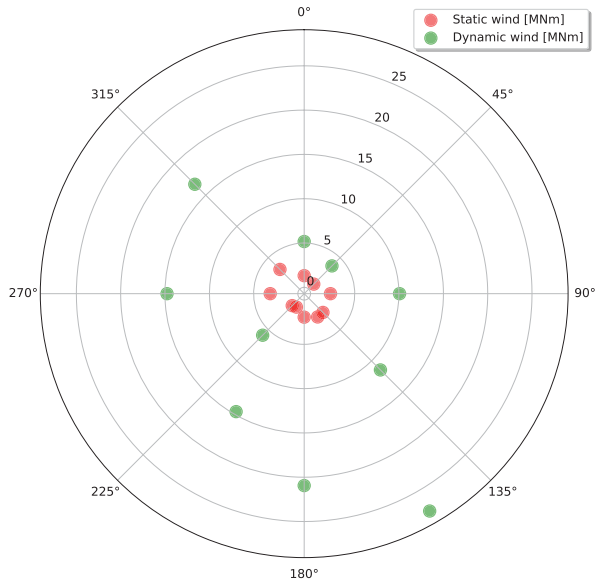
Stage A2 - Tower leg below cross beam, west - Axial force

56.8 [MN] from perm. loads



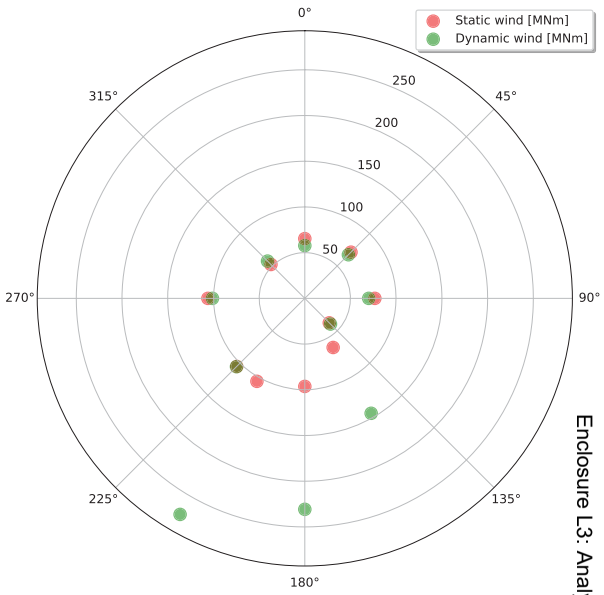
Stage A2 - Tower leg below cross beam, west - Moment about longitudinal axis

71.2 [MNm] from perm. loads



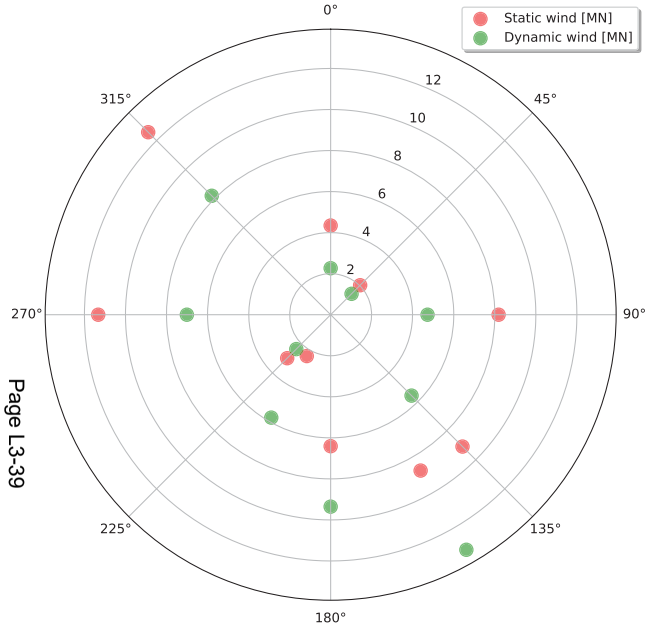
Stage A2 - Tower leg below cross beam, west - Moment about transverse axis

0.0 [MNm] from perm. loads



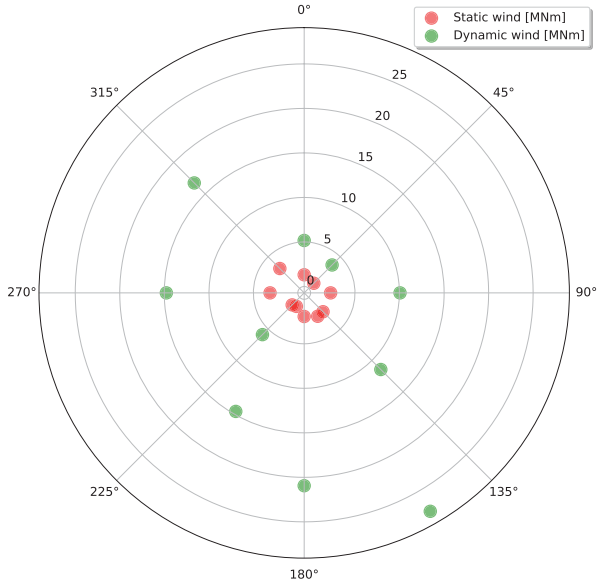
Stage A2 - Tower leg below cross beam, east - Axial force

56.8 [MN] from perm. loads



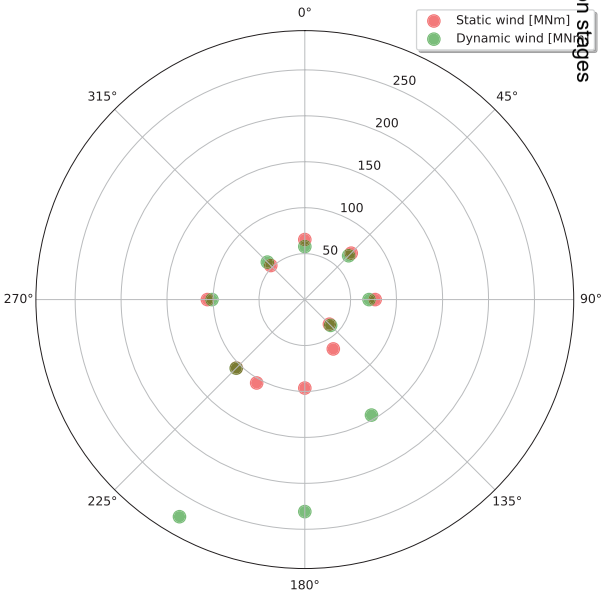
Stage A2 - Tower leg below cross beam, east - Moment about longitudinal axis

71.2 [MNm] from perm. loads



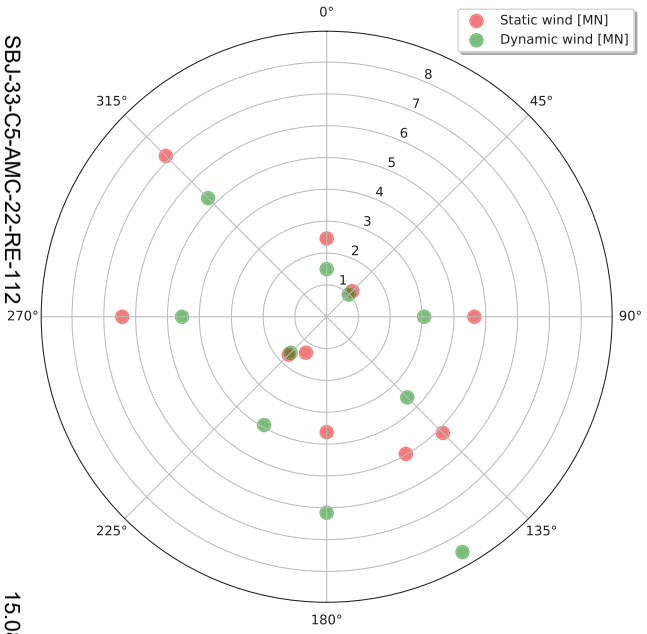
Stage A2 - Tower leg below cross beam, east - Moment about transverse axis

0.0 [MNm] from perm. loads



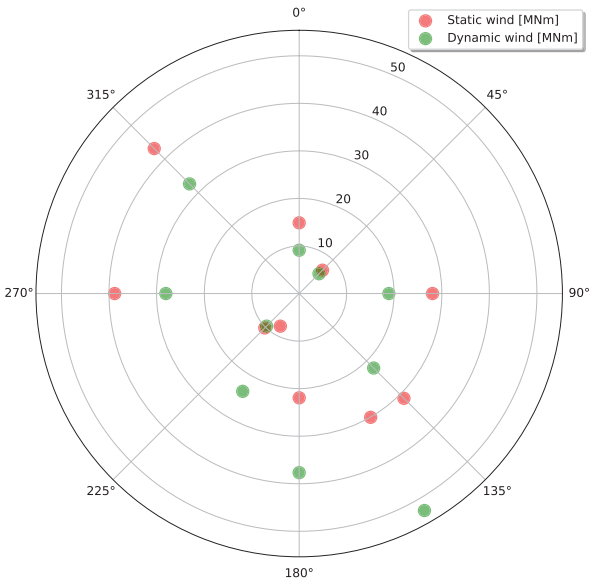
Stage A2 - Tower leg above cross beam, west - Axial force

53.4 [MN] from perm. loads



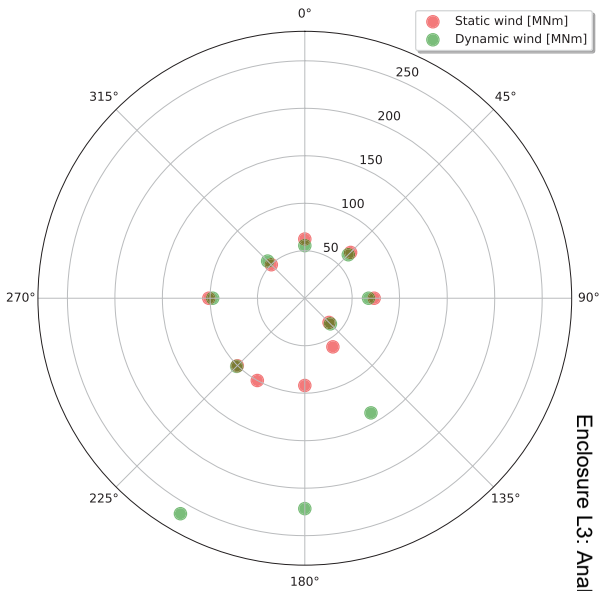
Stage A2 - Tower leg above cross beam, west - Moment about longitudinal axis

68.7 [MNm] from perm. loads



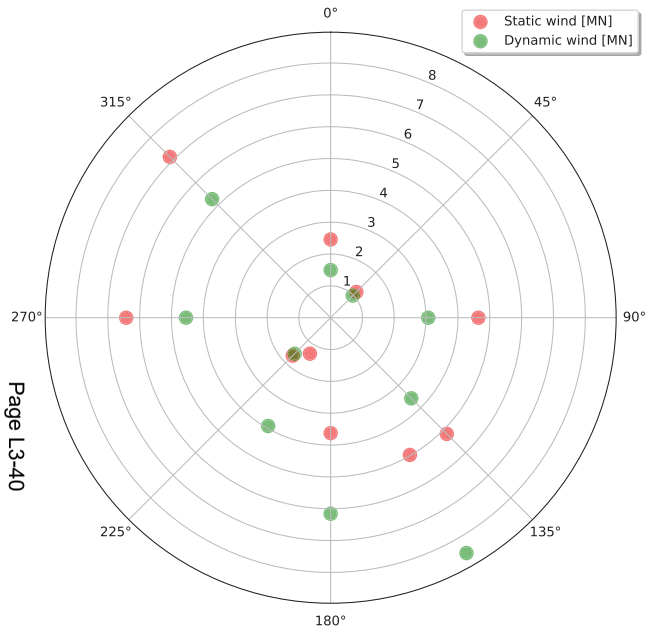
Stage A2 - Tower leg above cross beam, west - Moment about transverse axis

0.0 [MNm] from perm. loads



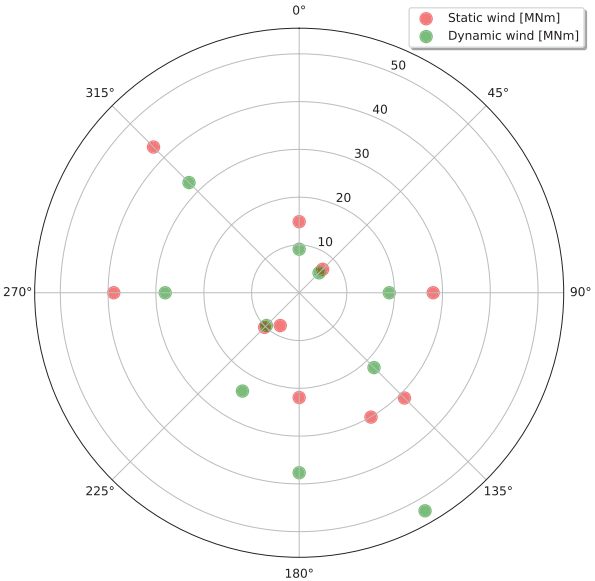
Stage A2 - Tower leg above cross beam, east - Axial force

53.4 [MN] from perm. loads



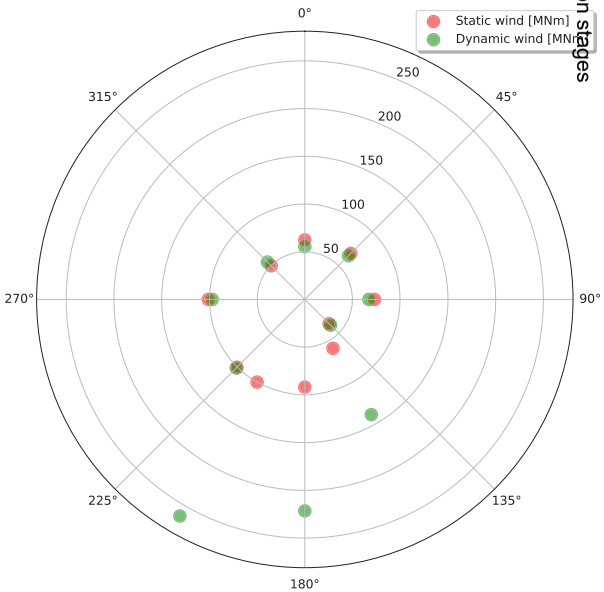
Stage A2 - Tower leg above cross beam, east - Moment about longitudinal axis

68.7 [MNm] from perm. loads



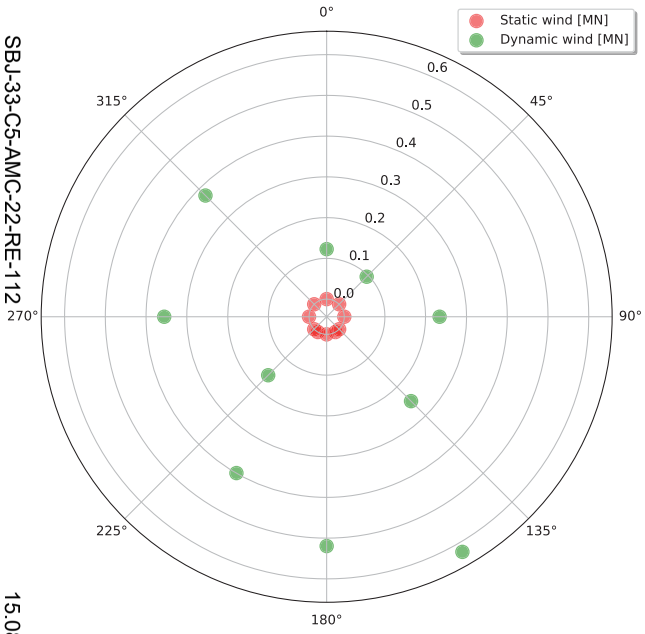
Stage A2 - Tower leg above cross beam, east - Moment about transverse axis

0.0 [MNm] from perm. loads



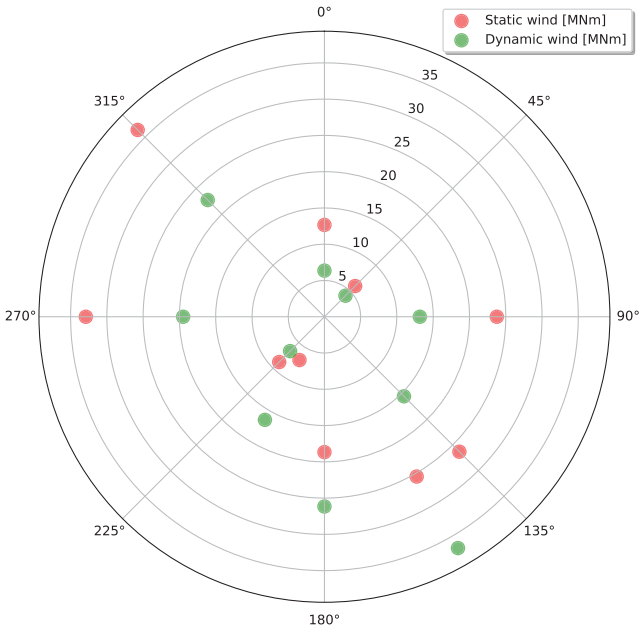
Stage A2 - Cross beam, end west - Axial force

8.3 [MN] from perm. loads



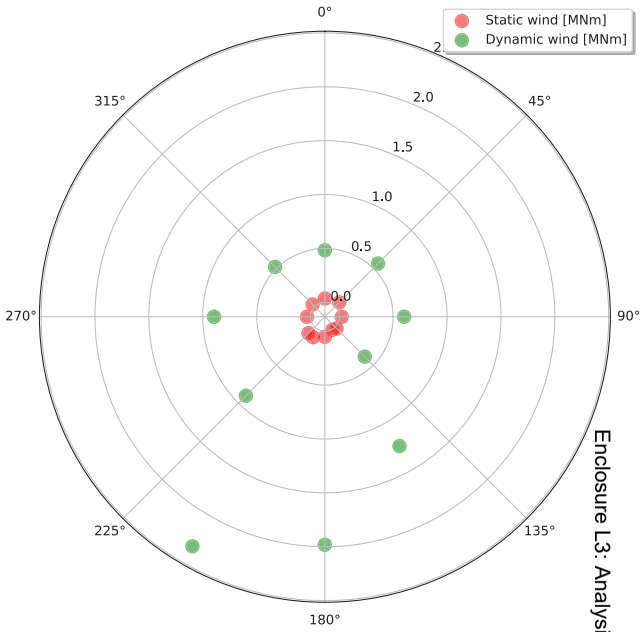
Stage A2 - Cross beam, end west - Moment about longitudinal axis

28.1 [MNm] from perm. loads



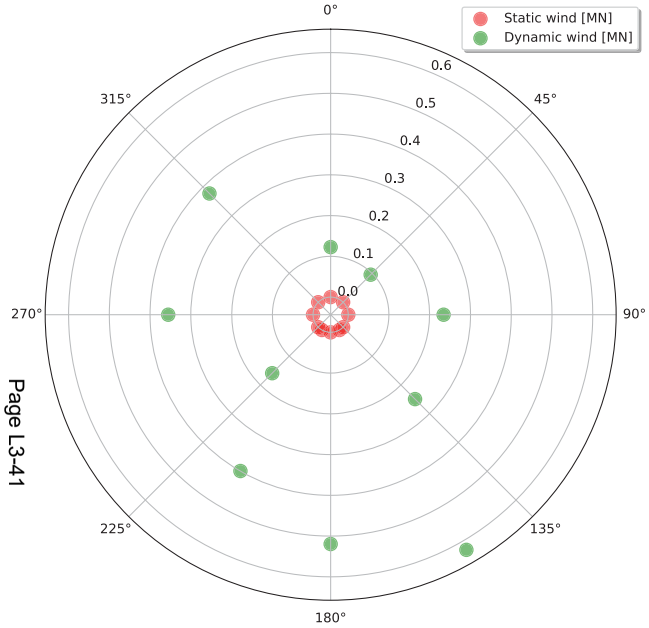
Stage A2 - Cross beam, end west - Moment about vertical axis

0.0 [MNm] from perm. loads



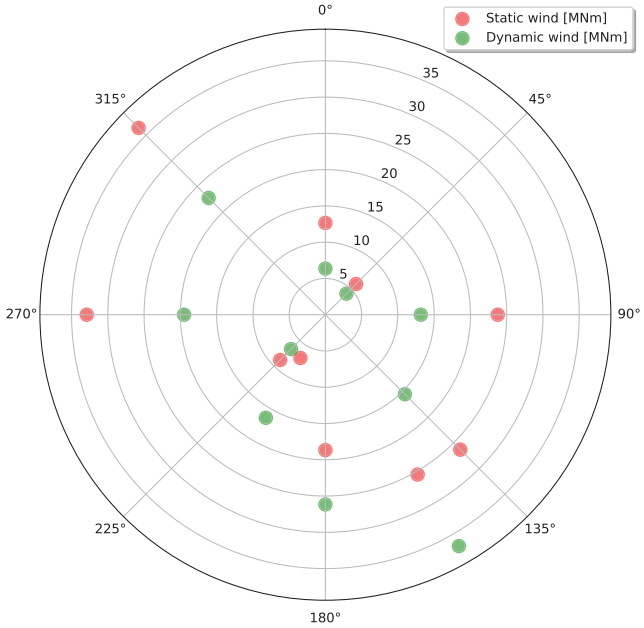
Stage A2 - Cross beam, end east - Axial force

8.3 [MN] from perm. loads



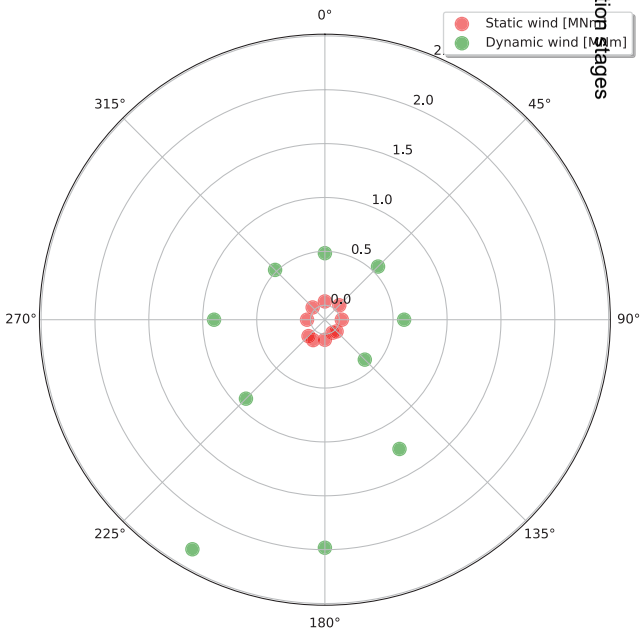
Stage A2 - Cross beam, end east - Moment about longitudinal axis

28.1 [MNm] from perm. loads



Stage A2 - Cross beam, end east - Moment about vertical axis

0.0 [MNm] from perm. loads



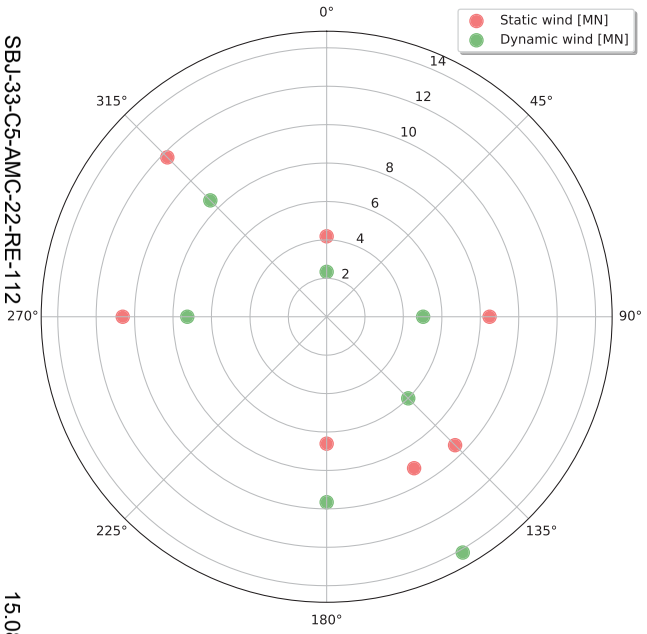
Analysis of construction stages

7.2.3 Stage B

Analysis of construction stages

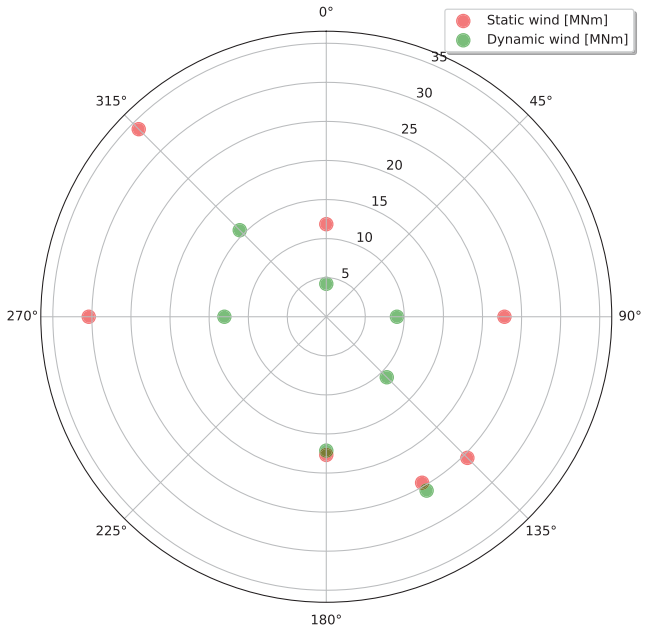
Stage B - Foundation, west - Axial force

151.5 [MN] from perm. loads



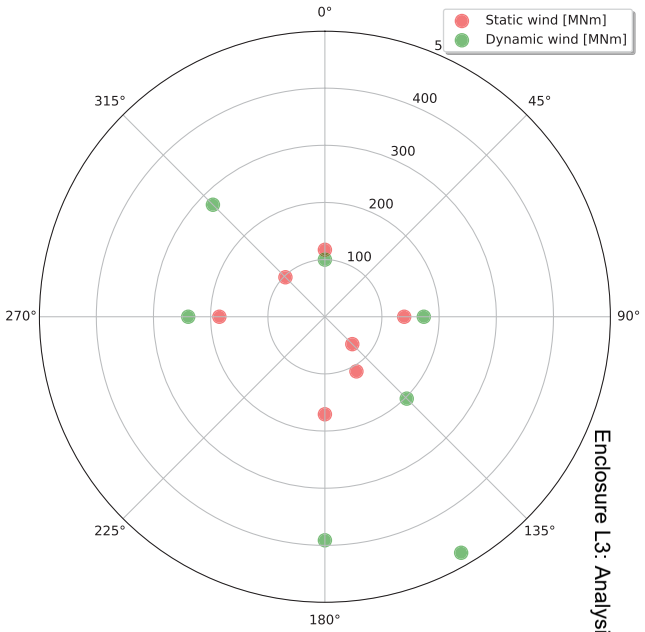
Stage B - Foundation, west - Moment about longitudinal axis

4.8 [MNm] from perm. loads



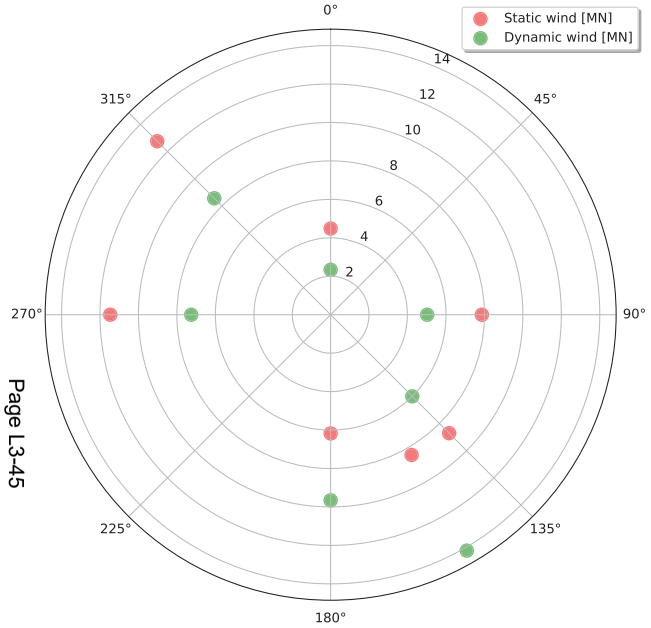
Stage B - Foundation, west - Moment about transverse axis

30.9 [MNm] from perm. loads



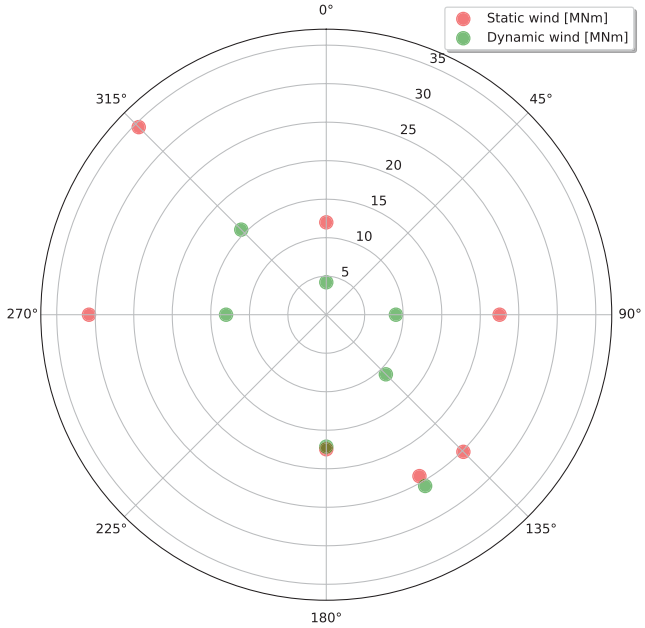
Stage B - Foundation, east - Axial force

151.5 [MN] from perm. loads



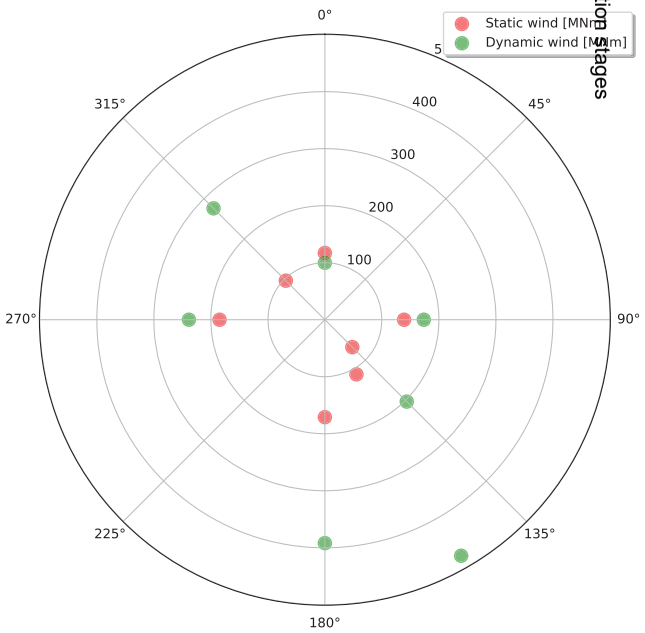
Stage B - Foundation, east - Moment about longitudinal axis

4.8 [MNm] from perm. loads



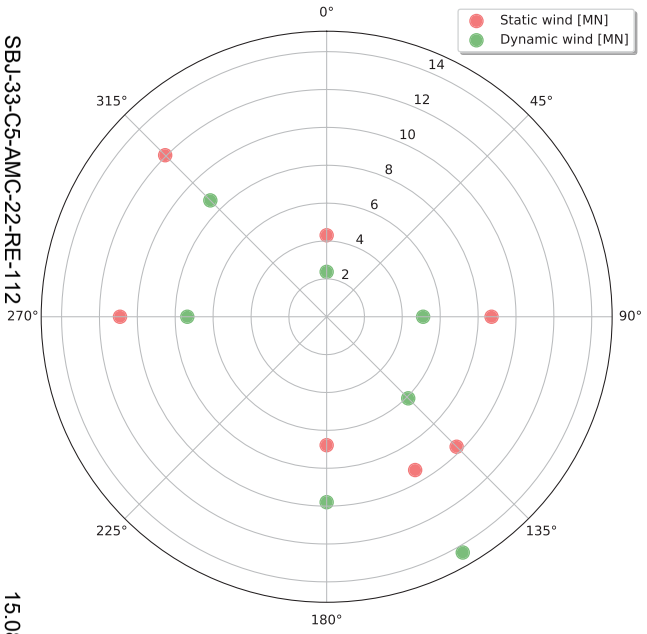
Stage B - Foundation, east - Moment about transverse axis

30.9 [MNm] from perm. loads



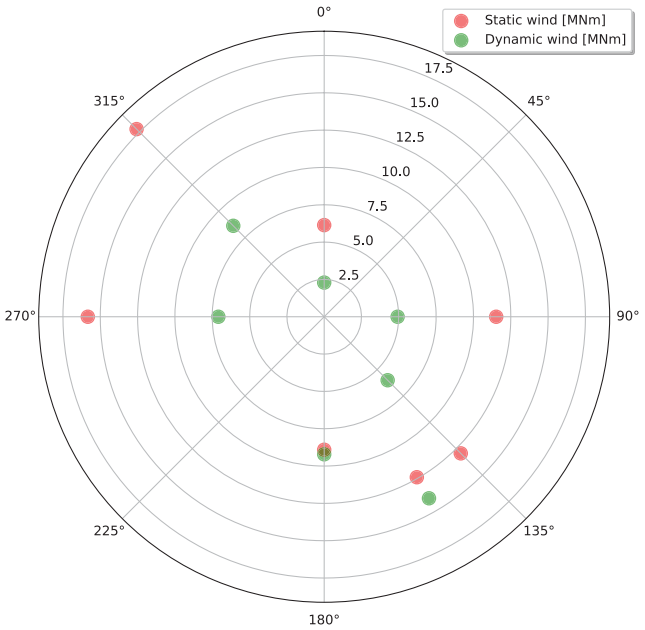
Stage B - Tower leg bottom, west - Axial force

123.1 [MN] from perm. loads



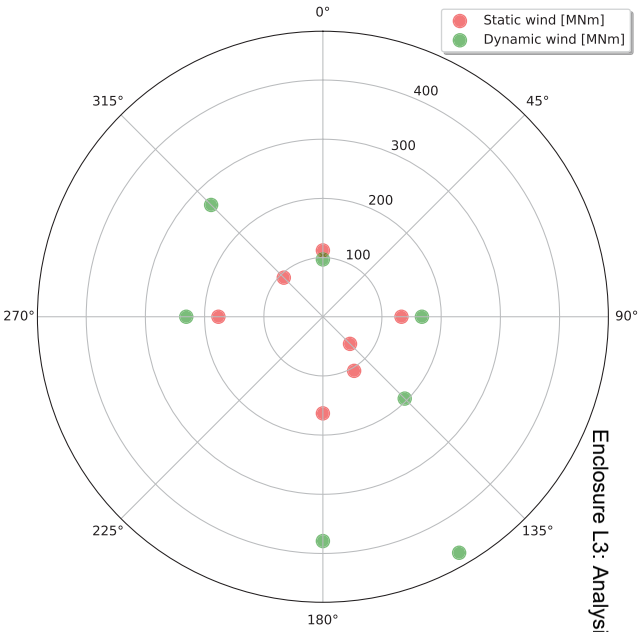
Stage B - Tower leg bottom, west - Moment about longitudinal axis

70.5 [MNm] from perm. loads



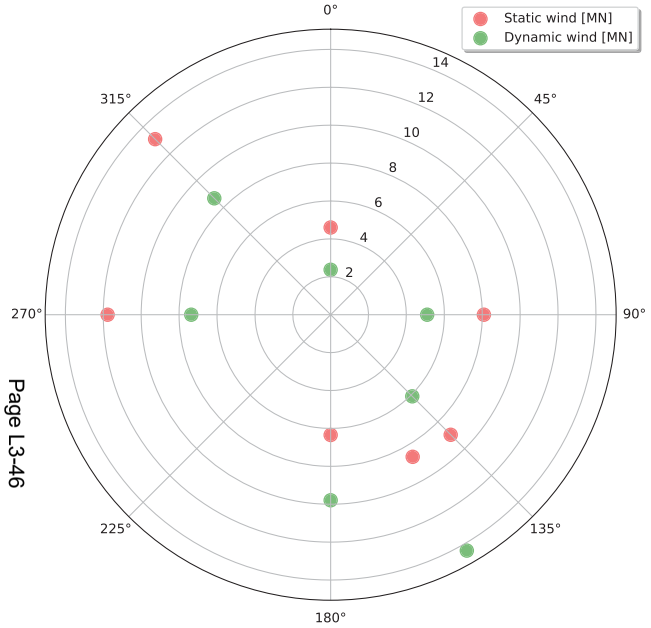
Stage B - Tower leg bottom, west - Moment about transverse axis

30.9 [MNm] from perm. loads



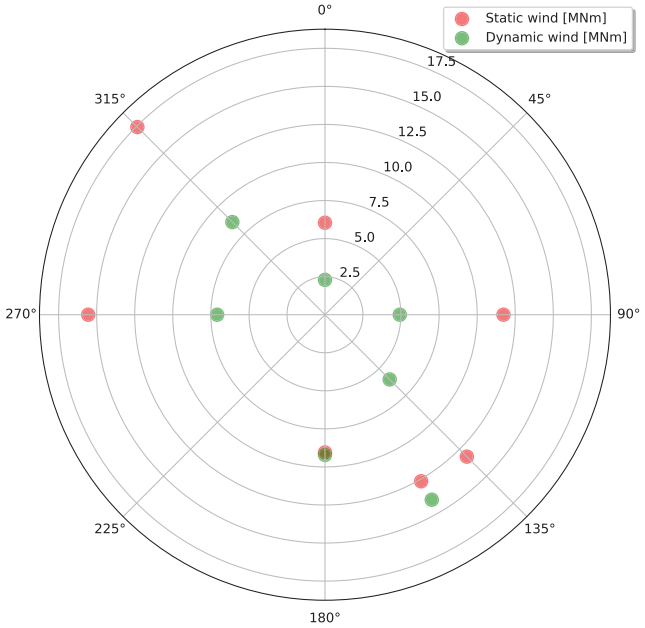
Stage B - Tower leg bottom, east - Axial force

123.1 [MN] from perm. loads



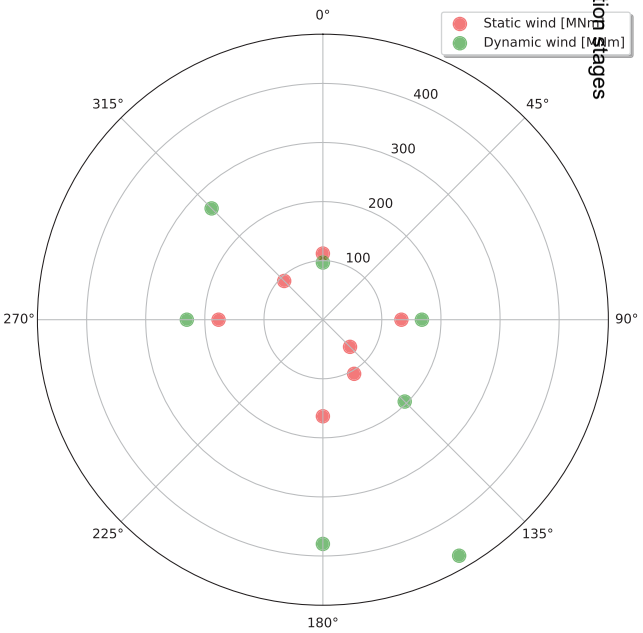
Stage B - Tower leg bottom, east - Moment about longitudinal axis

70.5 [MNm] from perm. loads



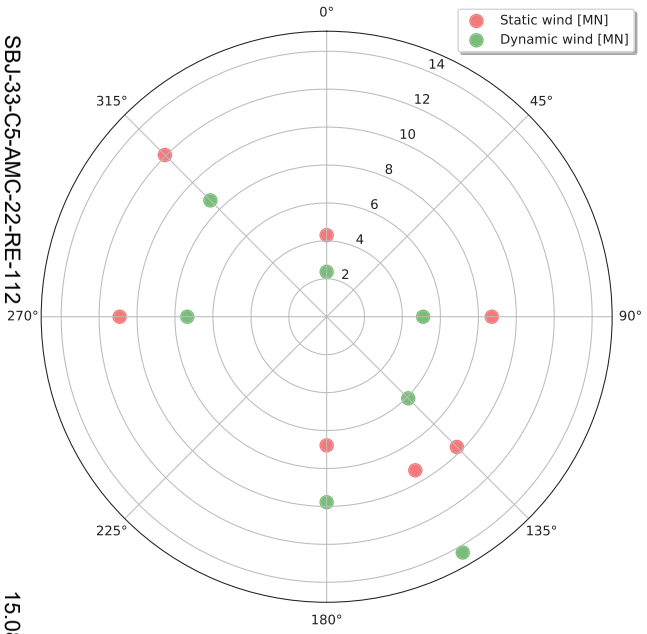
Stage B - Tower leg bottom, east - Moment about transverse axis

30.9 [MNm] from perm. loads



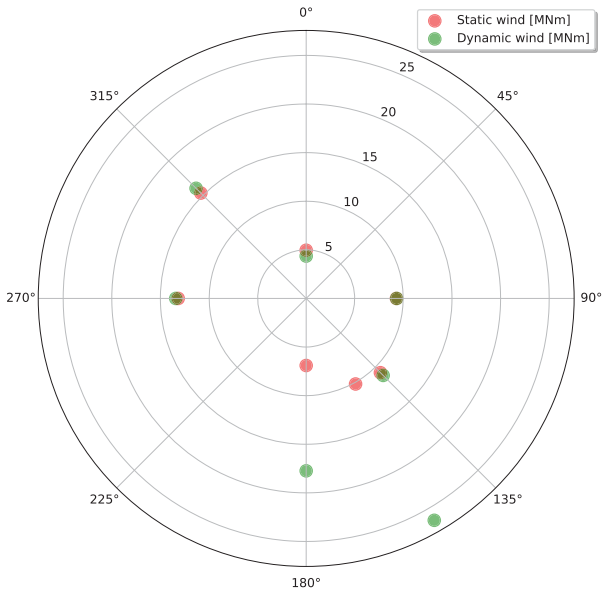
Stage B - Tower leg below cross beam, west - Axial force

76.3 [MN] from perm. loads



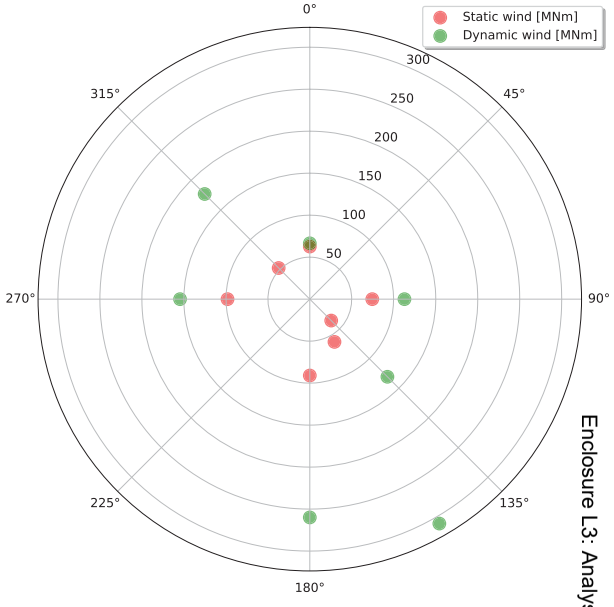
Stage B - Tower leg below cross beam, west - Moment about longitudinal axis

102.5 [MNm] from perm. loads



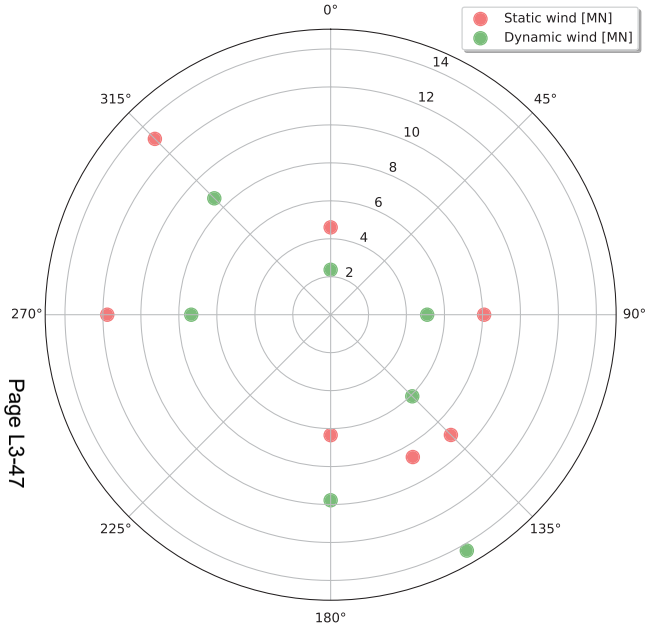
Stage B - Tower leg below cross beam, west - Moment about transverse axis

30.9 [MNm] from perm. loads



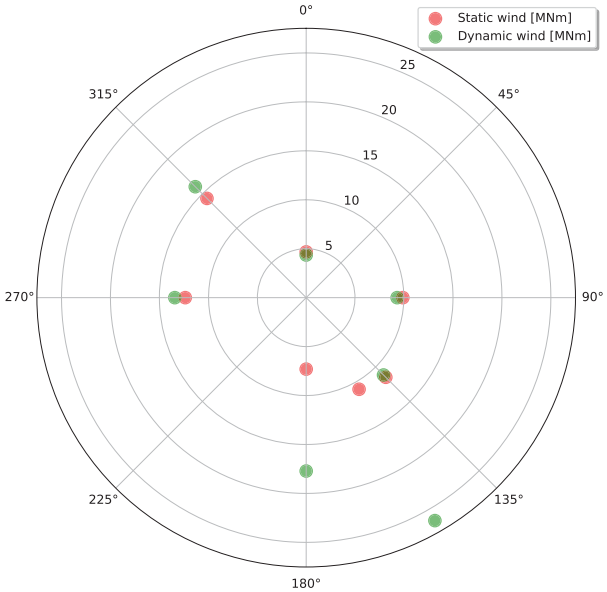
Stage B - Tower leg below cross beam, east - Axial force

76.3 [MN] from perm. loads



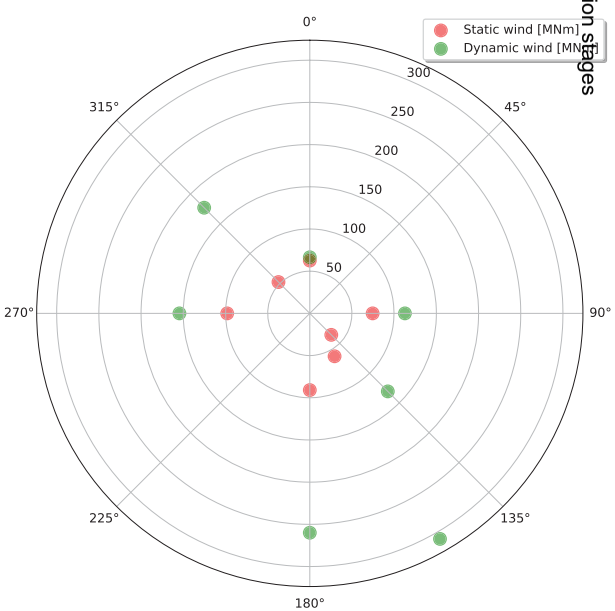
Stage B - Tower leg below cross beam, east - Moment about longitudinal axis

102.5 [MNm] from perm. loads



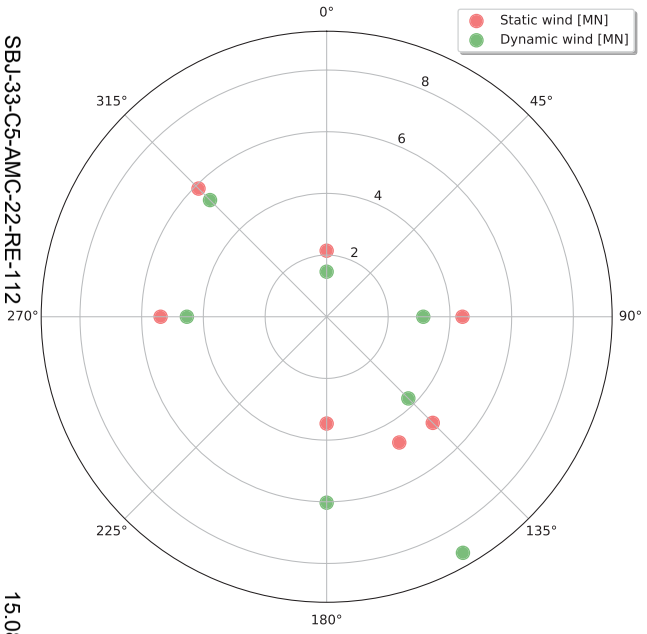
Stage B - Tower leg below cross beam, east - Moment about transverse axis

30.9 [MNm] from perm. loads



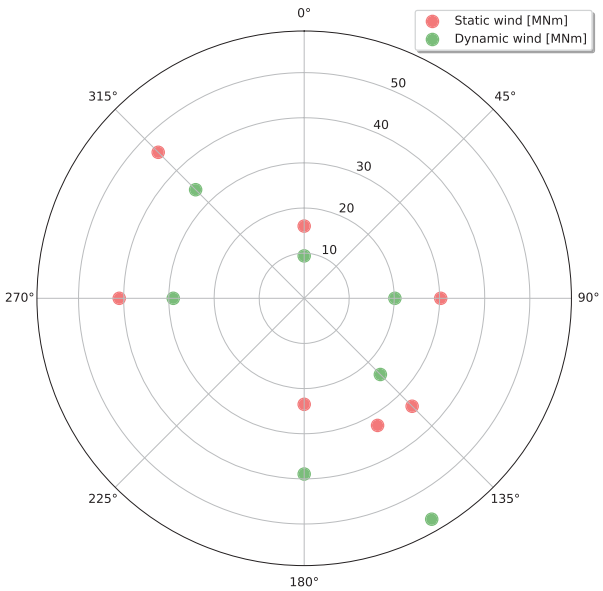
Stage B - Tower leg above cross beam, west - Axial force

69.9 [MN] from perm. loads



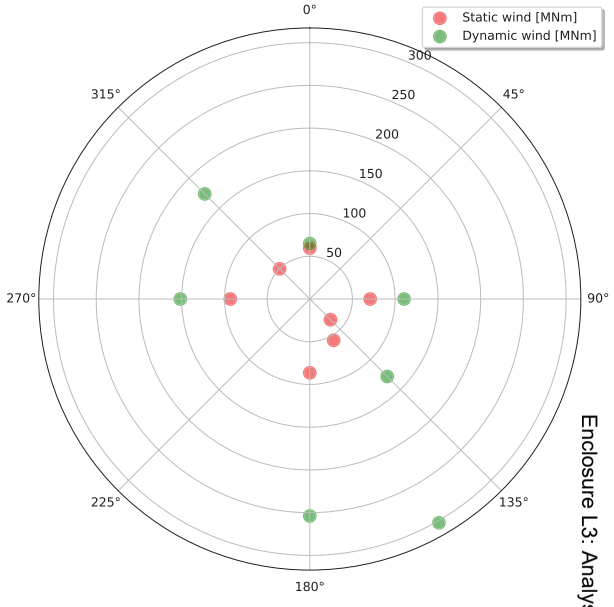
Stage B - Tower leg above cross beam, west - Moment about longitudinal axis

76.1 [MNm] from perm. loads



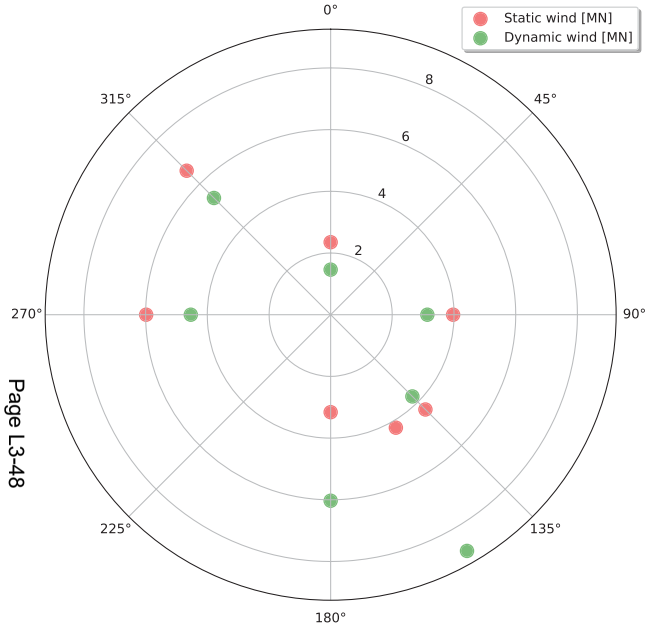
Stage B - Tower leg above cross beam, west - Moment about transverse axis

32.1 [MNm] from perm. loads



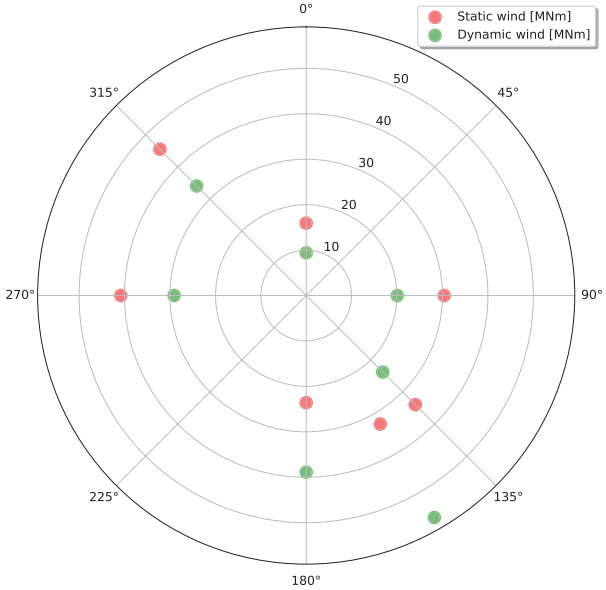
Stage B - Tower leg above cross beam, east - Axial force

69.9 [MN] from perm. loads



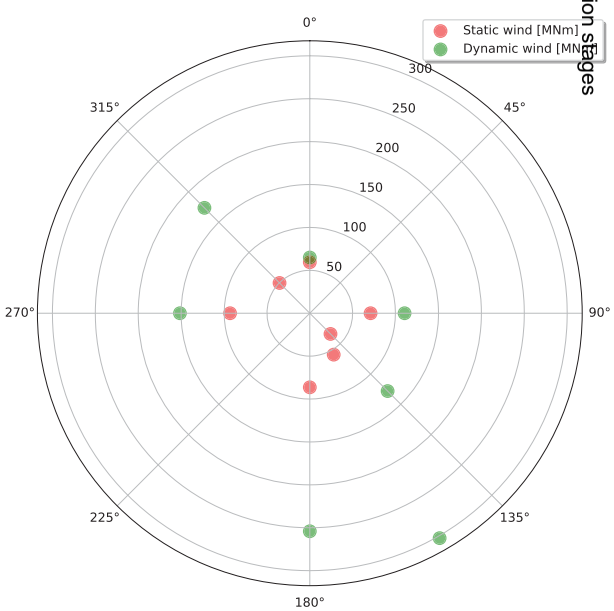
Stage B - Tower leg above cross beam, east - Moment about longitudinal axis

76.1 [MNm] from perm. loads



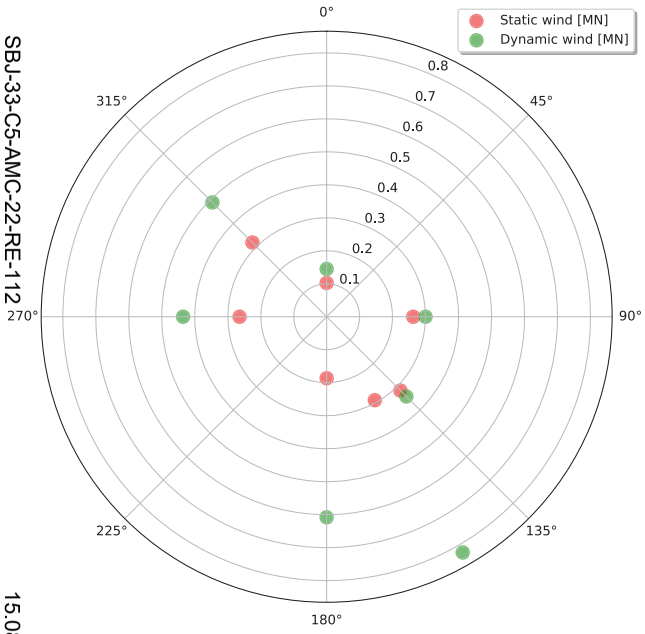
Stage B - Tower leg above cross beam, east - Moment about transverse axis

32.1 [MNm] from perm. loads



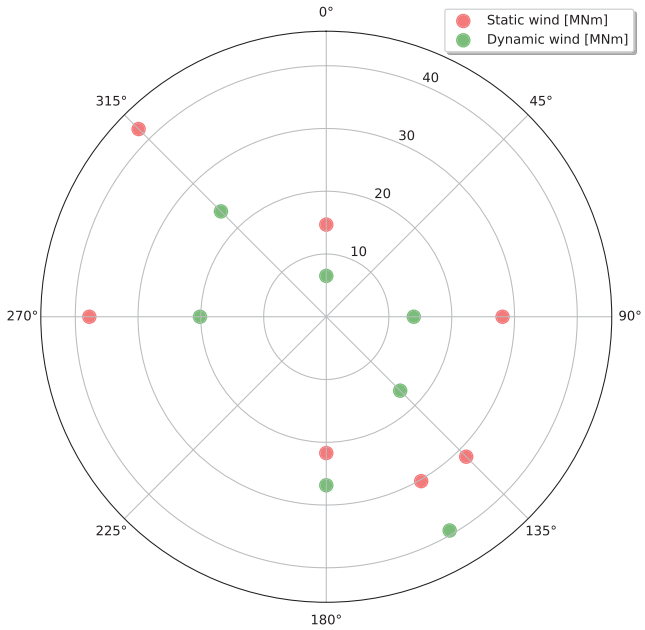
Stage B - Cross beam, end west - Axial force

9.3 [MN] from perm. loads



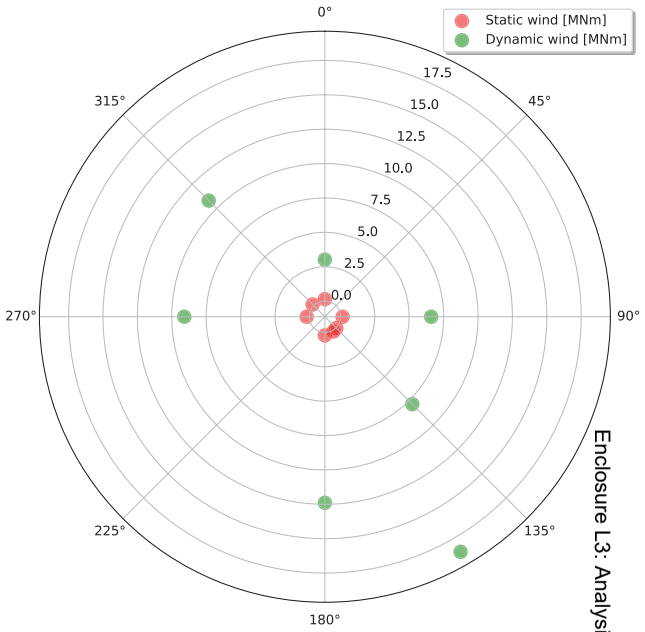
Stage B - Cross beam, end west - Moment about longitudinal axis

34.2 [MNm] from perm. loads



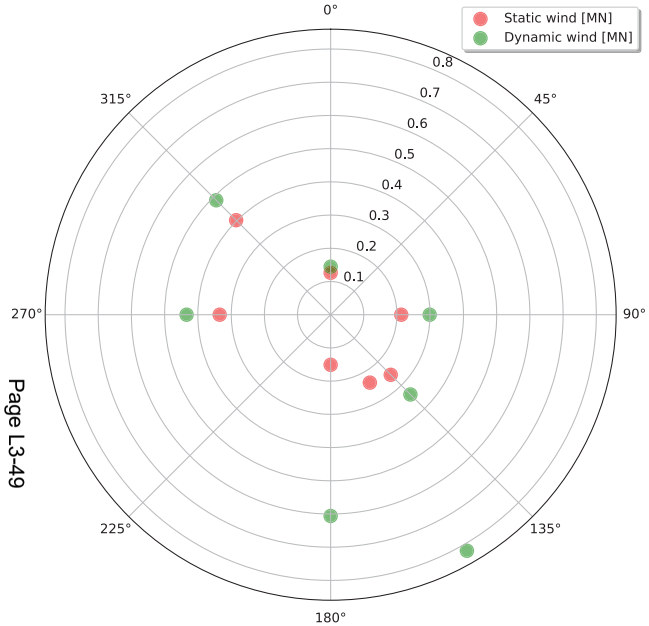
Stage B - Cross beam, end west - Moment about vertical axis

1.4 [MNm] from perm. loads



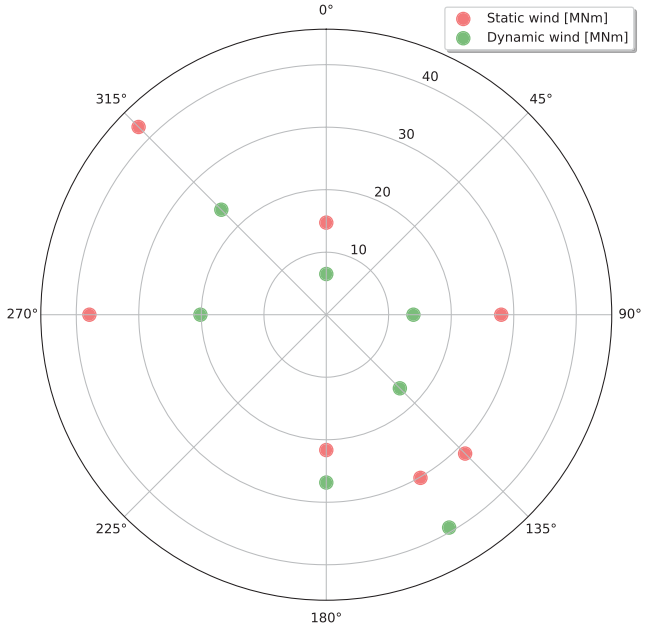
Stage B - Cross beam, end east - Axial force

9.3 [MN] from perm. loads



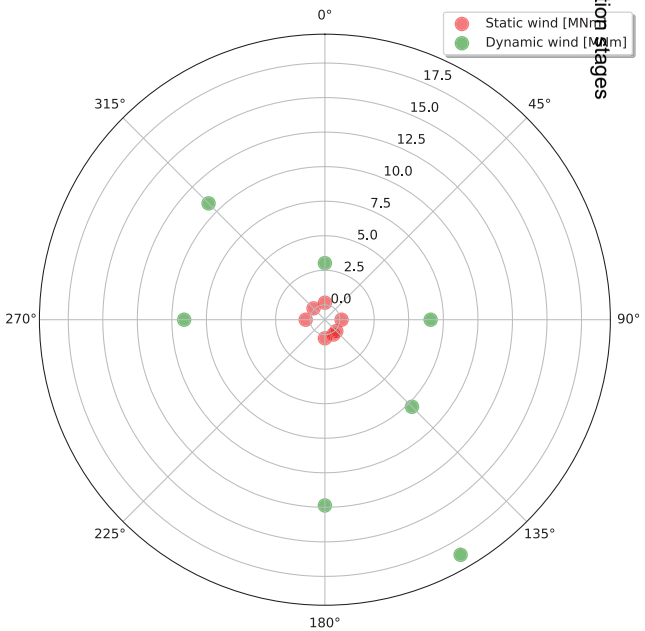
Stage B - Cross beam, end east - Moment about longitudinal axis

34.2 [MNm] from perm. loads



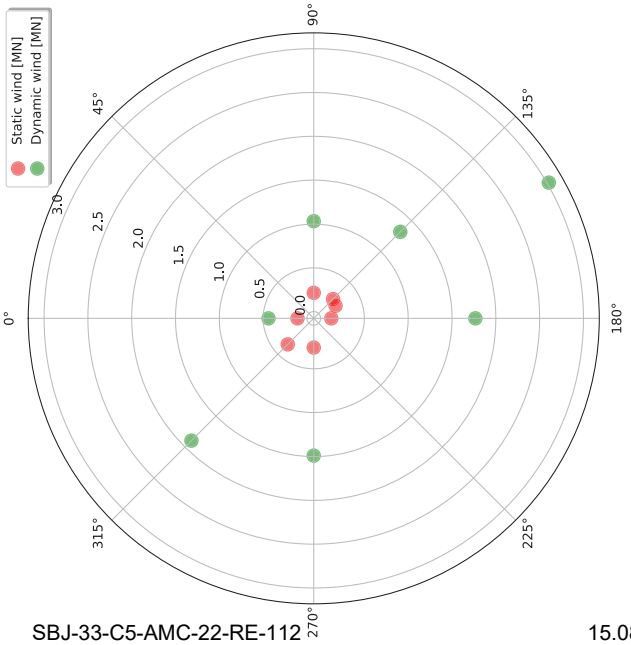
Stage B - Cross beam, end east - Moment about vertical axis

1.4 [MNm] from perm. loads



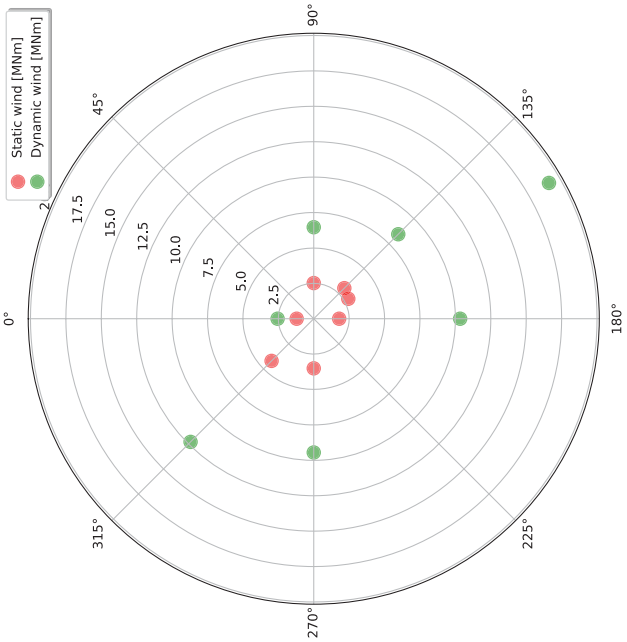
Stage B - Bridge girder axis 2 - Axial force

14.3 [MN] from perm. loads



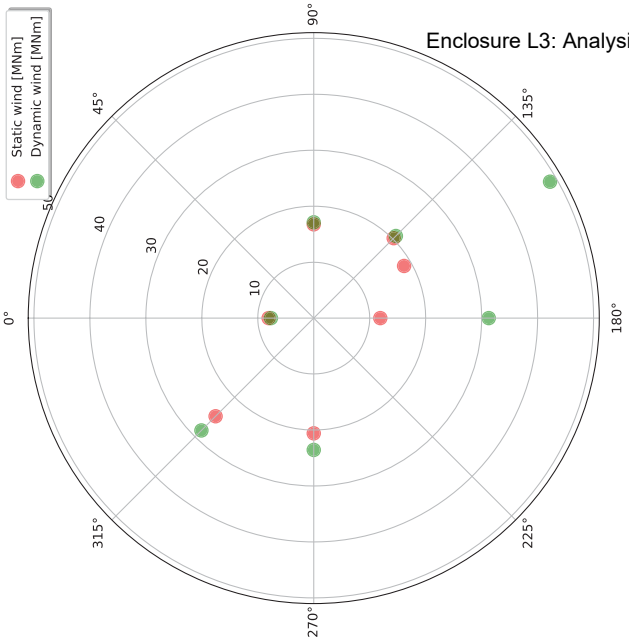
Stage B - Bridge girder axis 2 - Moment about weak axis

35.4 [MNm] from perm. loads



Stage B - Bridge girder axis 2 - Moment about strong axis

0.0 [MNm] from perm. loads

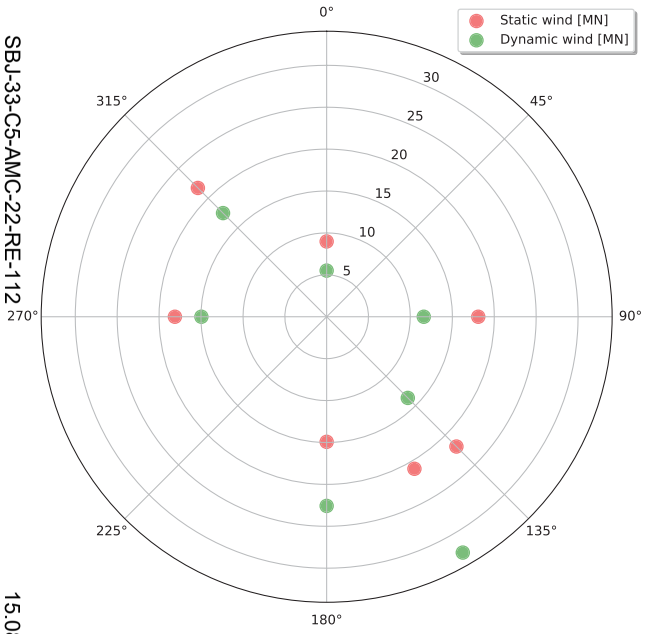


7.2.4 Stage C

Analysis of construction stages

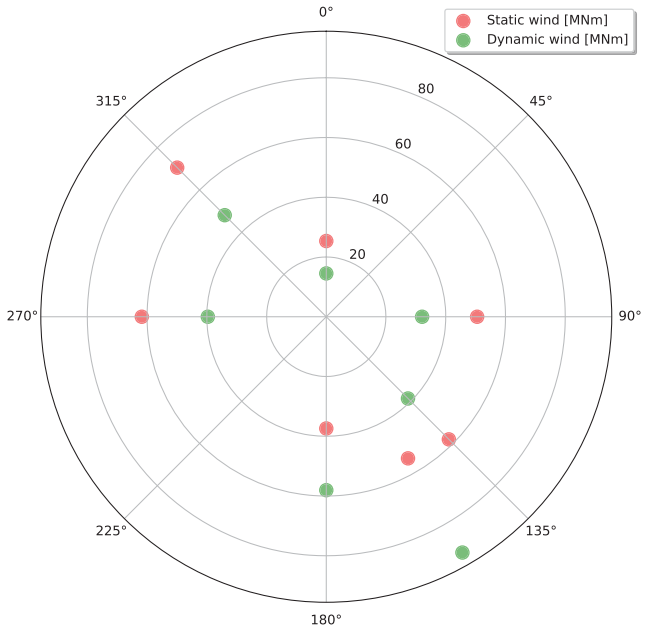
Stage C - Foundation, west - Axial force

196.6 [MN] from perm. loads



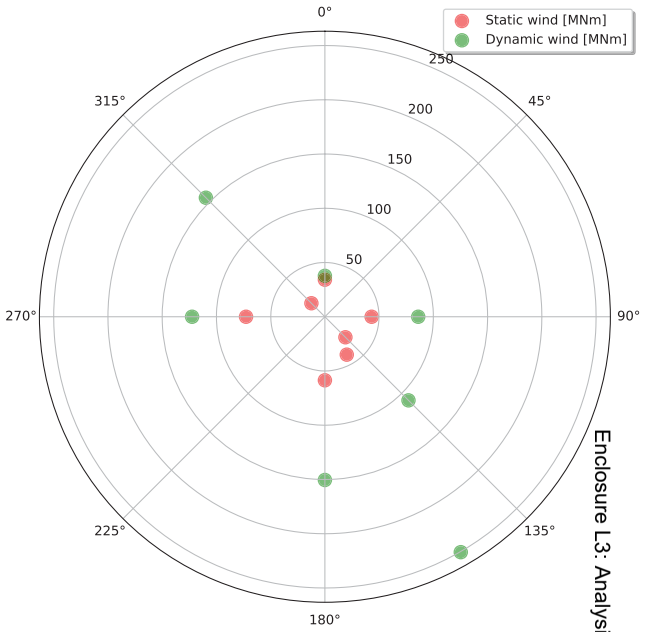
Stage C - Foundation, west - Moment about longitudinal axis

9.2 [MNm] from perm. loads



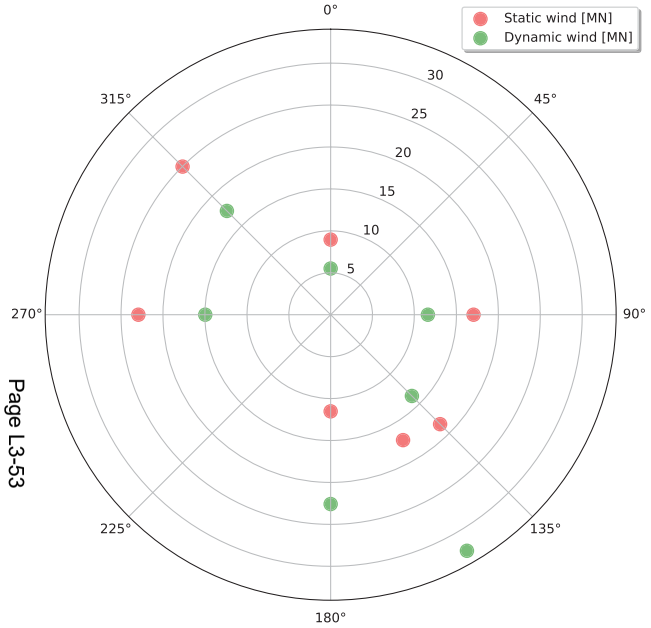
Stage C - Foundation, west - Moment about transverse axis

36.0 [MNm] from perm. loads



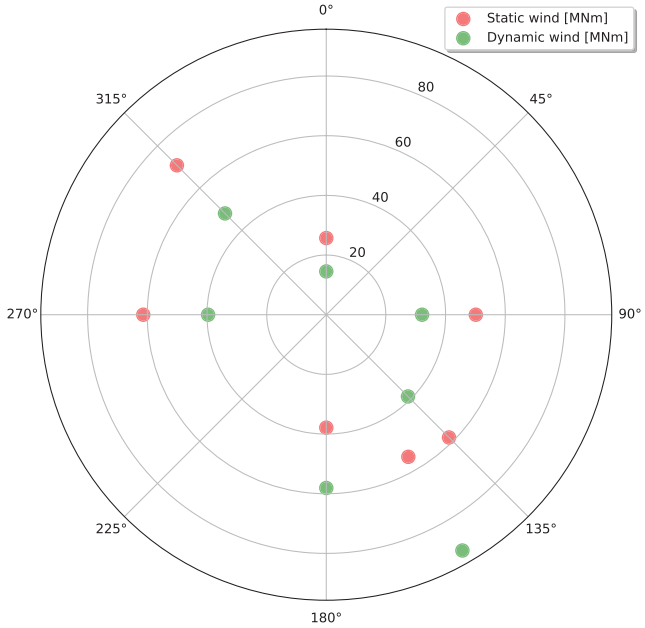
Stage C - Foundation, east - Axial force

196.6 [MN] from perm. loads



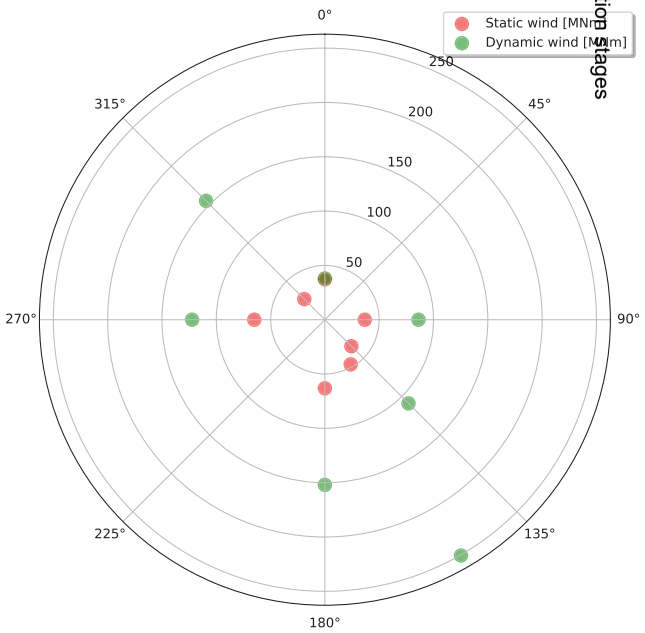
Stage C - Foundation, east - Moment about longitudinal axis

9.1 [MNm] from perm. loads



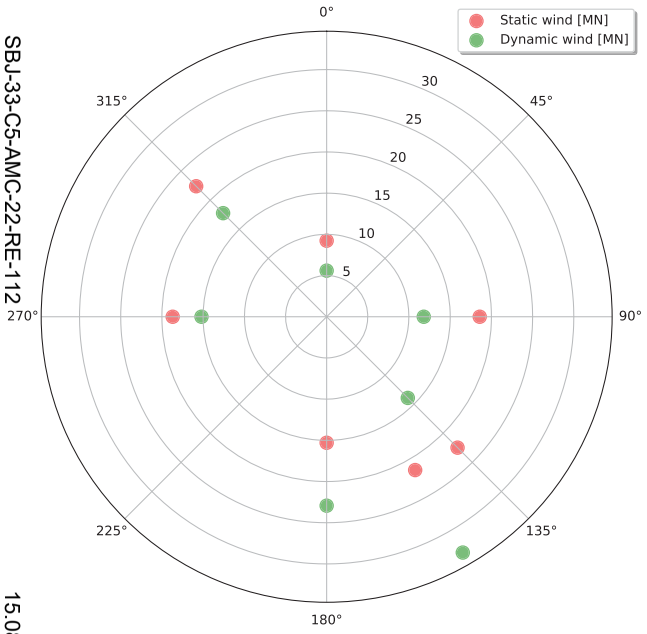
Stage C - Foundation, east - Moment about transverse axis

36.0 [MNm] from perm. loads



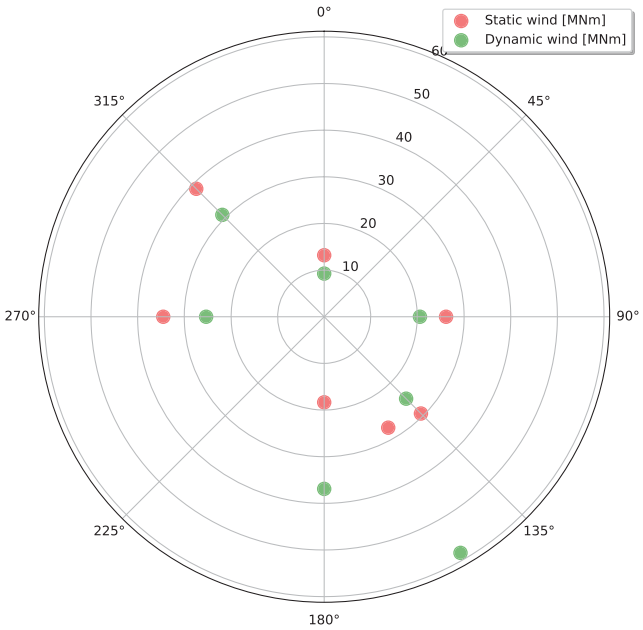
Stage C - Tower leg bottom, west - Axial force

168.4 [MN] from perm. loads



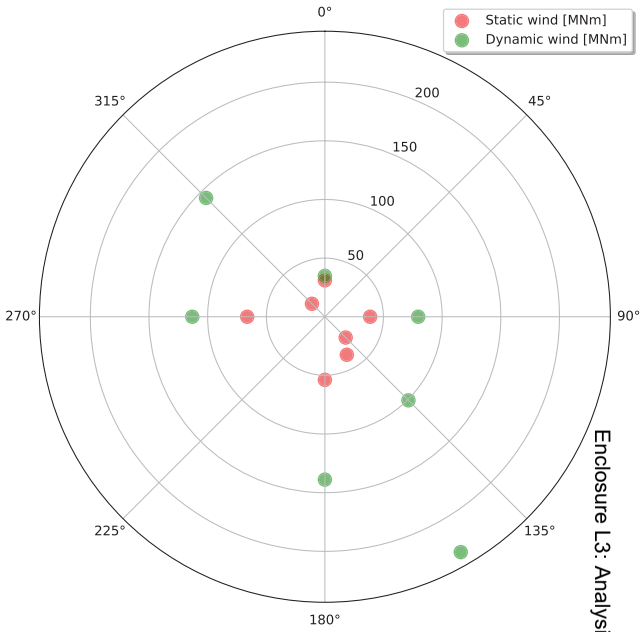
Stage C - Tower leg bottom, west - Moment about longitudinal axis

109.9 [MNm] from perm. loads



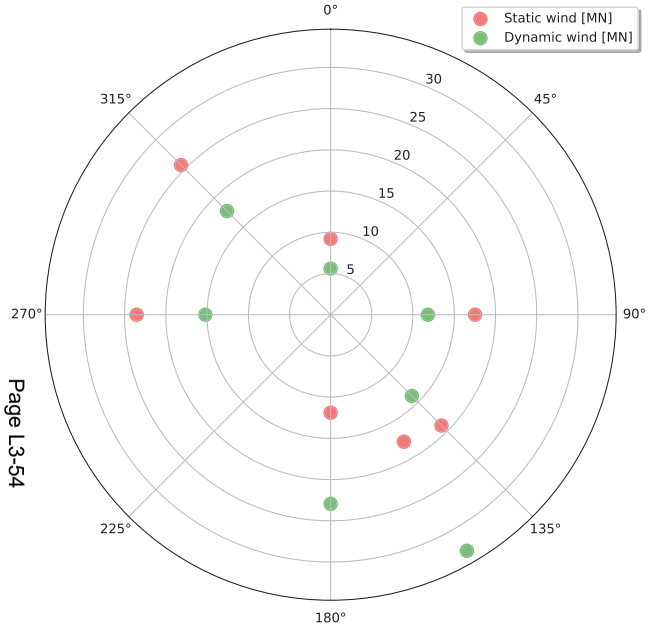
Stage C - Tower leg bottom, west - Moment about transverse axis

35.3 [MNm] from perm. loads



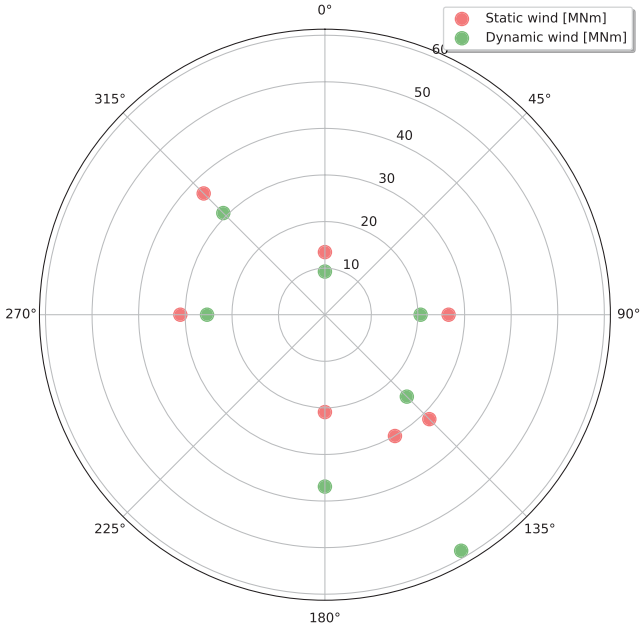
Stage C - Tower leg bottom, east - Axial force

168.4 [MN] from perm. loads



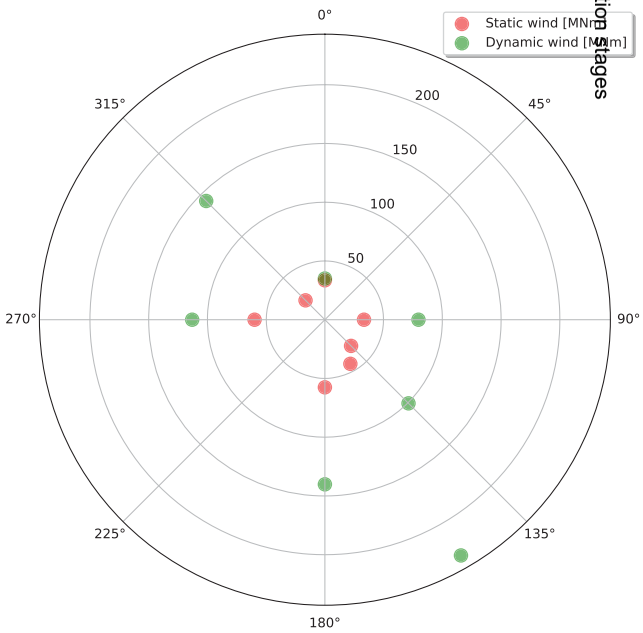
Stage C - Tower leg bottom, east - Moment about longitudinal axis

109.9 [MNm] from perm. loads



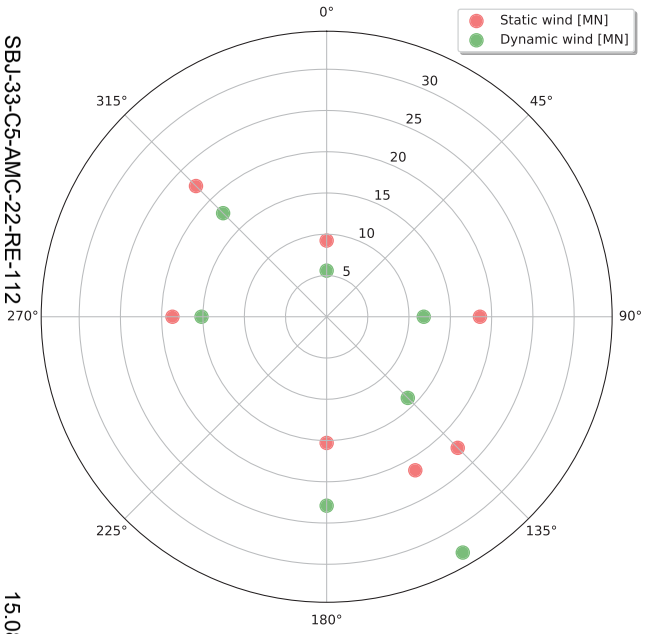
Stage C - Tower leg bottom, east - Moment about transverse axis

35.3 [MNm] from perm. loads



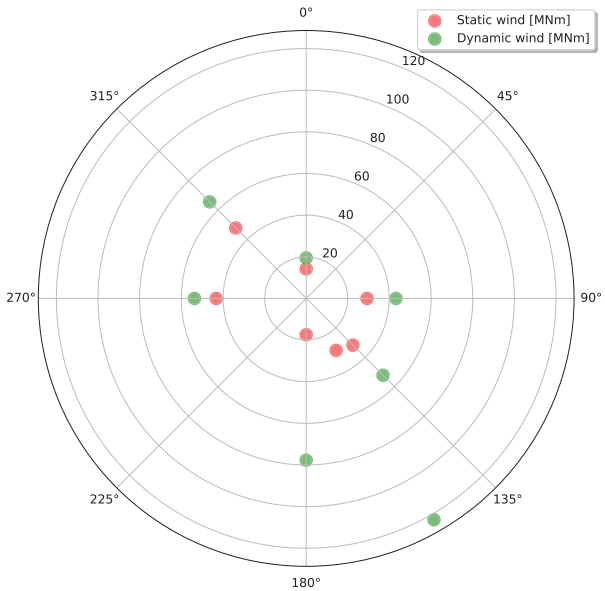
Stage C - Tower leg below cross beam, west - Axial force

121.6 [MN] from perm. loads



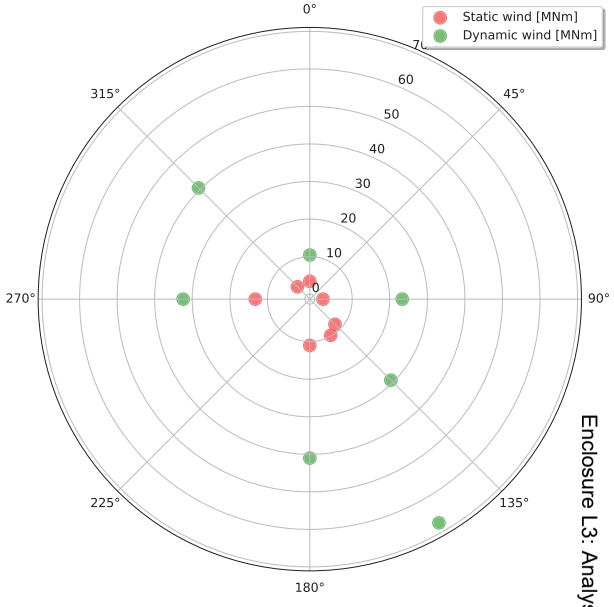
Stage C - Tower leg below cross beam, west - Moment about longitudinal axis

231.4 [MNm] from perm. loads



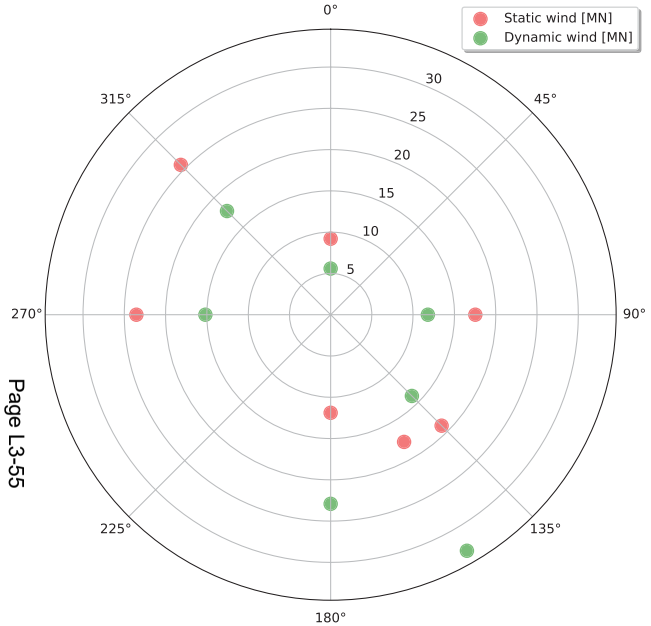
Stage C - Tower leg below cross beam, west - Moment about transverse axis

27.6 [MNm] from perm. loads



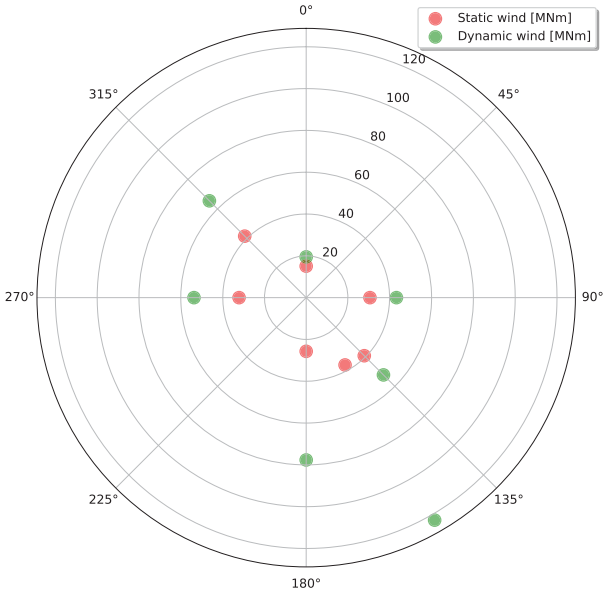
Stage C - Tower leg below cross beam, east - Axial force

121.6 [MN] from perm. loads



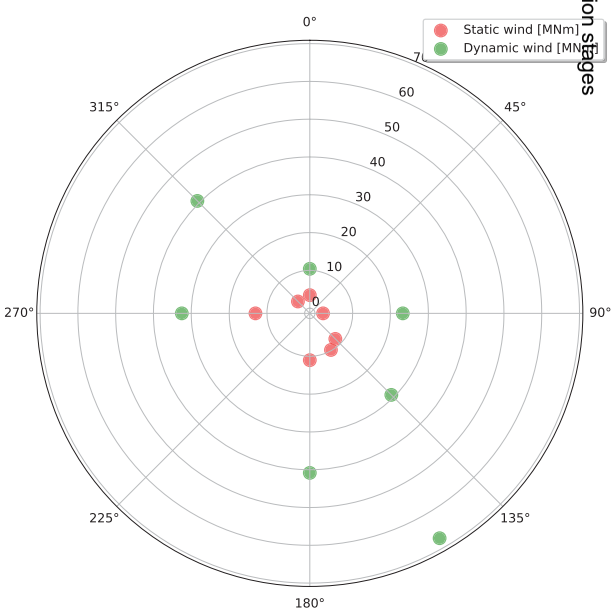
Stage C - Tower leg below cross beam, east - Moment about longitudinal axis

231.4 [MNm] from perm. loads



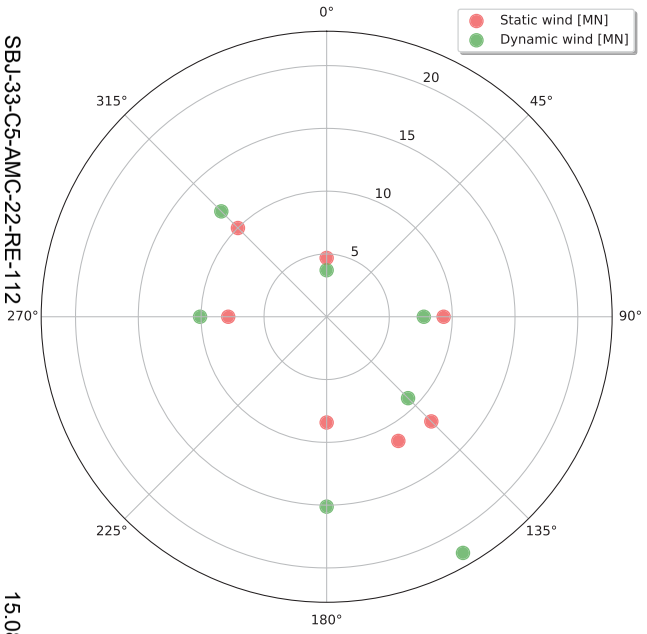
Stage C - Tower leg below cross beam, east - Moment about transverse axis

27.5 [MNm] from perm. loads



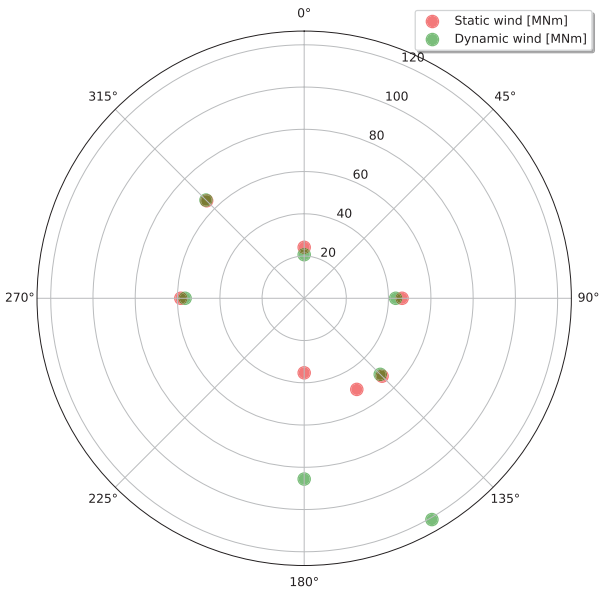
Stage C - Tower leg above cross beam, west - Axial force

117.3 [MN] from perm. loads



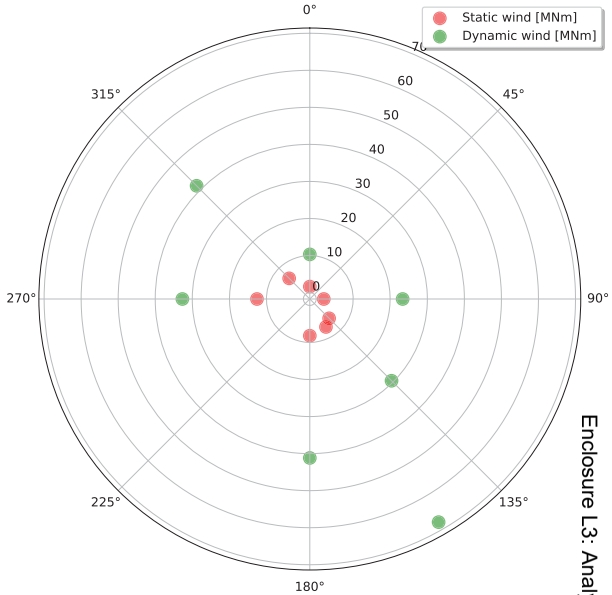
Stage C - Tower leg above cross beam, west - Moment about longitudinal axis

85.4 [MNm] from perm. loads



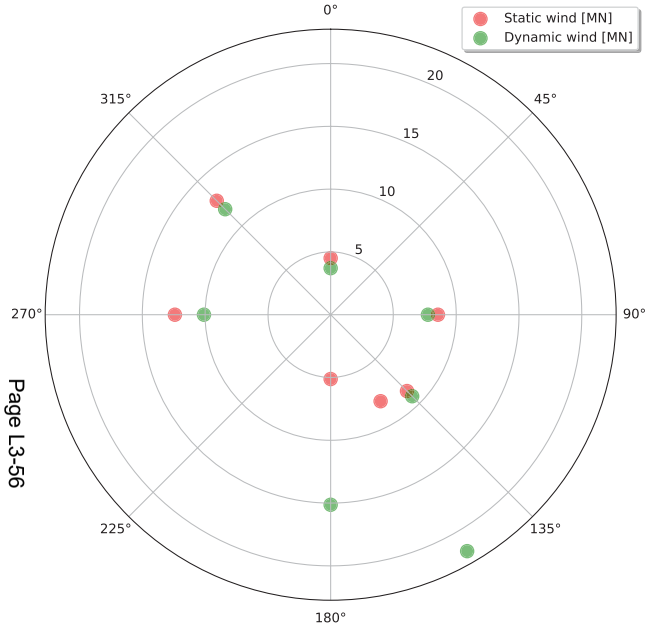
Stage C - Tower leg above cross beam, west - Moment about transverse axis

26.9 [MNm] from perm. loads



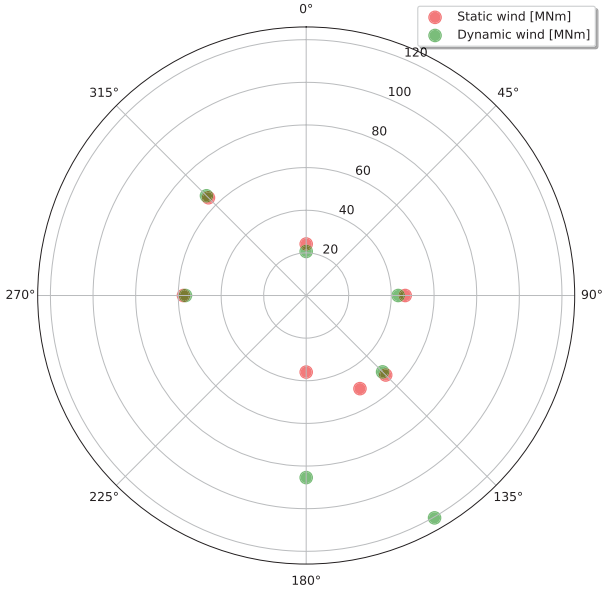
Stage C - Tower leg above cross beam, east - Axial force

117.3 [MN] from perm. loads



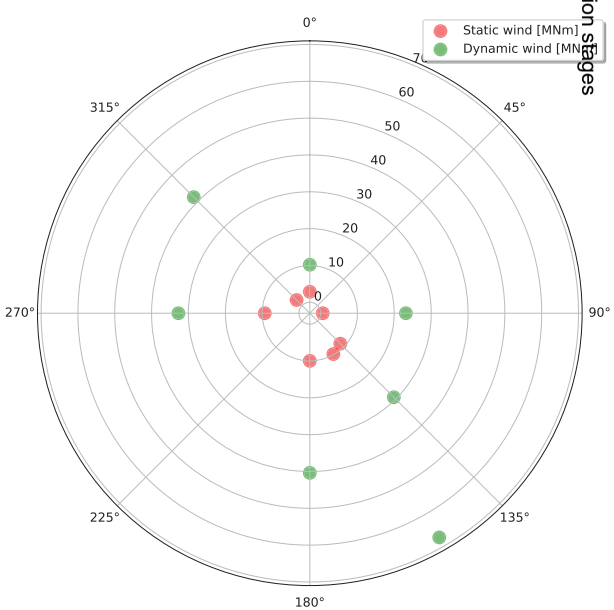
Stage C - Tower leg above cross beam, east - Moment about longitudinal axis

85.4 [MNm] from perm. loads



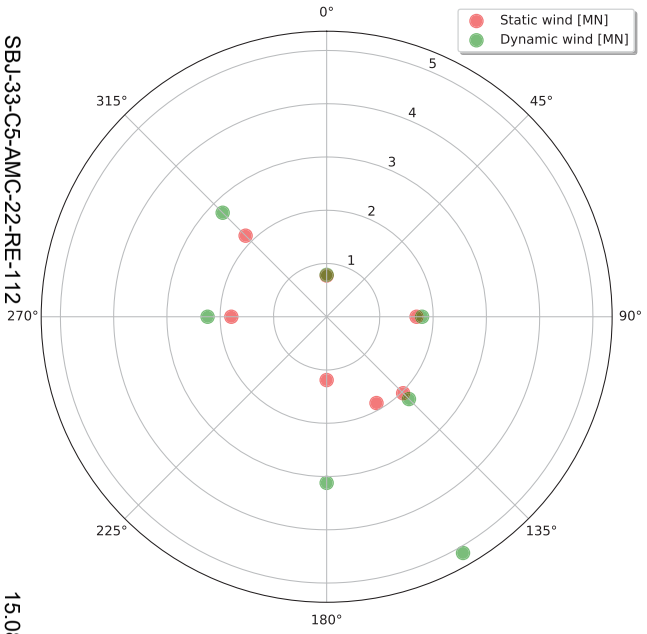
Stage C - Tower leg above cross beam, east - Moment about transverse axis

26.9 [MNm] from perm. loads



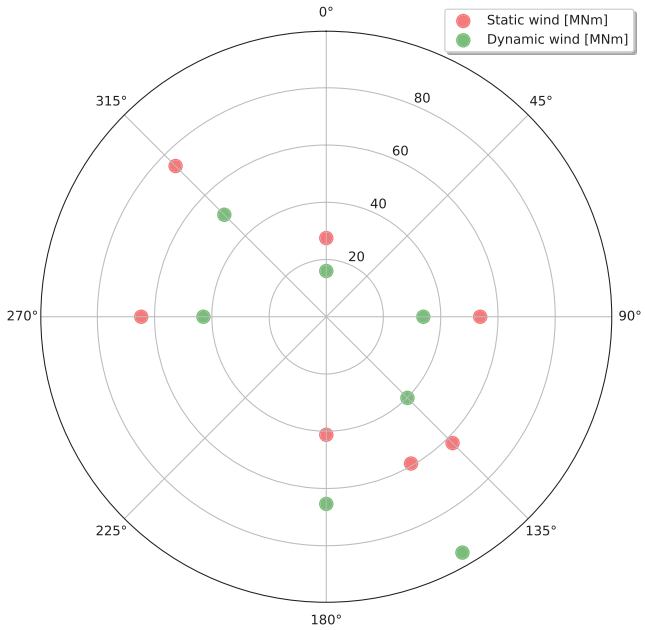
Stage C - Cross beam, end west - Axial force

8.9 [MN] from perm. loads



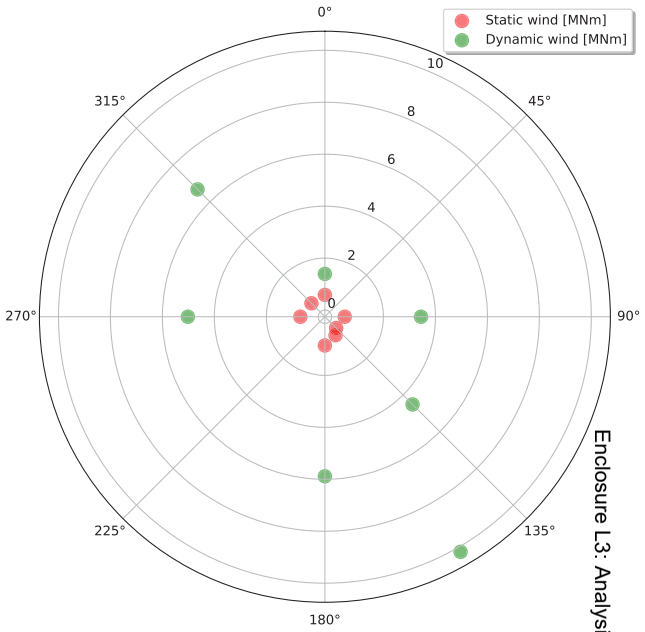
Stage C - Cross beam, end west - Moment about longitudinal axis

60.8 [MNm] from perm. loads



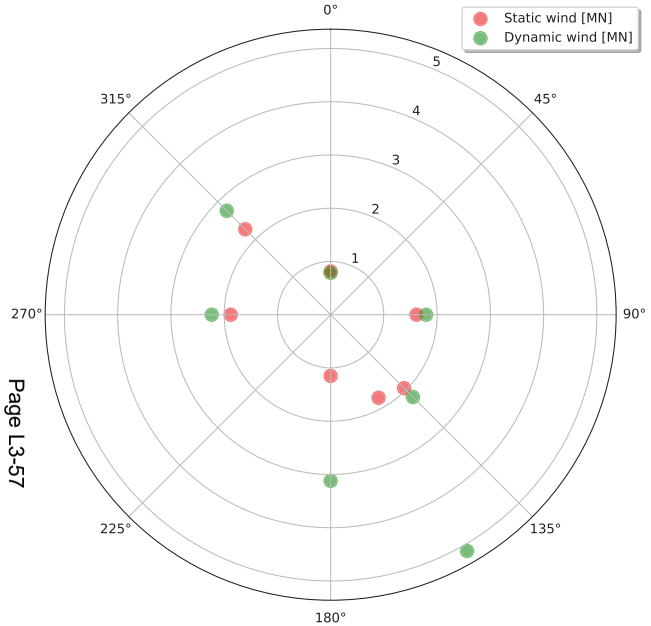
Stage C - Cross beam, end west - Moment about vertical axis

0.4 [MNm] from perm. loads



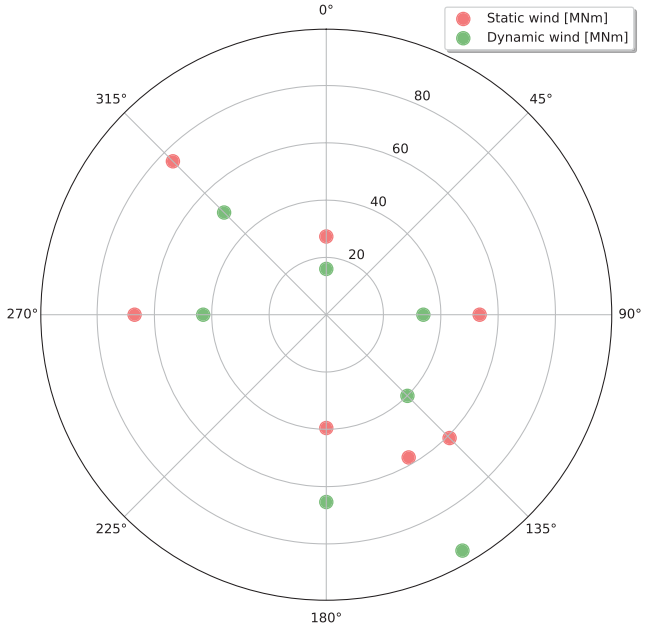
Stage C - Cross beam, end east - Axial force

8.9 [MN] from perm. loads



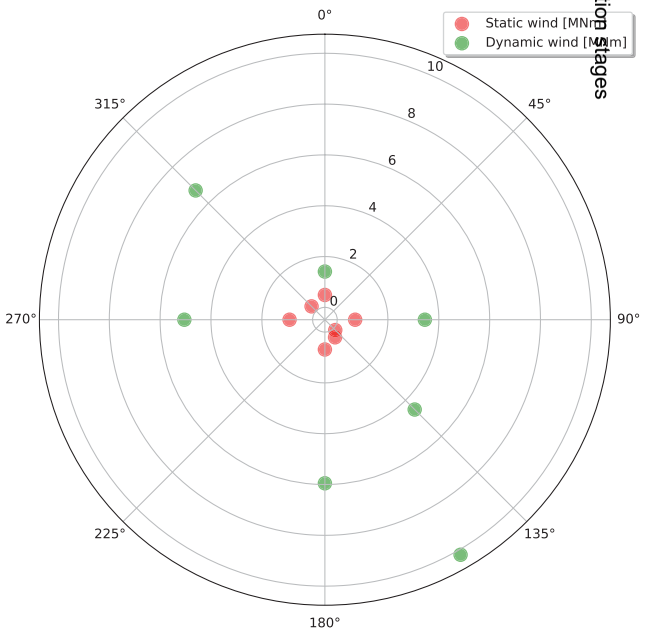
Stage C - Cross beam, end east - Moment about longitudinal axis

60.8 [MNm] from perm. loads



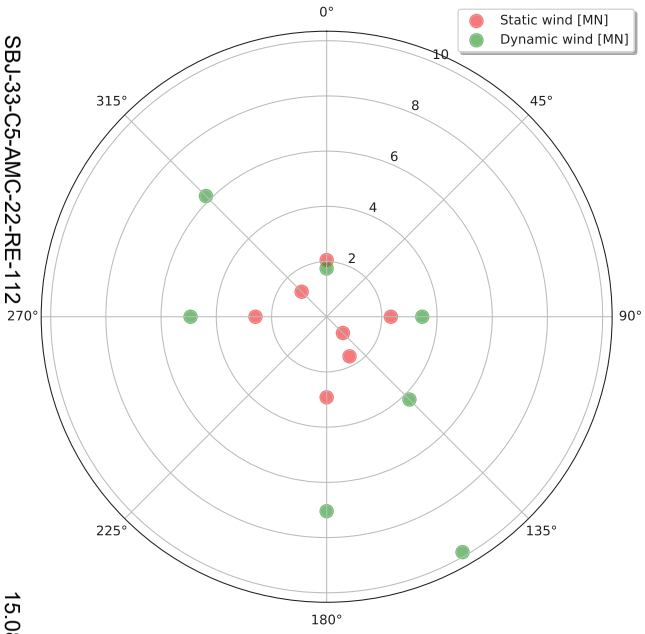
Stage C - Cross beam, end east - Moment about vertical axis

0.4 [MNm] from perm. loads



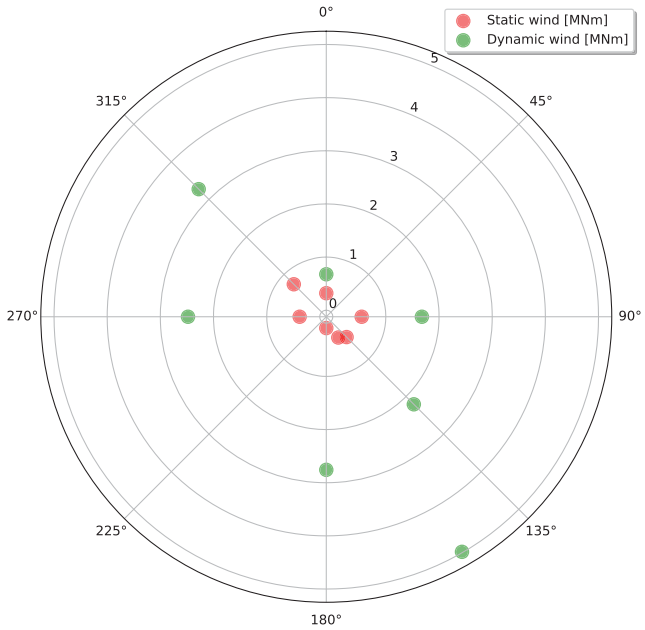
Stage C - Bridge girder axis 1 - Axial force

2.1 [MN] from perm. loads



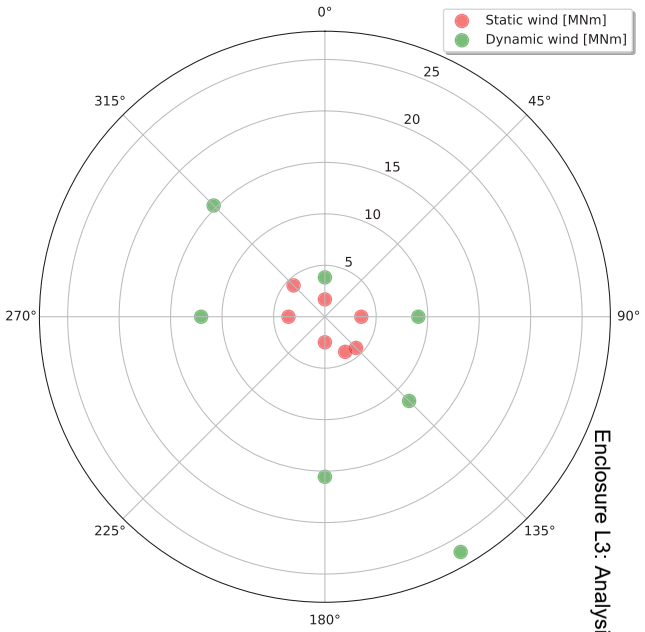
Stage C - Bridge girder axis 1 - Moment about weak axis

83.2 [MNm] from perm. loads



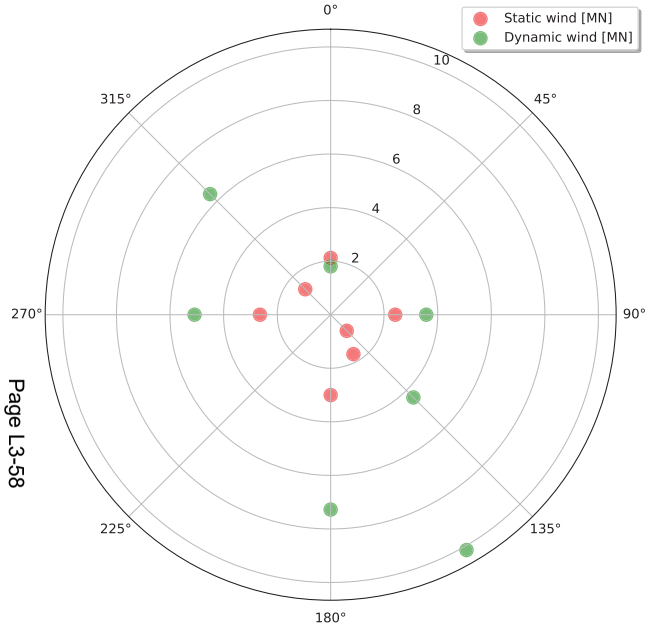
Stage C - Bridge girder axis 1 - Moment about strong axis

0.0 [MNm] from perm. loads



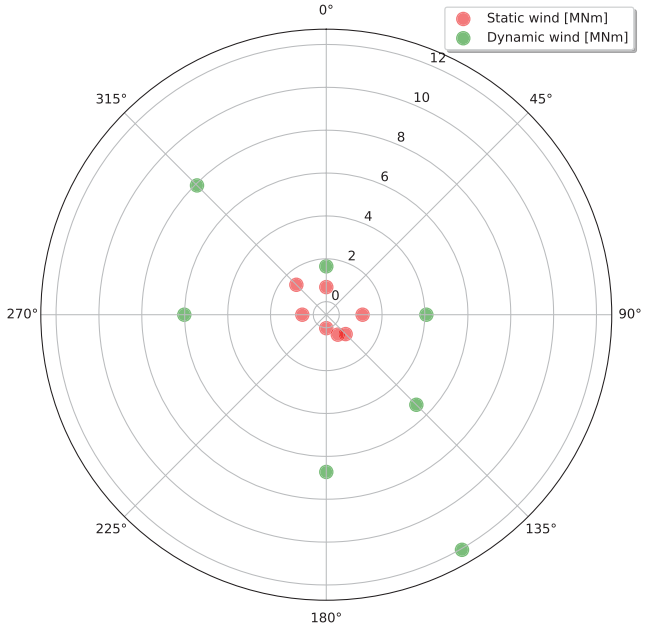
Stage C - Bridge girder axis 1A - Axial force

0.7 [MN] from perm. loads



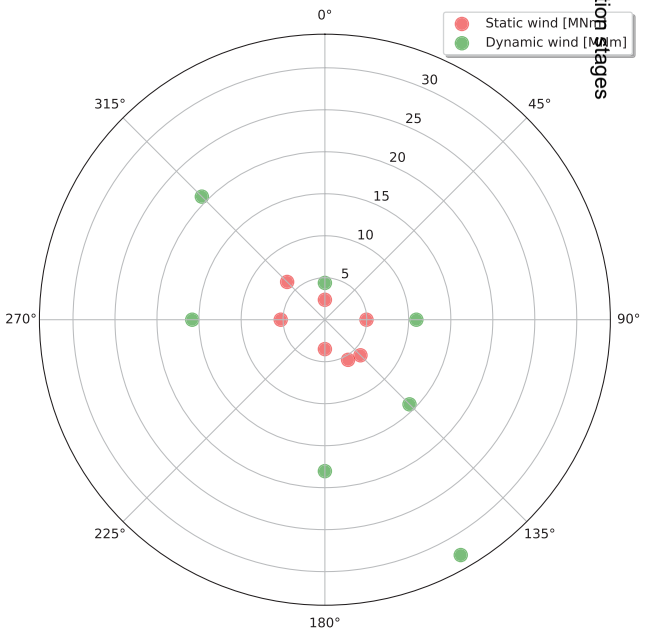
Stage C - Bridge girder axis 1A - Moment about weak axis

158.1 [MNm] from perm. loads



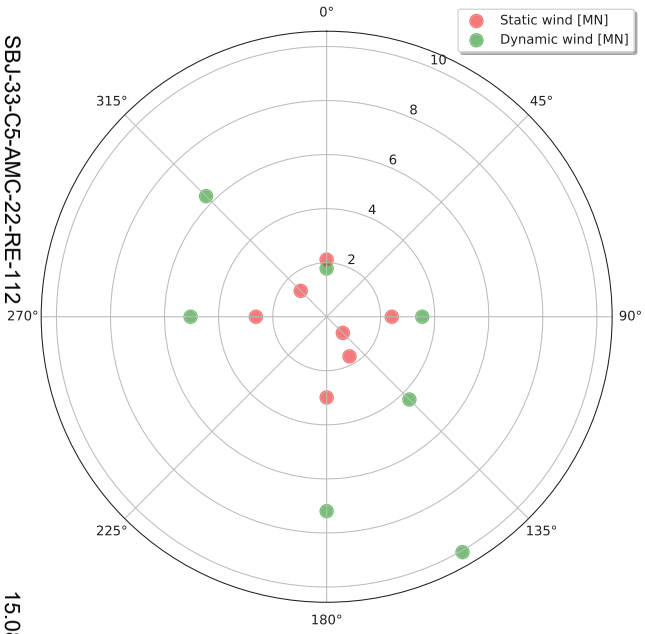
Stage C - Bridge girder axis 1A - Moment about strong axis

0.0 [MNm] from perm. loads



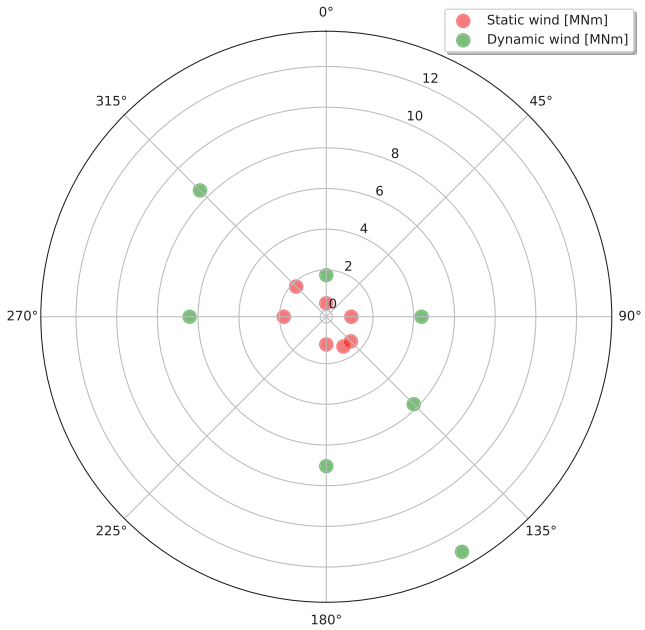
Stage C - Bridge girder axis 1B - Axial force

0.8 [MN] from perm. loads



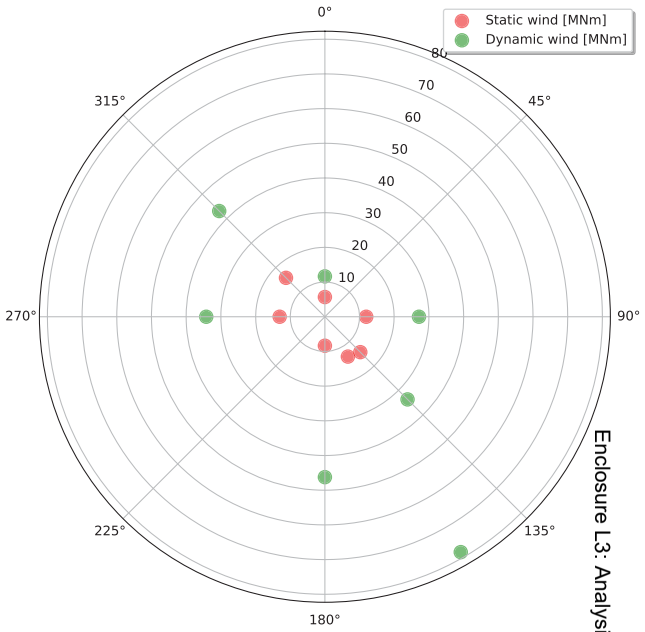
Stage C - Bridge girder axis 1B - Moment about weak axis

202.6 [MNm] from perm. loads



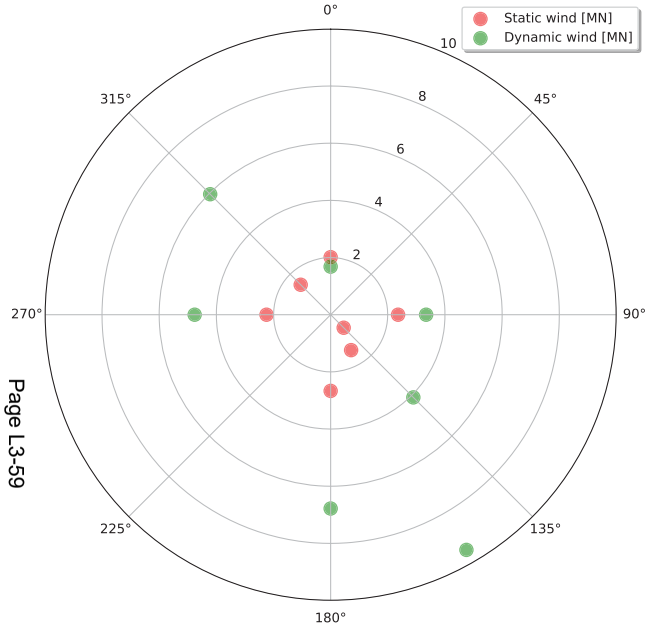
Stage C - Bridge girder axis 1B - Moment about strong axis

0.0 [MNm] from perm. loads



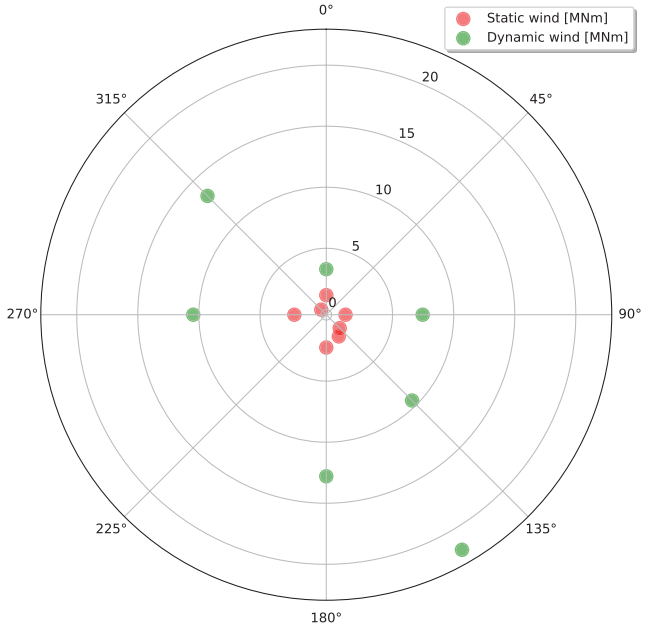
Stage C - Bridge girder axis 1C - Axial force

6.6 [MN] from perm. loads



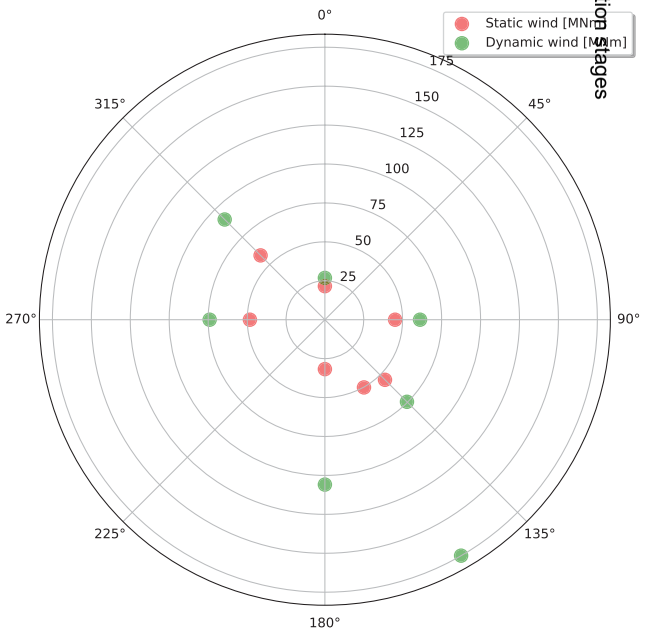
Stage C - Bridge girder axis 1C - Moment about weak axis

107.6 [MNm] from perm. loads



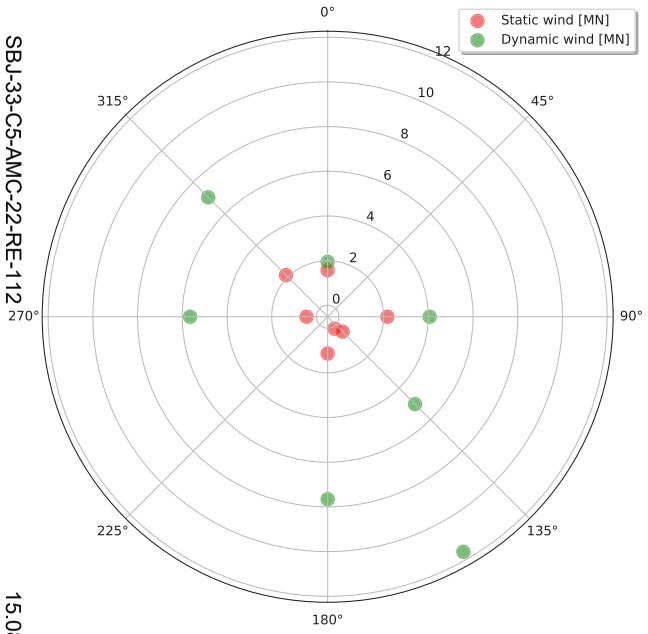
Stage C - Bridge girder axis 1C - Moment about strong axis

0.0 [MNm] from perm. loads



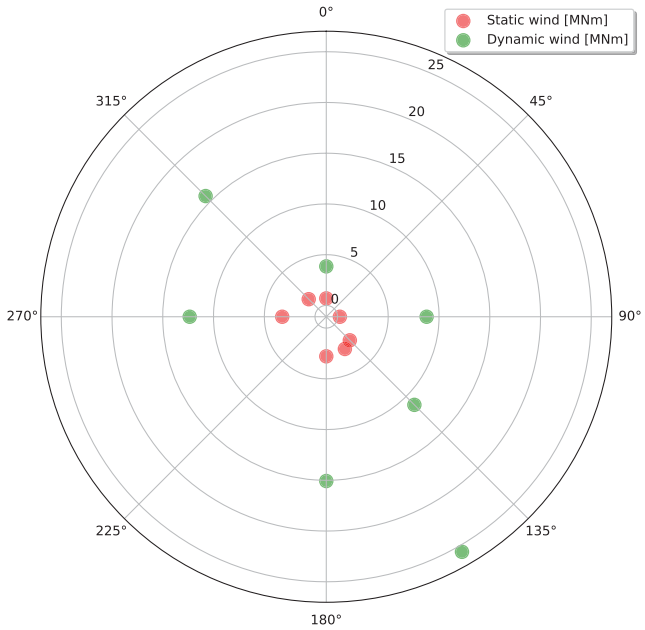
Stage C - Bridge girder axis 1D - Axial force

41.7 [MN] from perm. loads



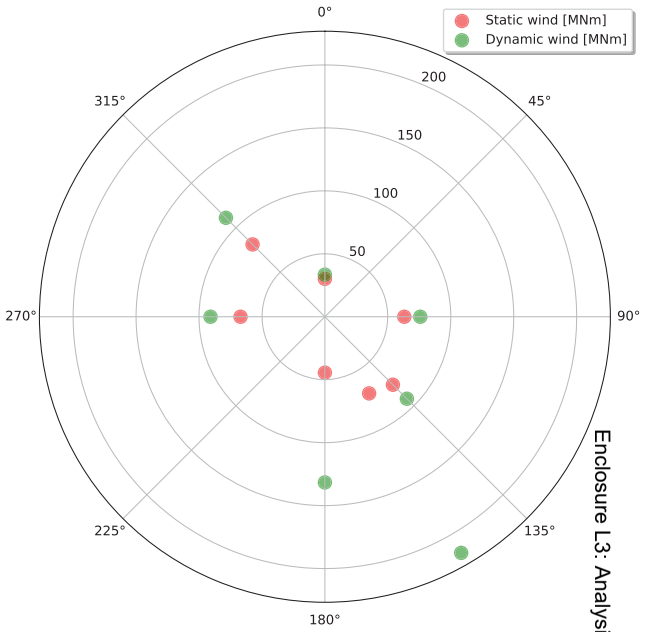
Stage C - Bridge girder axis 1D - Moment about weak axis

101.0 [MNm] from perm. loads



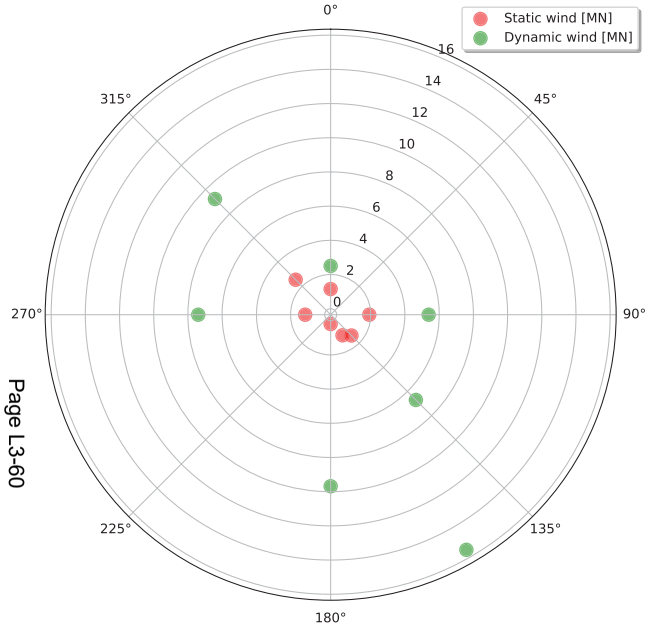
Stage C - Bridge girder axis 1D - Moment about strong axis

0.0 [MNm] from perm. loads



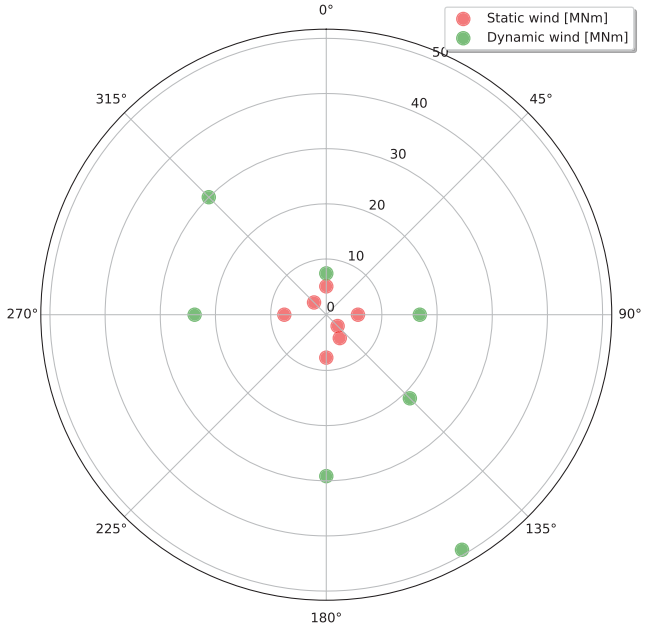
Stage C - Bridge girder axis 1E - Axial force

70.3 [MN] from perm. loads



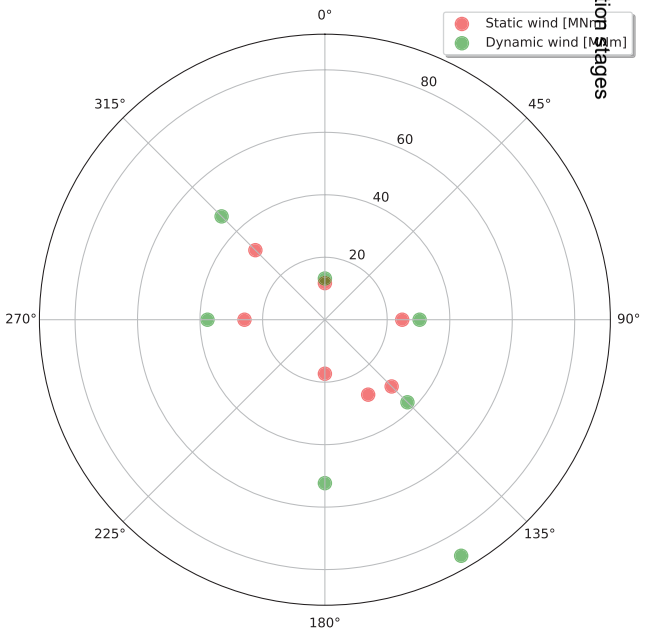
Stage C - Bridge girder axis 1E - Moment about weak axis

33.7 [MNm] from perm. loads



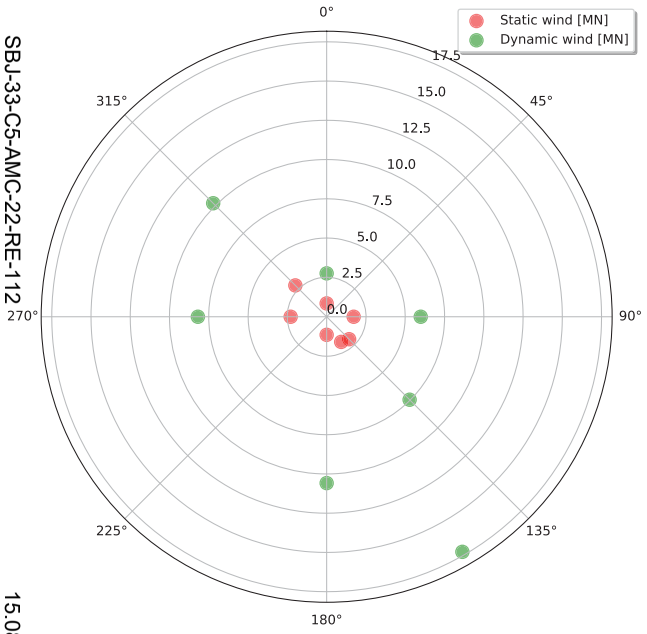
Stage C - Bridge girder axis 1E - Moment about strong axis

0.0 [MNm] from perm. loads



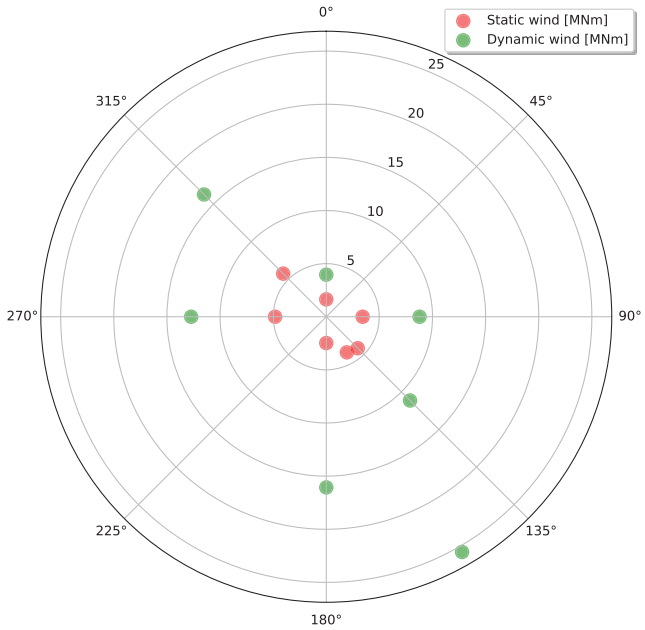
Stage C - Bridge girder axis 2 - Axial force

89.2 [MN] from perm. loads



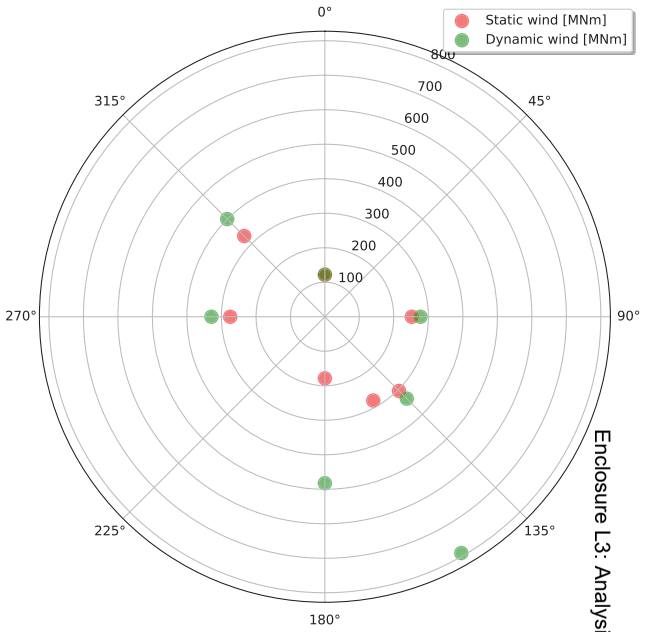
Stage C - Bridge girder axis 2 - Moment about weak axis

16.1 [MNm] from perm. loads



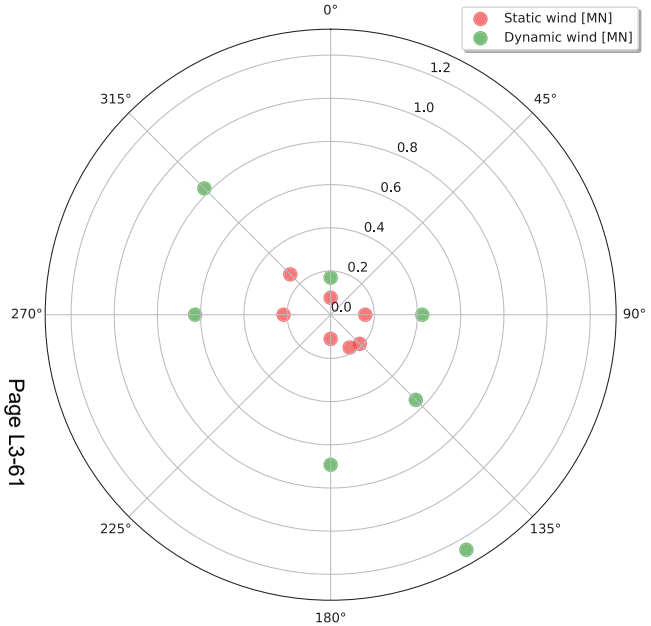
Stage C - Bridge girder axis 2 - Moment about strong axis

0.0 [MNm] from perm. loads



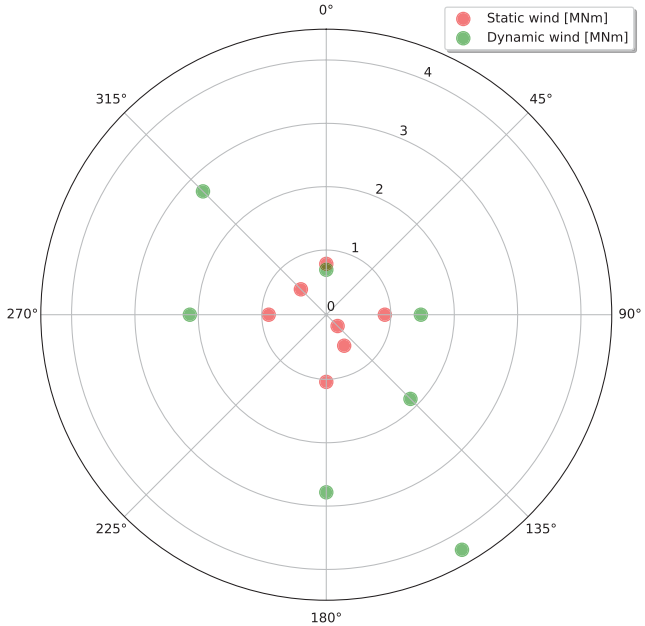
Stage C - Bottom column axis 1A - Axial force

39.3 [MN] from perm. loads



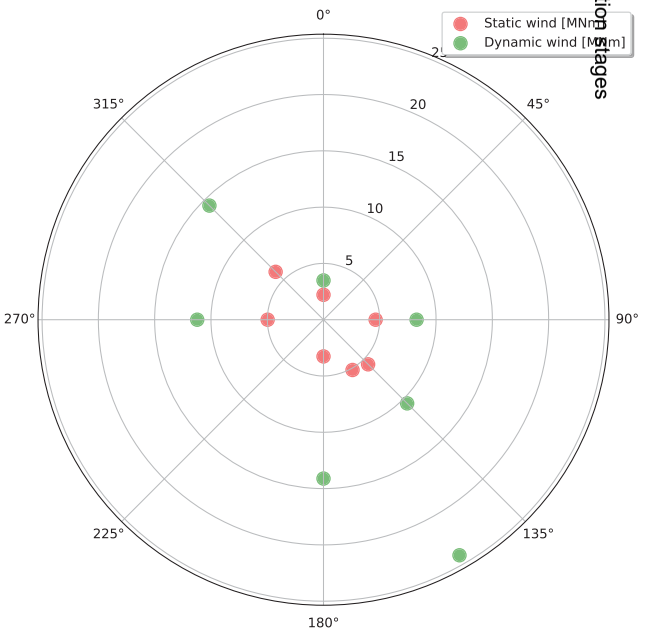
Stage C - Bottom column axis 1A - Moment about transverse axis

13.6 [MNm] from perm. loads



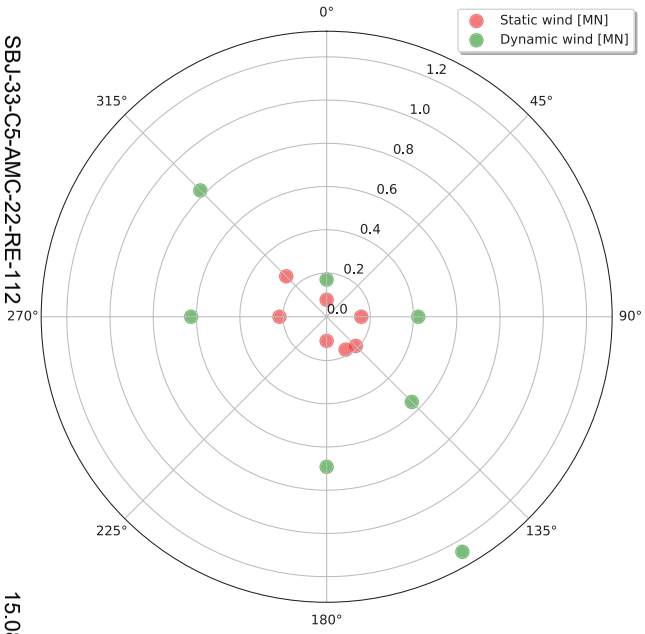
Stage C - Bottom column axis 1A - Moment about longitudinal axis

0.0 [MNm] from perm. loads



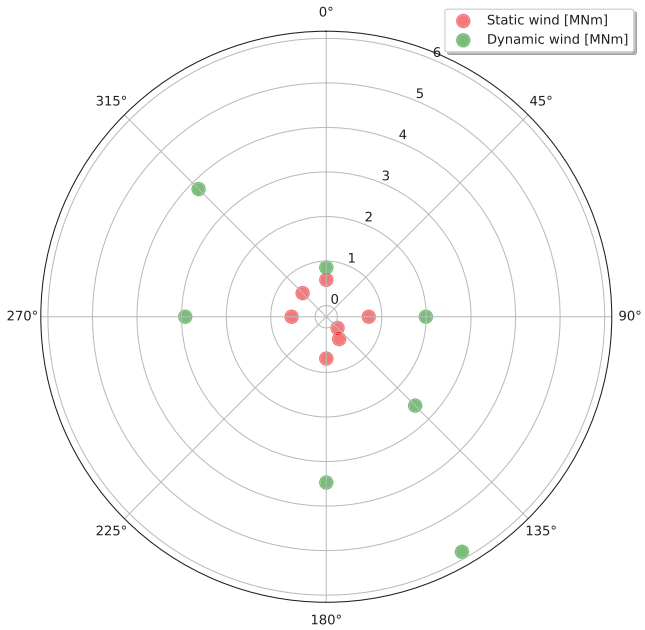
Stage C - Top column axis 1A - Axial force

35.1 [MN] from perm. loads



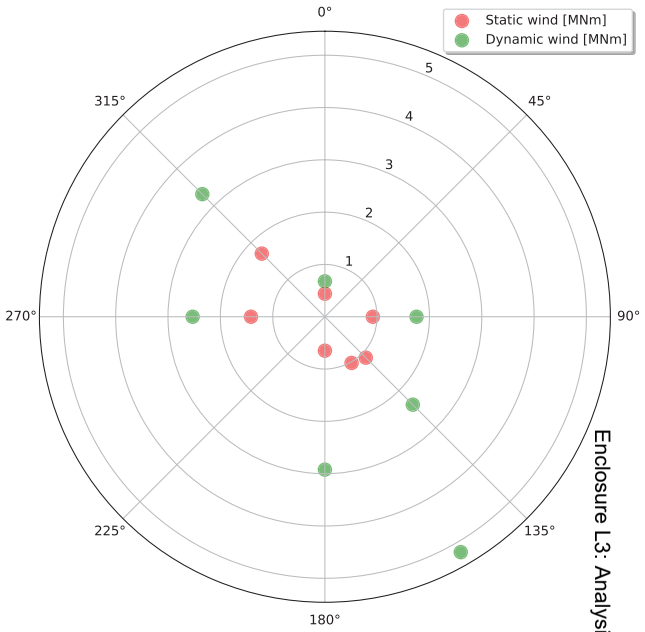
Stage C - Top column axis 1A - Moment about transverse axis

24.2 [MNm] from perm. loads



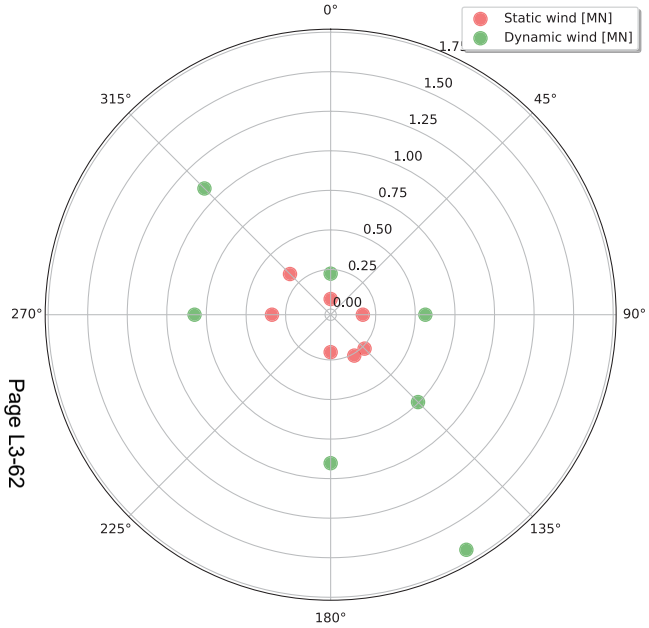
Stage C - Top column axis 1A - Moment about longitudinal axis

0.0 [MNm] from perm. loads



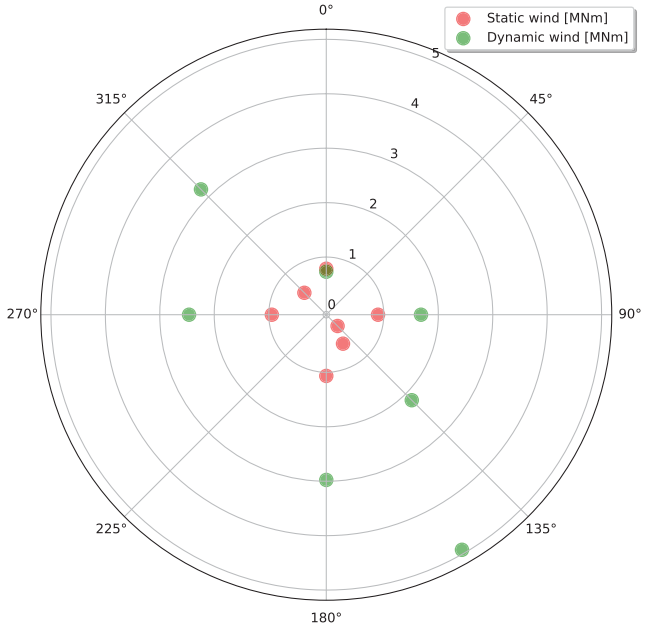
Stage C - Bottom column axis 1B - Axial force

49.2 [MN] from perm. loads



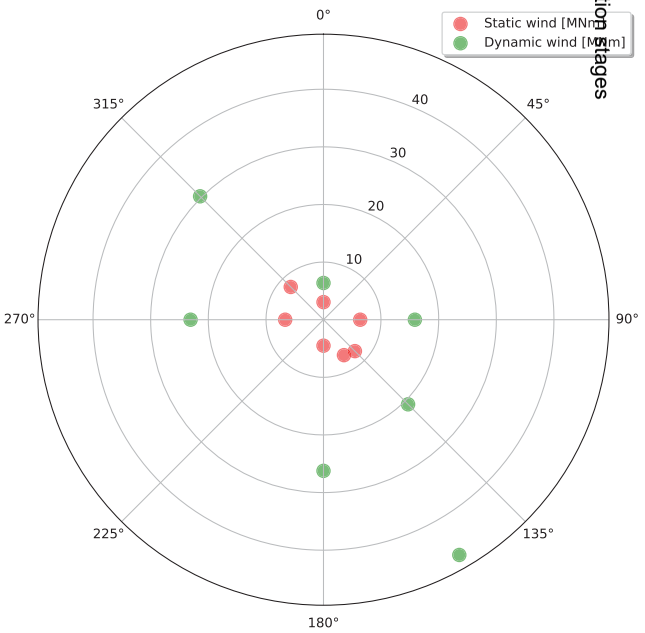
Stage C - Bottom column axis 1B - Moment about transverse axis

1.3 [MNm] from perm. loads



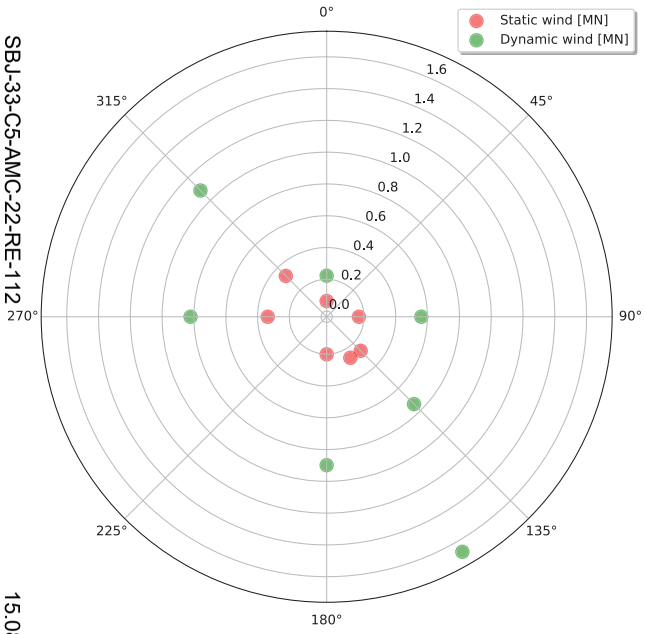
Stage C - Bottom column axis 1B - Moment about longitudinal axis

0.0 [MNm] from perm. loads



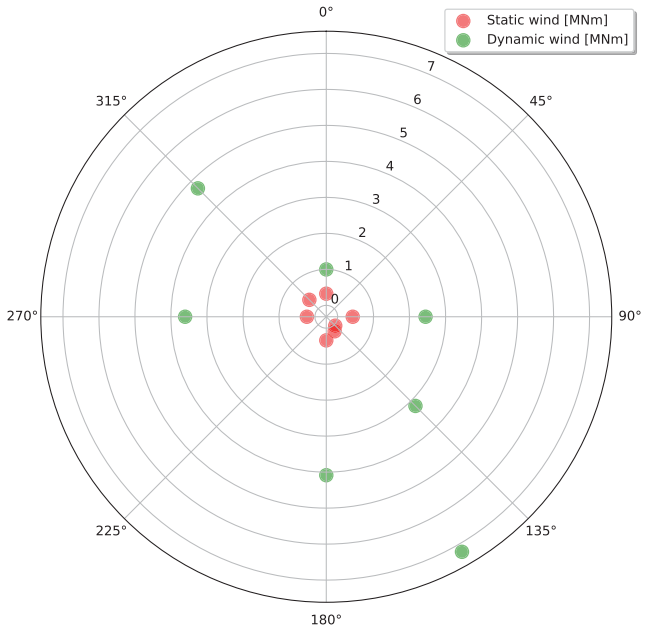
Stage C - Top column axis 1B - Axial force

42.1 [MN] from perm. loads



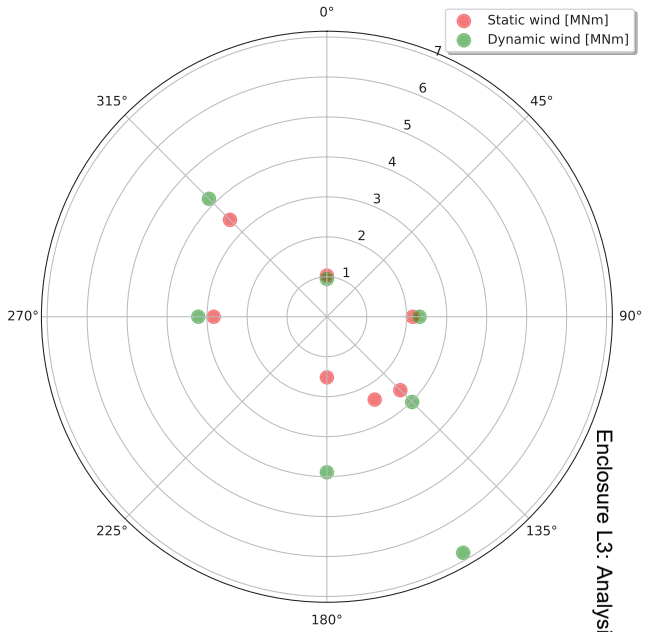
Stage C - Top column axis 1B - Moment about transverse axis

2.4 [MNm] from perm. loads



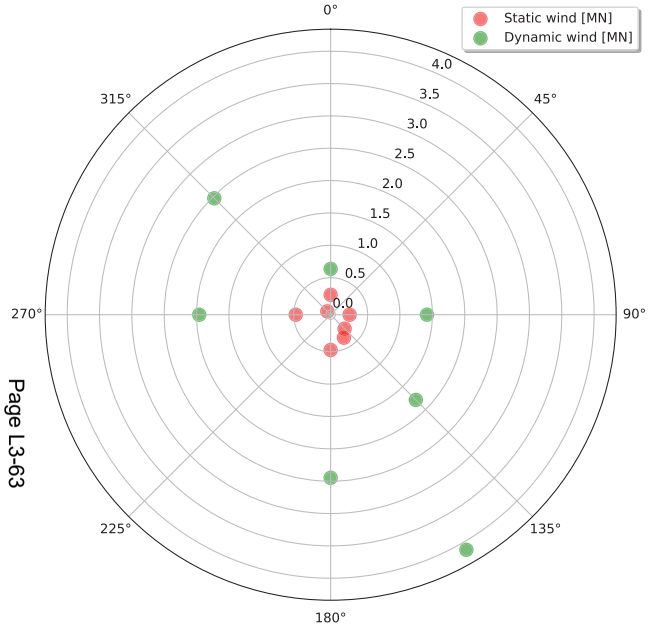
Stage C - Top column axis 1B - Moment about longitudinal axis

0.0 [MNm] from perm. loads



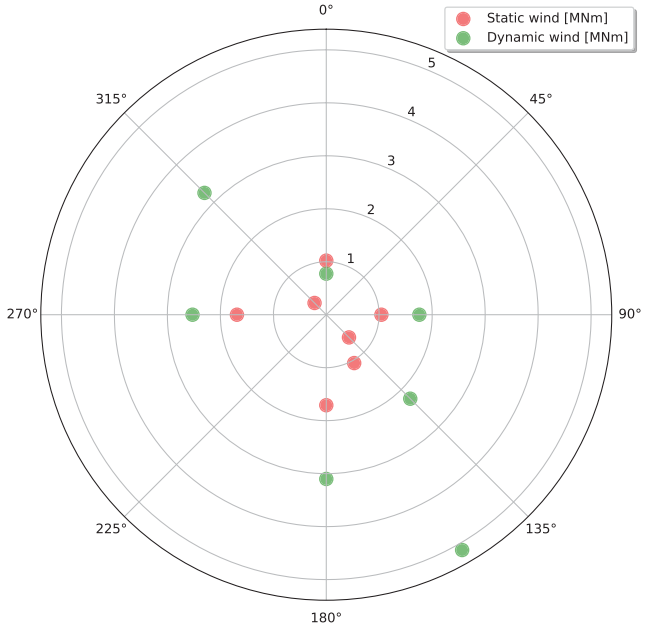
Stage C - Bottom column axis 1C - Axial force

35.8 [MN] from perm. loads



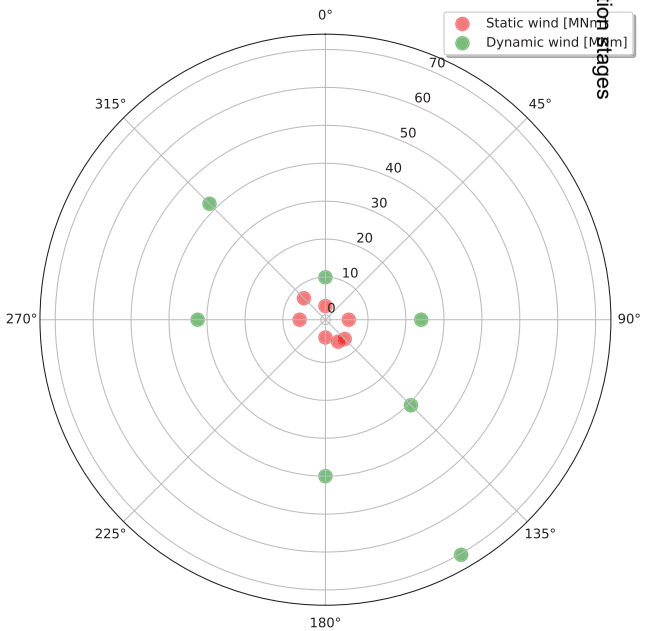
Stage C - Bottom column axis 1C - Moment about transverse axis

8.7 [MNm] from perm. loads



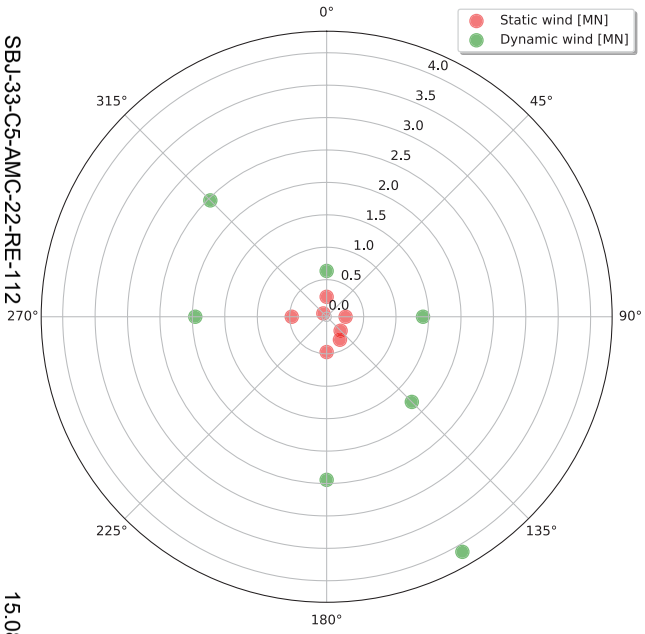
Stage C - Bottom column axis 1C - Moment about longitudinal axis

0.0 [MNm] from perm. loads



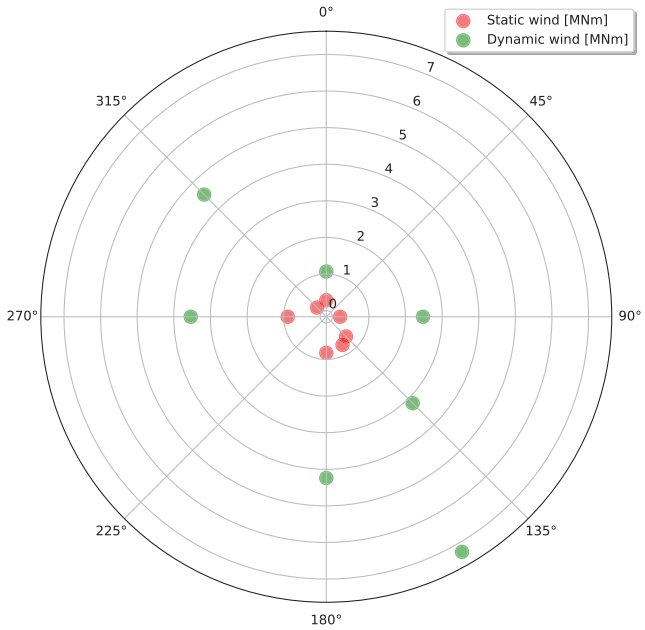
Stage C - Top column axis 1C - Axial force

25.3 [MN] from perm. loads



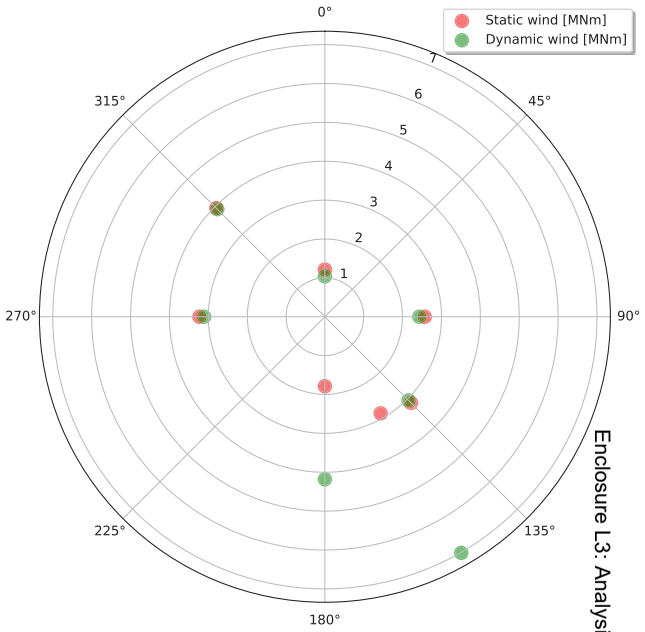
Stage C - Top column axis 1C - Moment about transverse axis

16.2 [MNm] from perm. loads



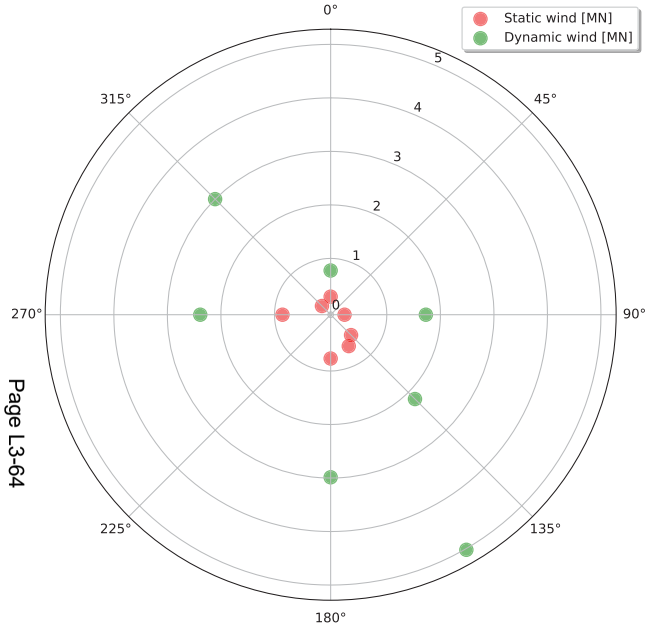
Stage C - Top column axis 1C - Moment about longitudinal axis

0.0 [MNm] from perm. loads



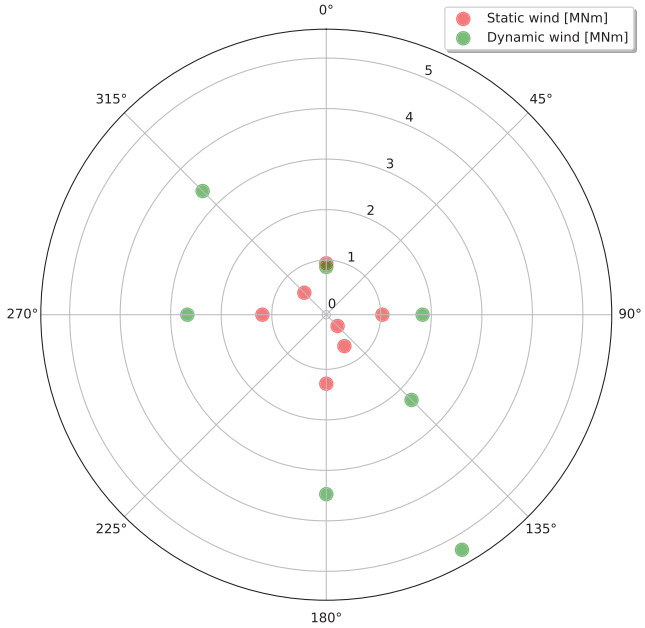
Stage C - Bottom column axis 1D - Axial force

32.9 [MN] from perm. loads



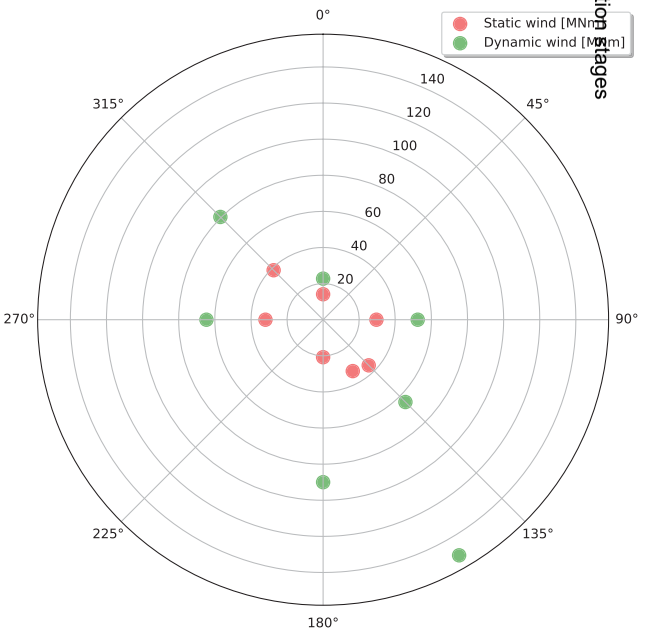
Stage C - Bottom column axis 1D - Moment about transverse axis

6.4 [MNm] from perm. loads



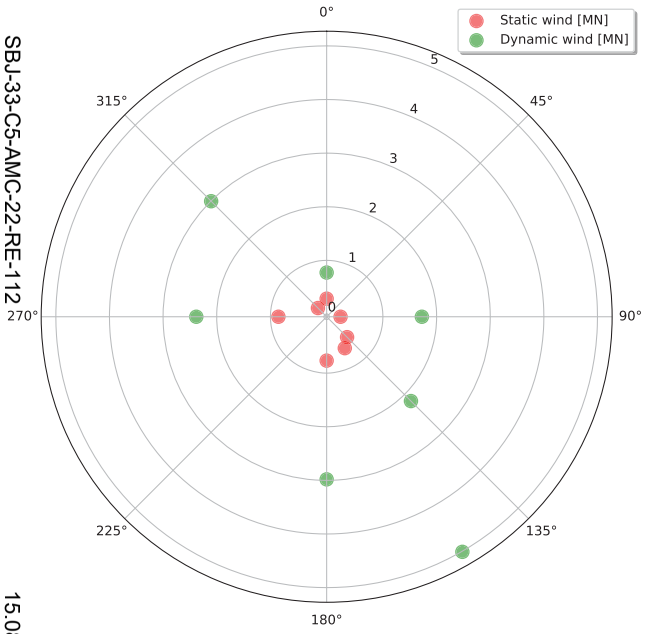
Stage C - Bottom column axis 1D - Moment about longitudinal axis

0.0 [MNm] from perm. loads



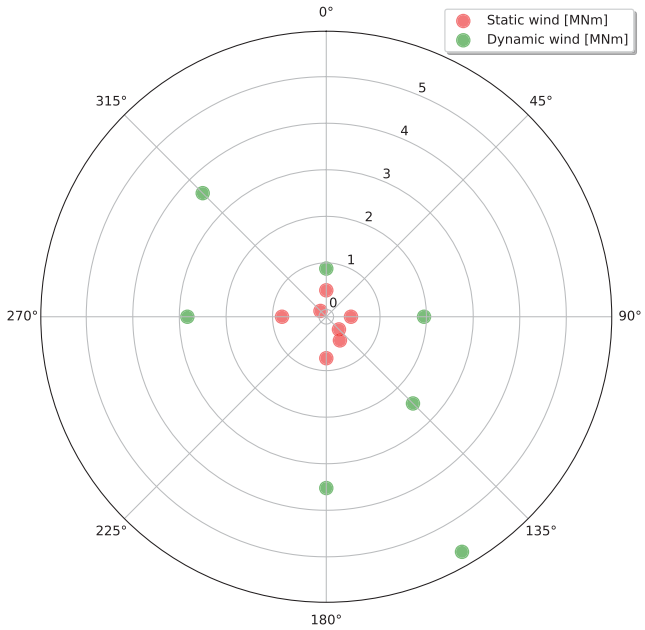
Stage C - Top column axis 1D - Axial force

19.9 [MN] from perm. loads



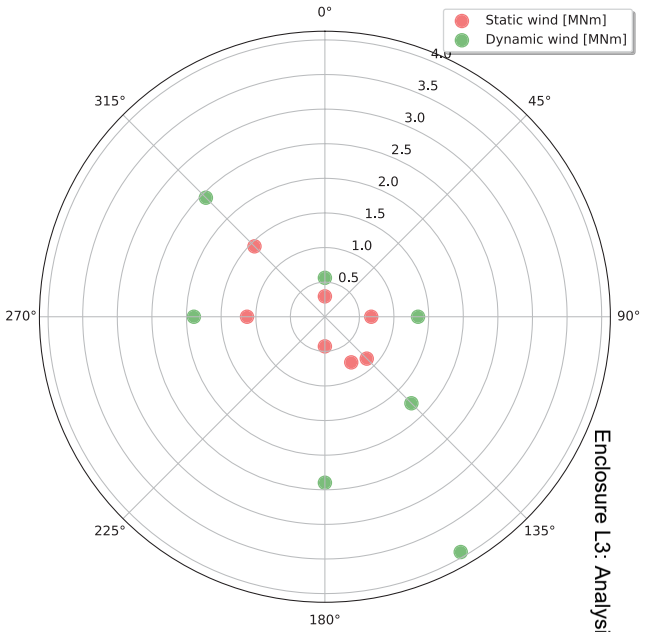
Stage C - Top column axis 1D - Moment about transverse axis

11.0 [MNm] from perm. loads



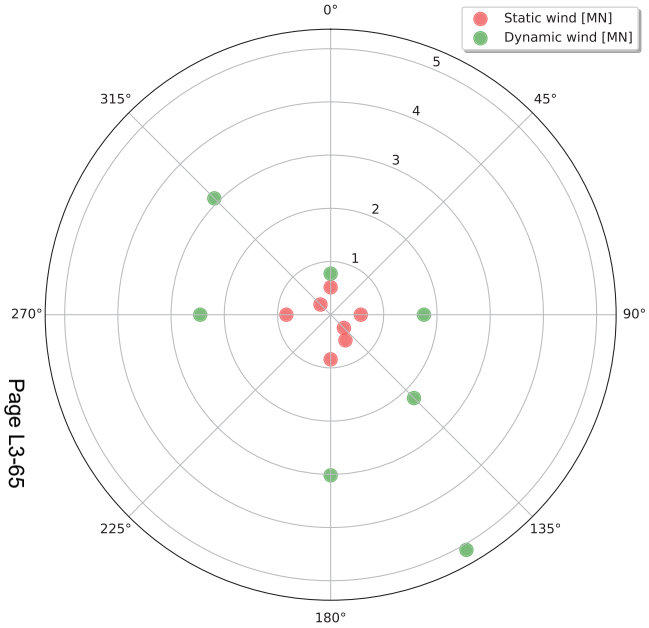
Stage C - Top column axis 1D - Moment about longitudinal axis

0.0 [MNm] from perm. loads



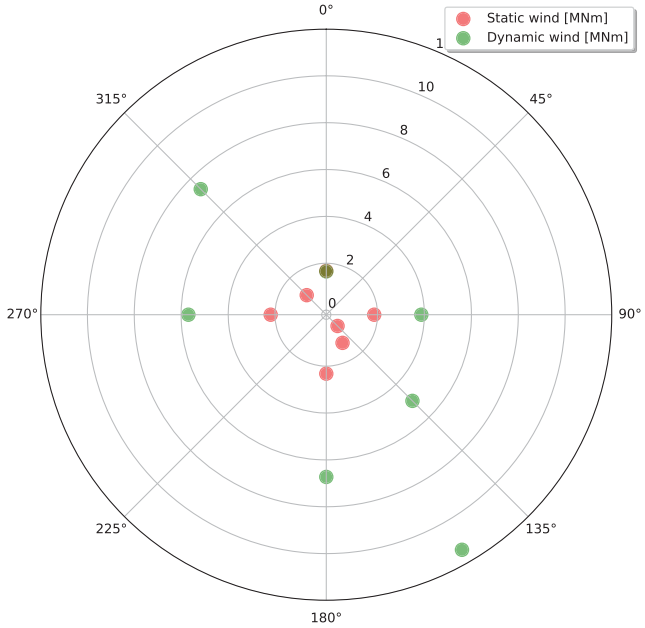
Stage C - Bottom column axis 1E - Axial force

30.0 [MN] from perm. loads



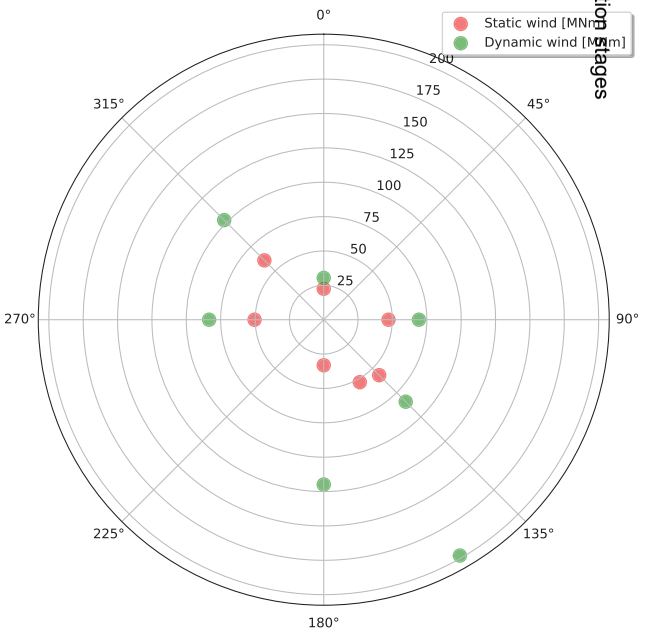
Stage C - Bottom column axis 1E - Moment about transverse axis

6.8 [MNm] from perm. loads



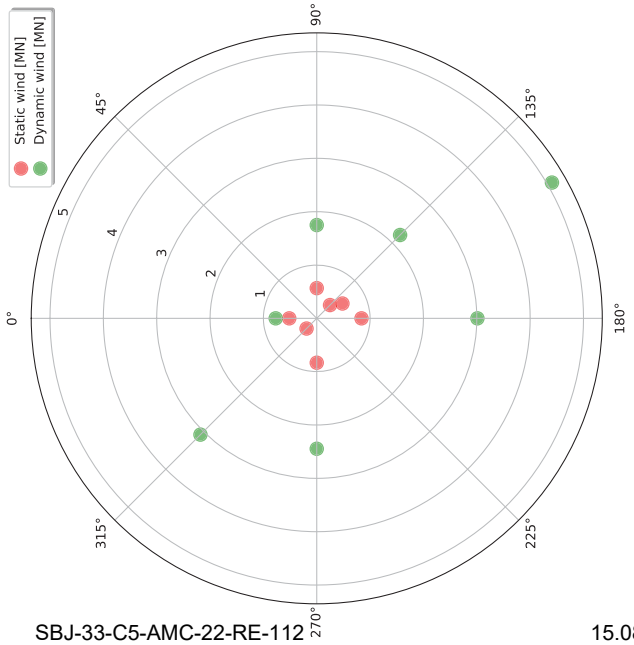
Stage C - Bottom column axis 1E - Moment about longitudinal axis

0.0 [MNm] from perm. loads



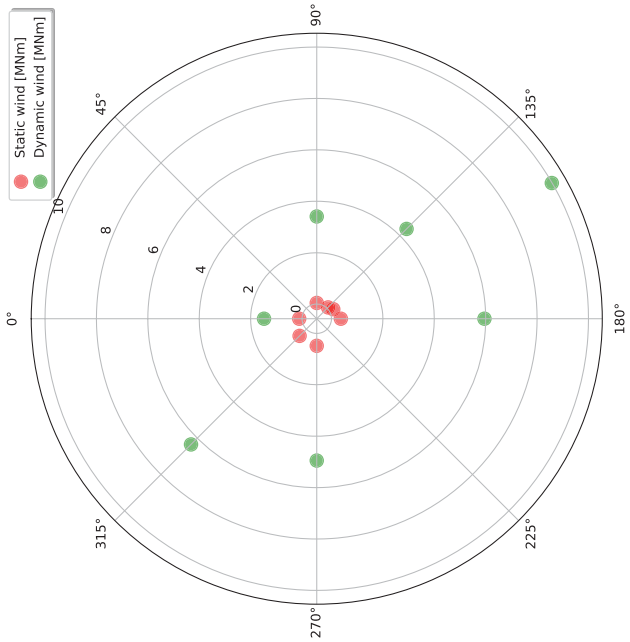
Stage C - Top column axis 1E - Axial force

12.5 [MN] from perm. loads



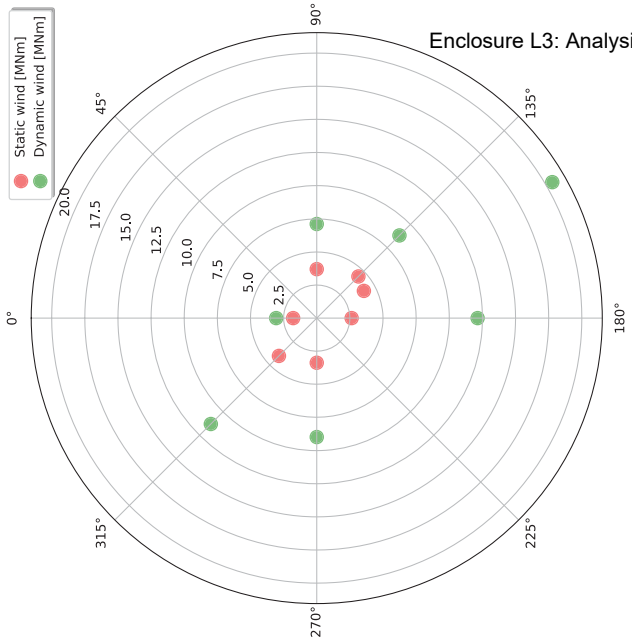
Stage C - Top column axis 1E - Moment about transverse axis

15.4 [MNm] from perm. loads



Stage C - Top column axis 1E - Moment about longitudinal axis

0.0 [MNm] from perm. loads



8 Natural modes of vibration

Listing of eigenvalues (without contribution from static wind to the geometric stiffness) and plots of mode shapes for the first 5 or 10 modes are shown in the following chapters.

8.1 Stage A1

Mode:	Freq. [Hz]	Omega [rad/s]	Period [sec.]
1	0.344	2.159	2.910
2	1.764	11.083	0.567
3	2.211	13.890	0.452
4	6.212	39.028	0.161
5	11.076	69.590	0.090
6	12.192	76.603	0.082
7	14.898	93.607	0.067
8	20.176	126.772	0.050
9	30.167	189.543	0.033
10	31.039	195.021	0.032

Mode 1: (longitudinal motion)

Mode 2: (transverse motion)

Mode 3: (longitudinal motion)

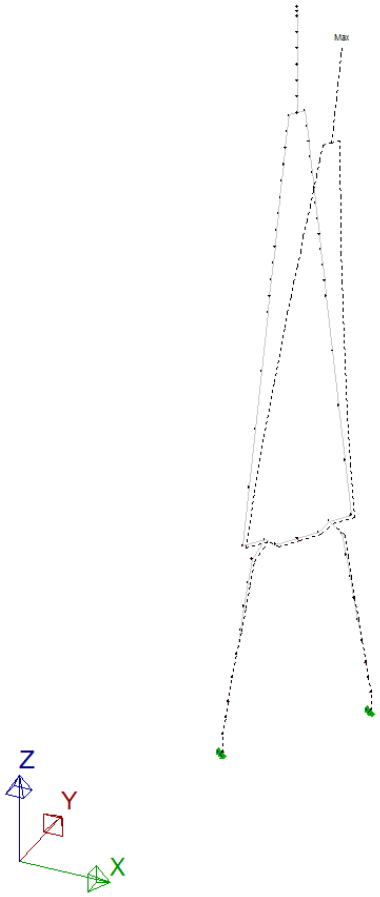
Mode 4: (longitudinal motion)

Mode5: (transverse motion)

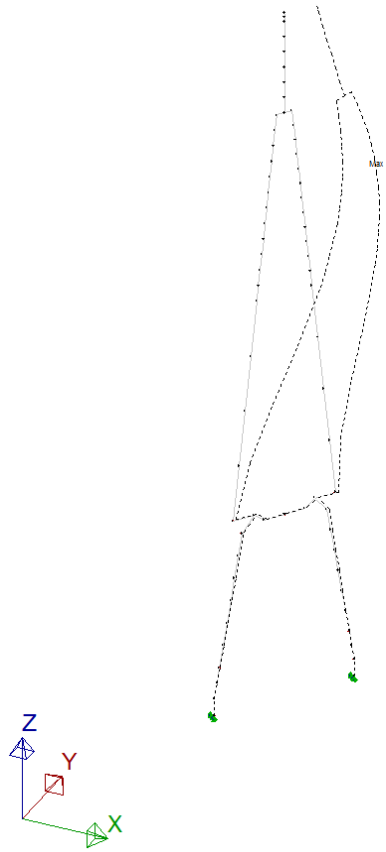
8.2 Stage A2

Mode:	Freq. [Hz]	Omega [rad/s]	Period [sec.]
1	0.177	1.111	5.654
2	0.517	3.247	1.935
3	0.778	4.888	1.285
4	1.127	7.078	0.888
5	1.139	7.154	0.878
6	1.174	7.374	0.852
7	1.842	11.573	0.543
8	1.924	12.092	0.520
9	2.679	16.831	0.373
10	2.825	17.749	0.354
11	3.094	19.441	0.323
12	3.447	21.661	0.290
13	4.286	26.927	0.233
14	4.533	28.480	0.221
15	4.908	30.840	0.204
16	5.490	34.495	0.182
17	6.068	38.128	0.165
18	7.026	44.146	0.142
19	7.145	44.896	0.140
20	7.431	46.690	0.135

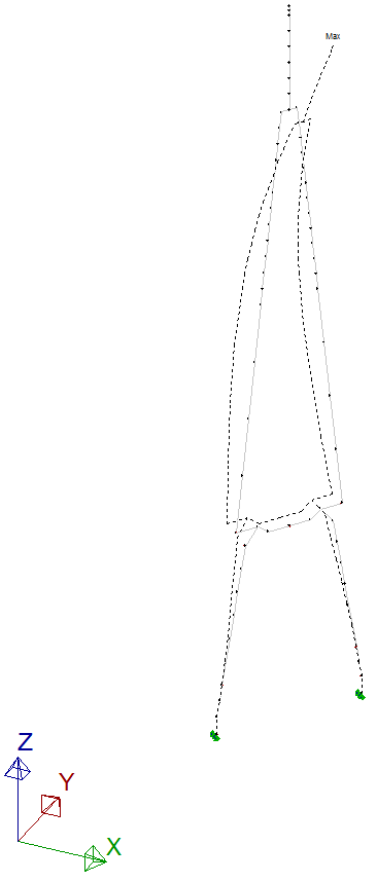
Mode 1 (longitudinal motion):



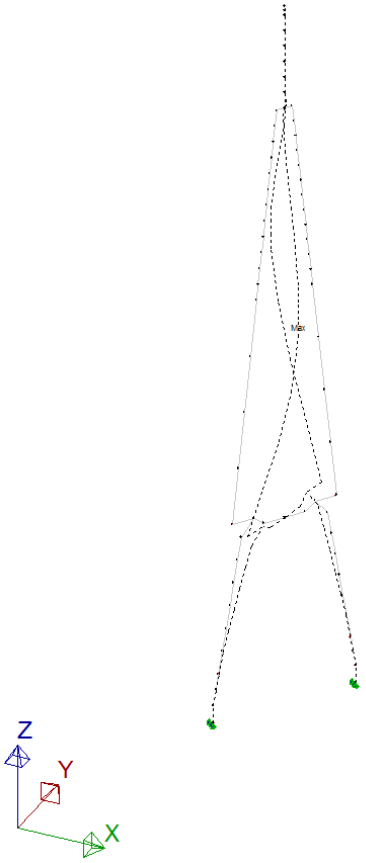
Mode 2 (transverse motion):



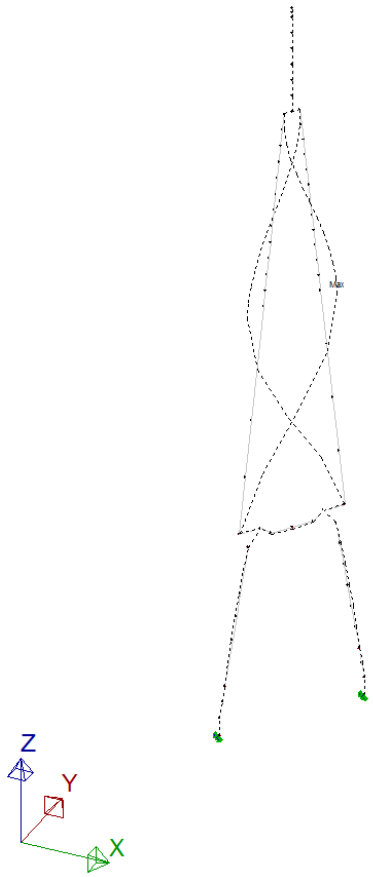
Mode 3 (longitudinal motion):



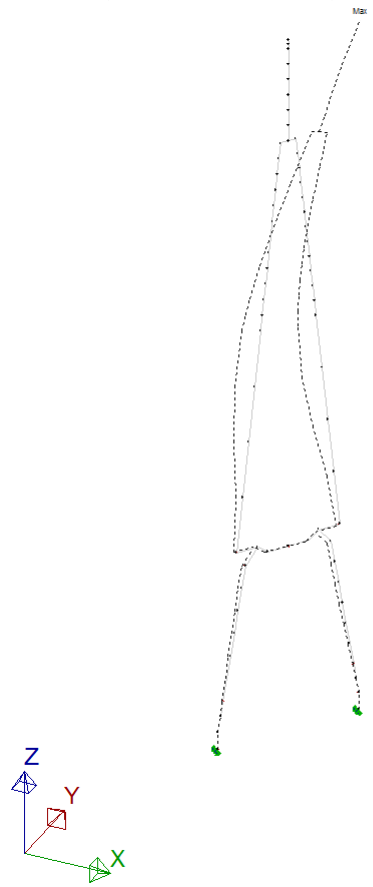
Mode 4 (rotational motion)::



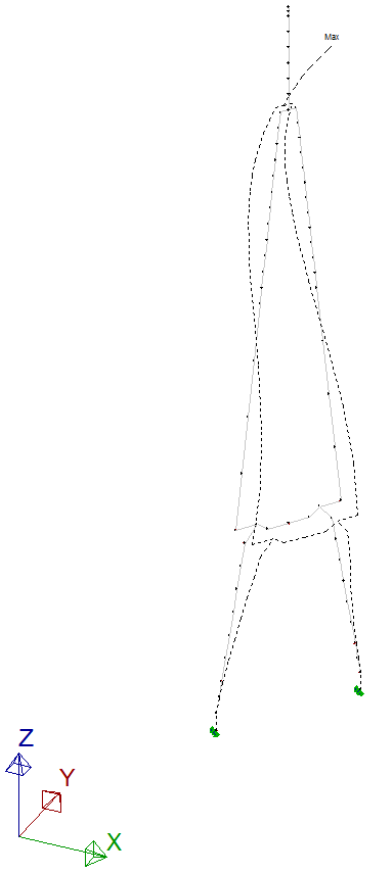
Mode 5 (transverse motion):



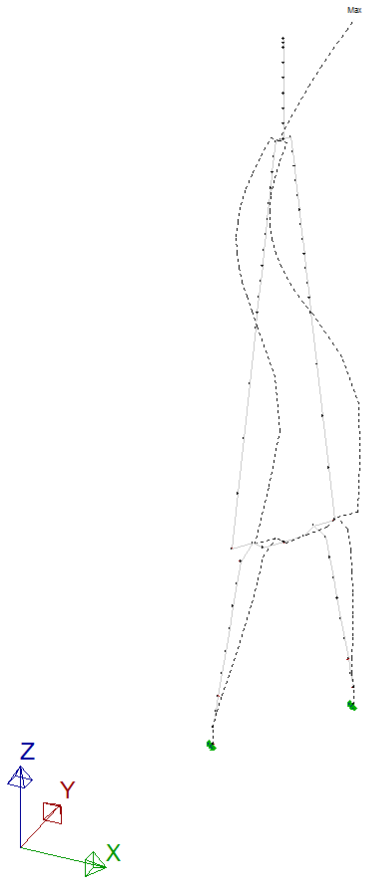
Mode 6 (transverse motion):



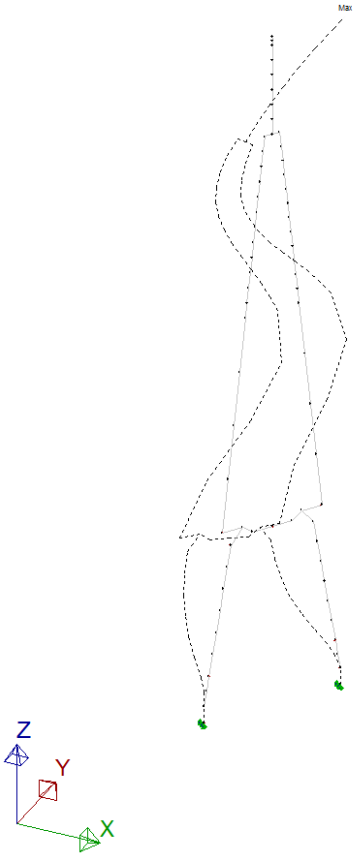
Mode 7 (longitudinal motion):



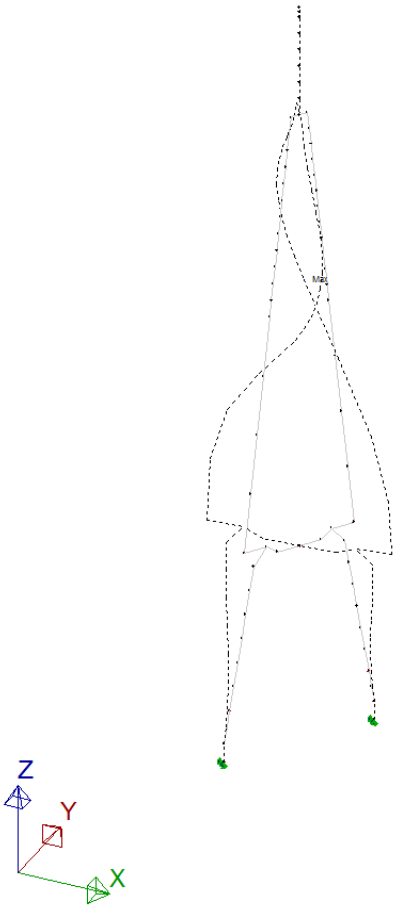
Mode 8 (transverse motion):



Mode 9 (transverse motion):



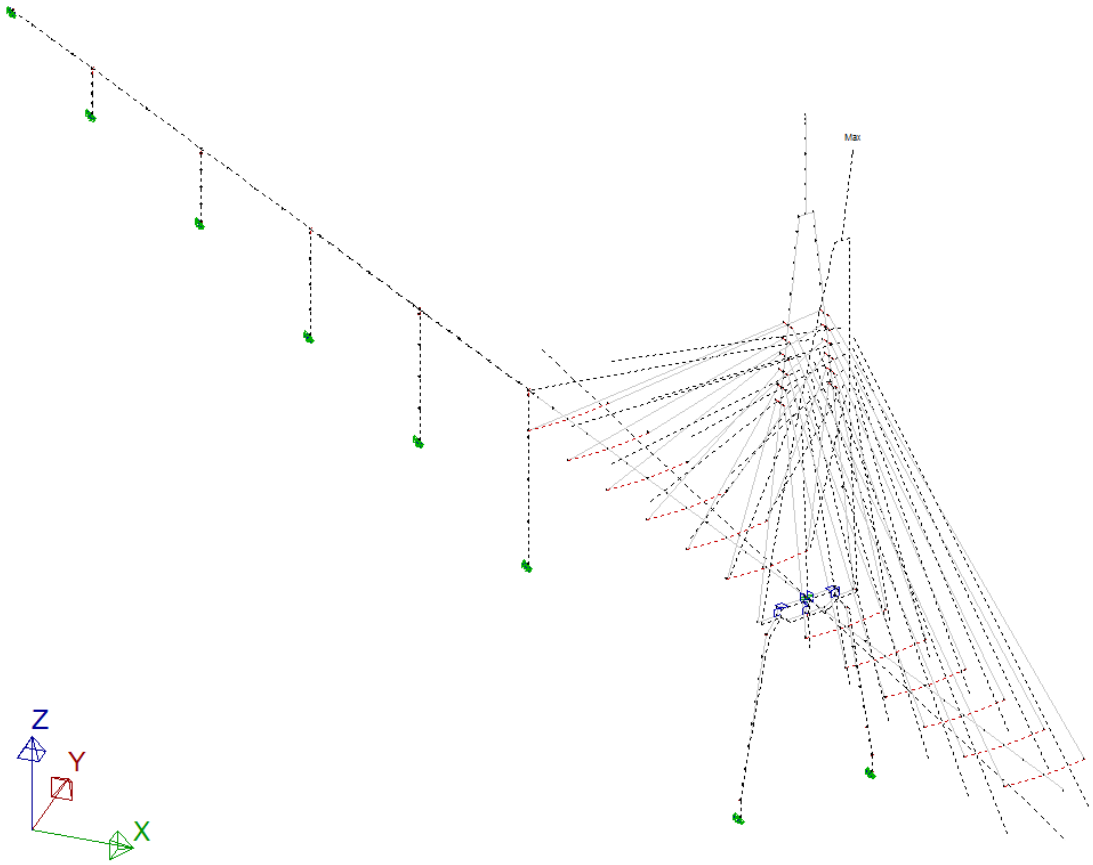
Mode 10 (rotational motion):



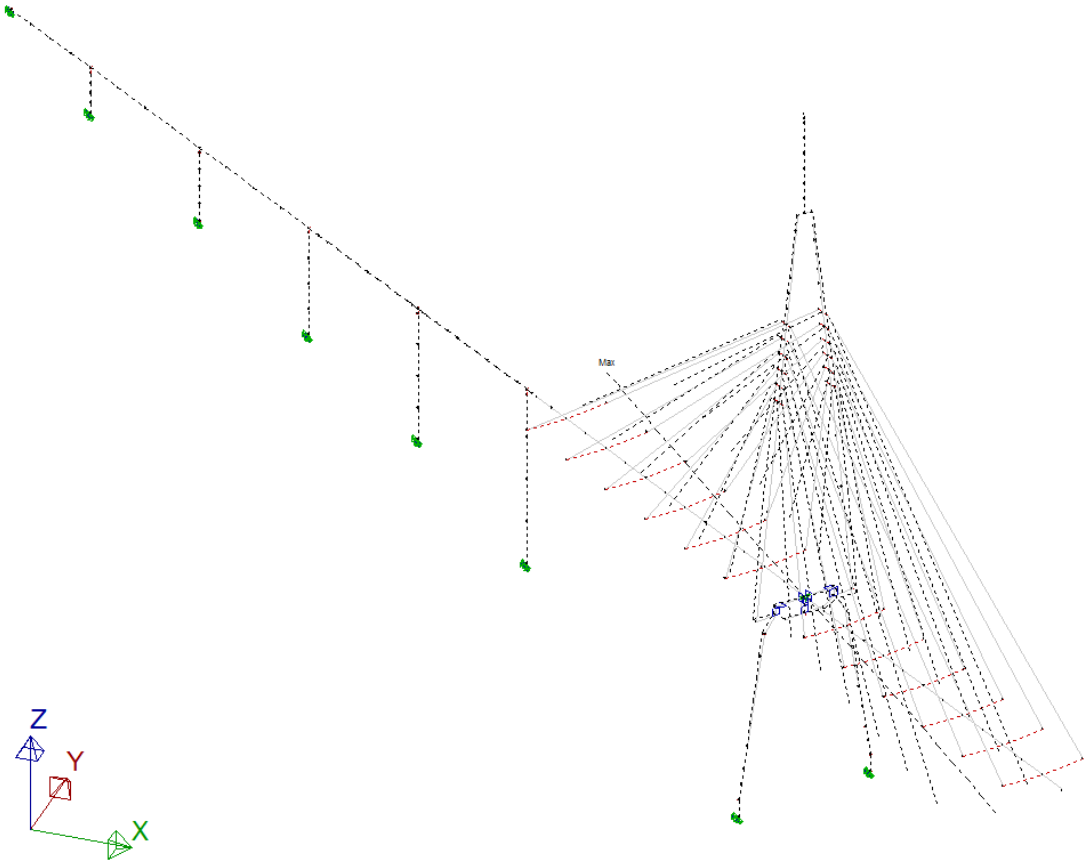
8.3 Stage B

Mode:	Freq. [Hz]	Omega [rad/s]	Period [sec.]
1	0.157	0.984	6.384
2	0.370	2.326	2.702
3	0.515	3.235	1.942
4	0.637	4.003	1.569
5	0.671	4.215	1.491
6	0.742	4.662	1.348
7	1.050	6.597	0.952
8	1.081	6.789	0.925
9	1.114	7.000	0.898
10	1.134	7.123	0.882
11	1.232	7.740	0.812
12	1.317	8.272	0.760
13	1.491	9.366	0.671
14	1.823	11.451	0.549
15	1.946	12.228	0.514
16	2.099	13.190	0.476
17	2.282	14.339	0.438
18	2.316	14.554	0.432
19	2.379	14.948	0.420
20	2.487	15.624	0.402
21	2.542	15.971	0.393
22	2.604	16.359	0.384
23	2.823	17.736	0.354
24	2.973	18.679	0.336
25	3.078	19.340	0.325
26	3.134	19.694	0.319
27	3.207	20.151	0.312
28	3.431	21.558	0.291
29	3.625	22.779	0.276
30	3.854	24.218	0.259
31	4.338	27.257	0.231
32	4.419	27.763	0.226
33	4.600	28.905	0.217
34	4.661	29.286	0.215
35	4.946	31.079	0.202

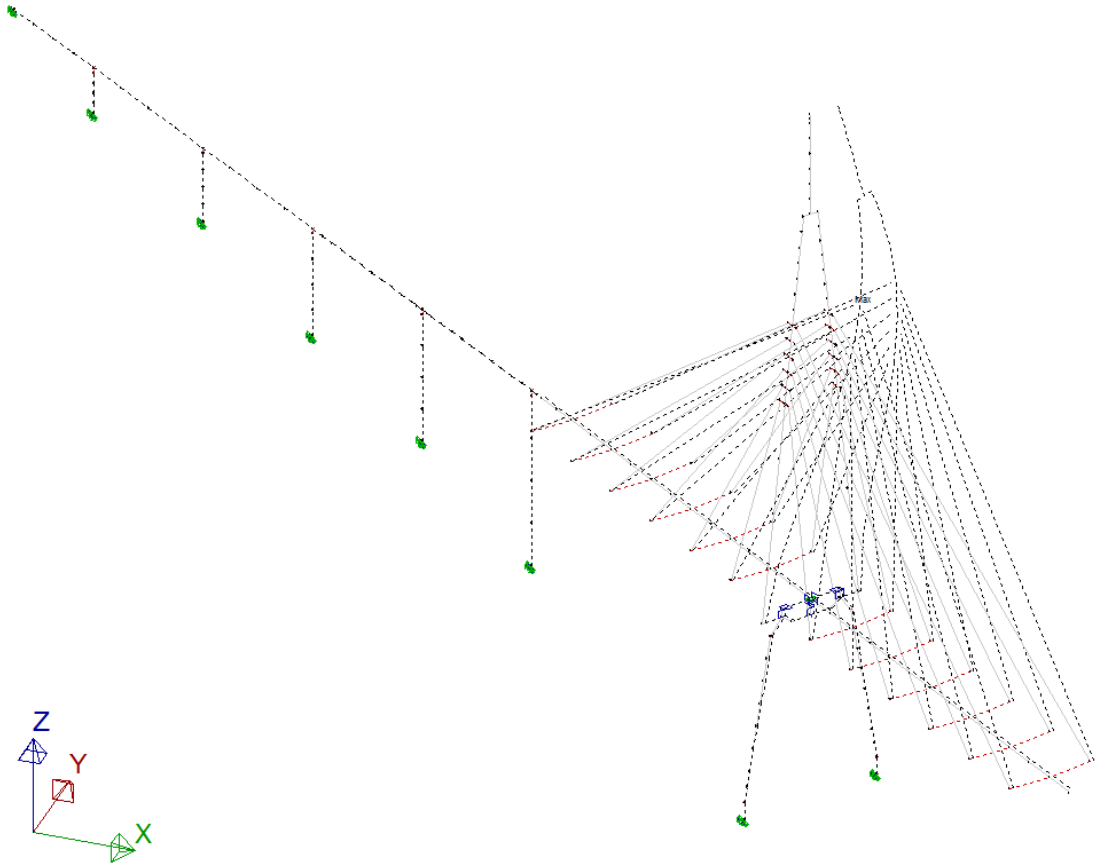
Mode 1 (longitudinal motion tower, vertical motion bridge girder):



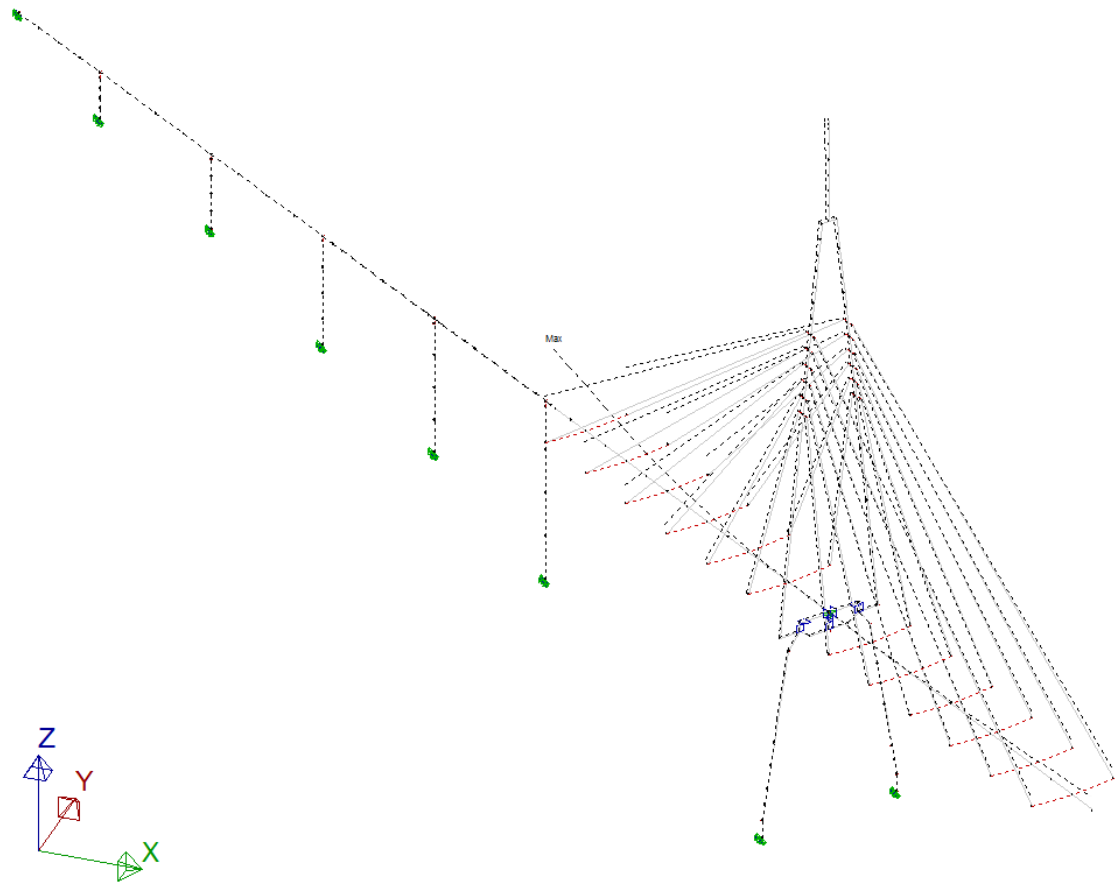
Mode 2 (rotational motion tower, transverse motion bridge girder):



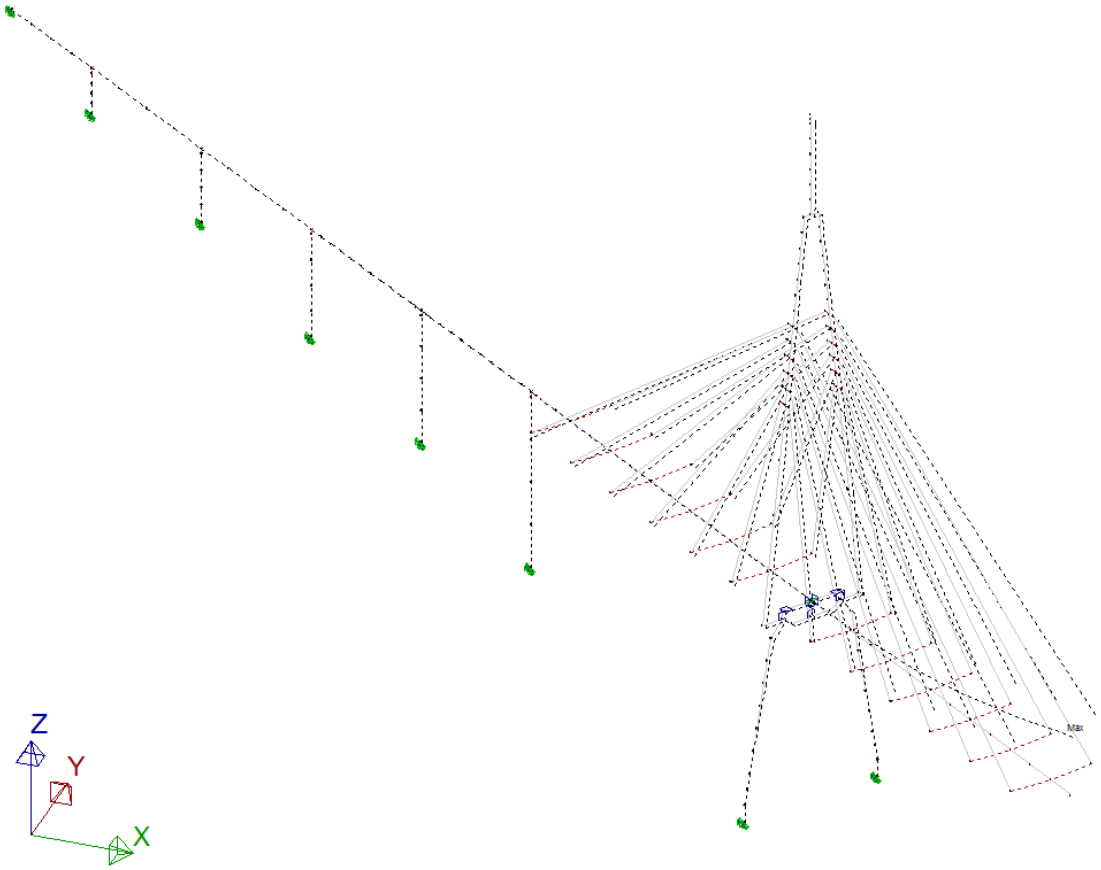
Mode 3 (transverse motion tower):



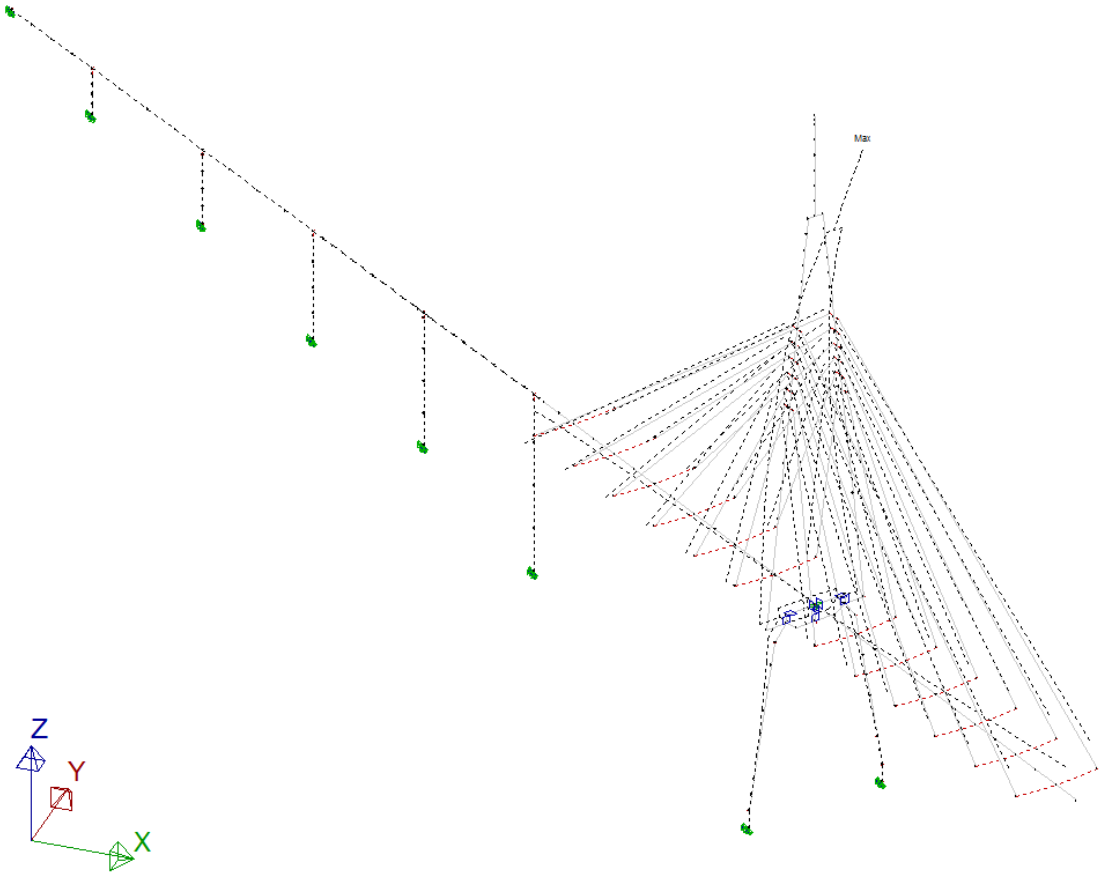
Mode 4 (vertical motion bridge girder):



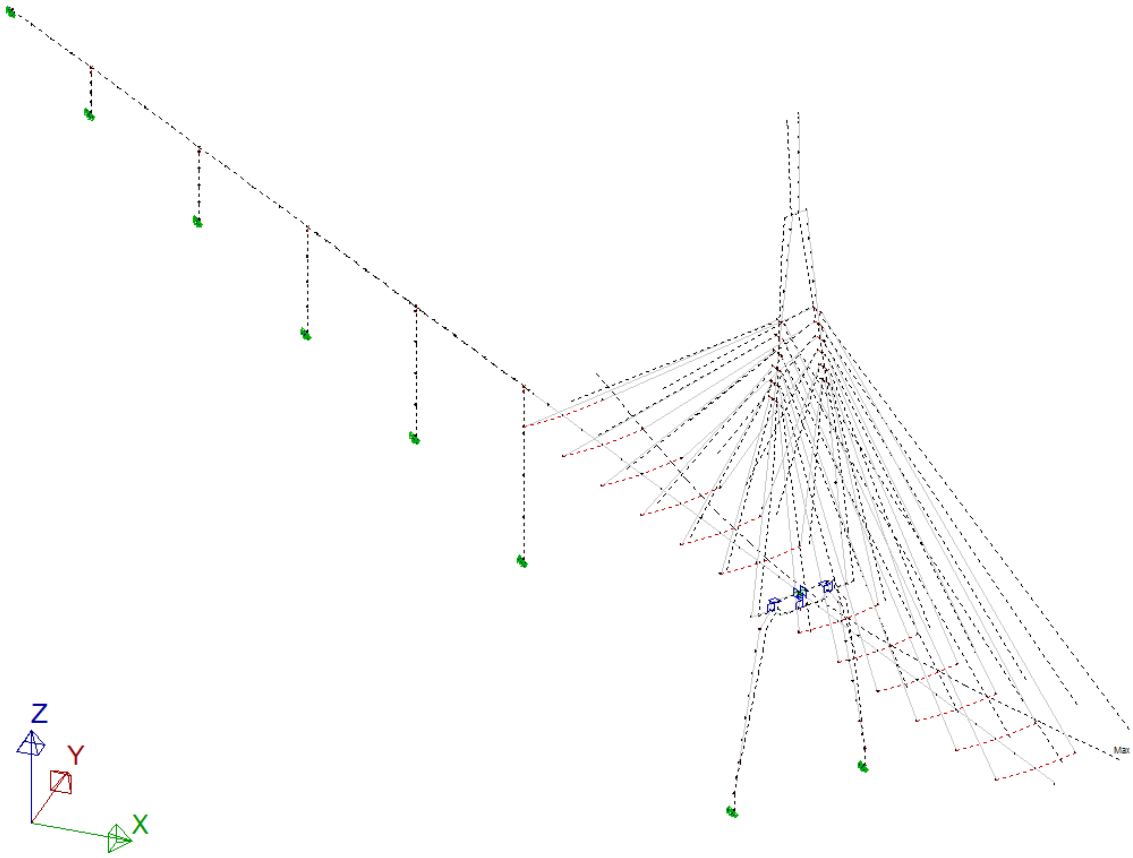
Mode 5 (longitudinal motion tower, vertical motion bridge girder):



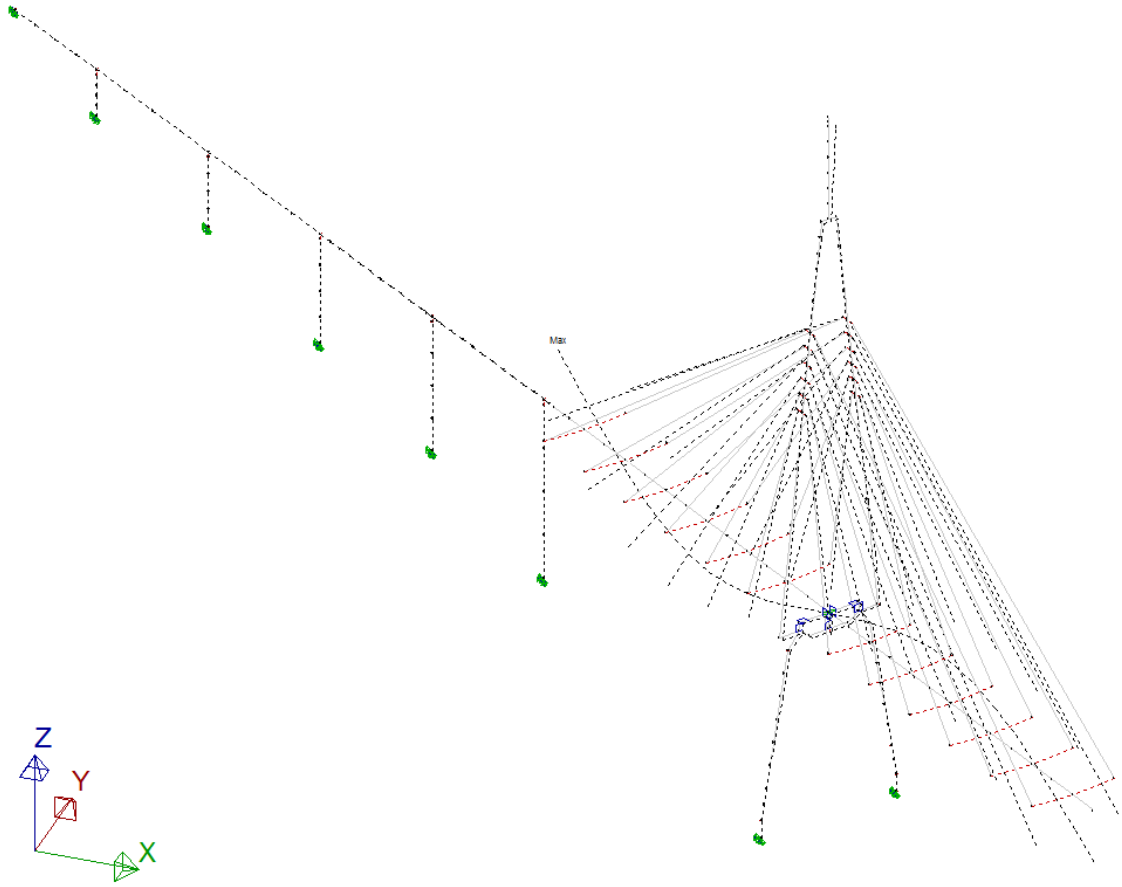
Mode 6 (longitudinal motion tower, vertical motion bridge girder):



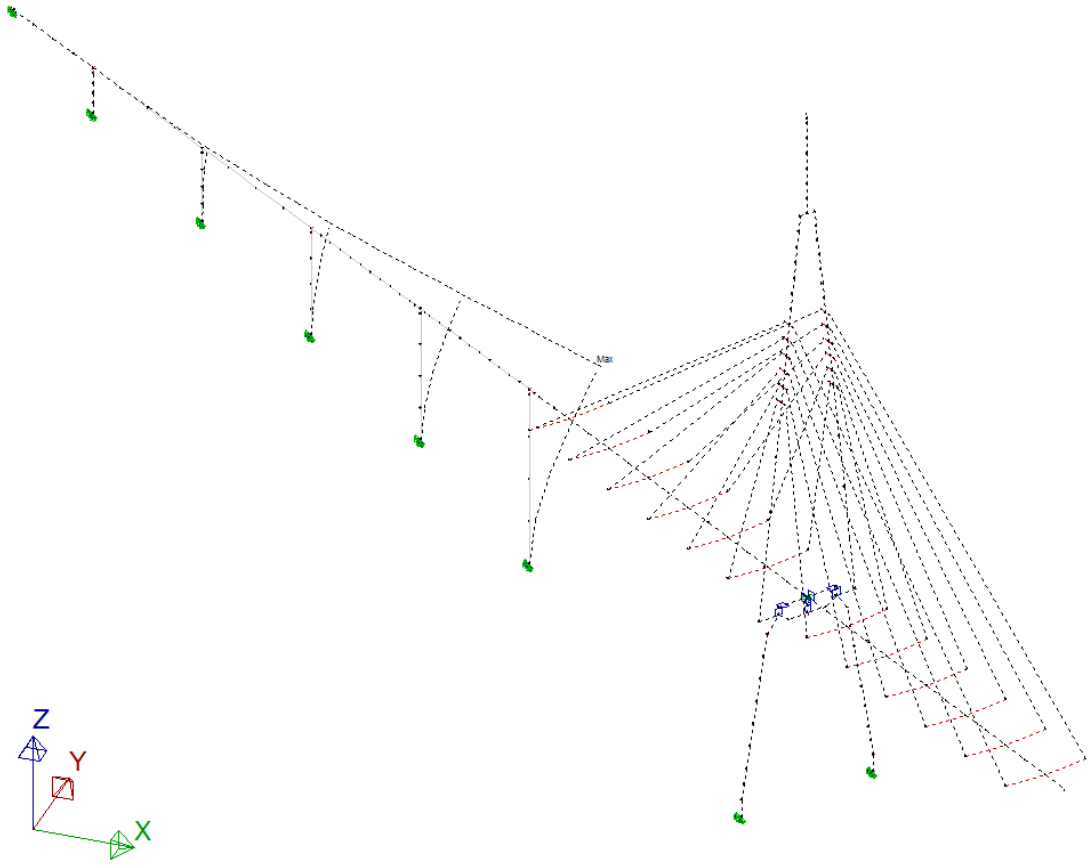
Mode 7 (transverse motion):



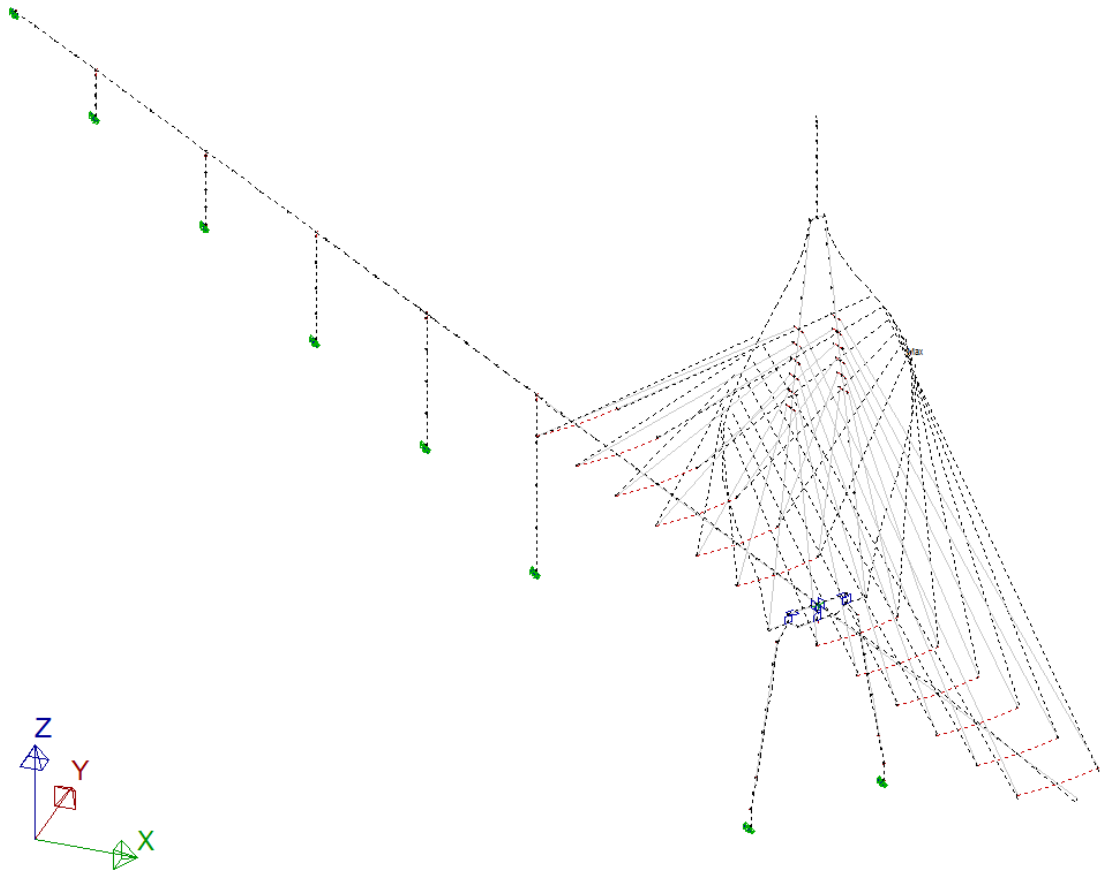
Mode 8 (longitudinal motion tower, vertical motion bridge girder):



Mode 9 (transverse motion back spans):



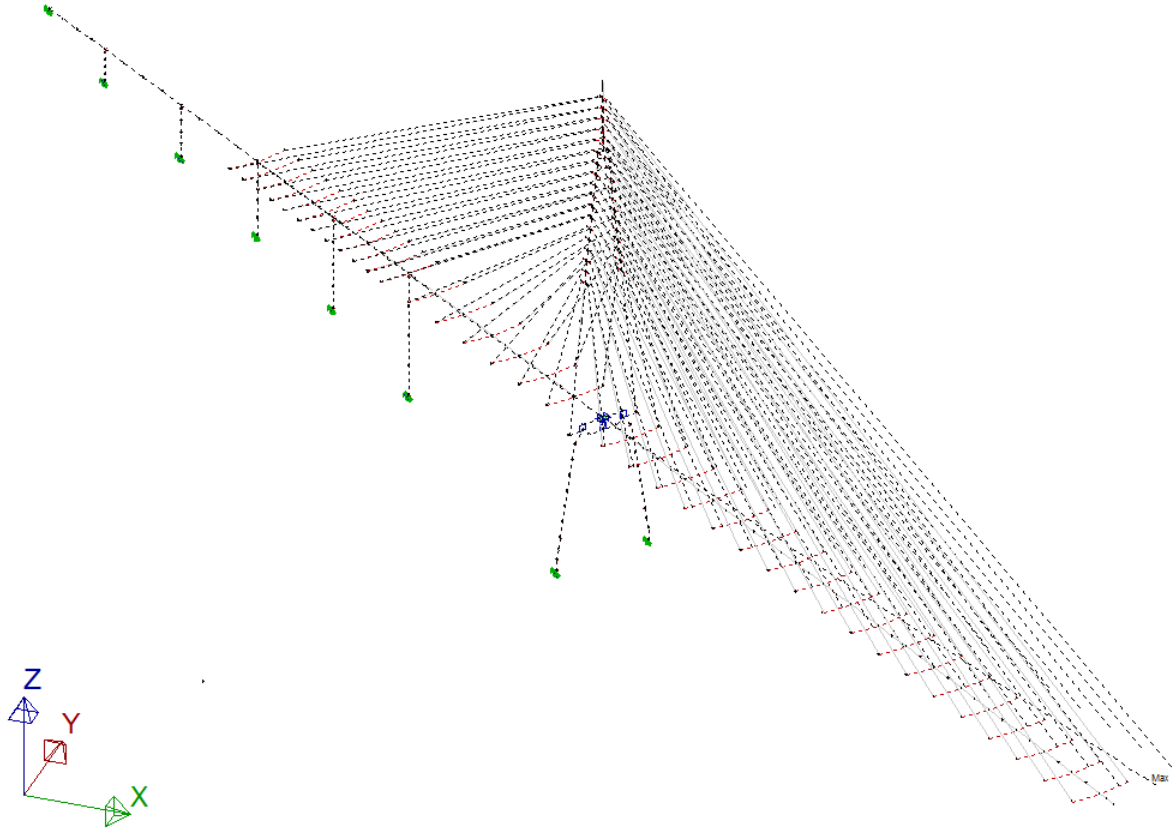
Mode 10 (transverse motion tower):



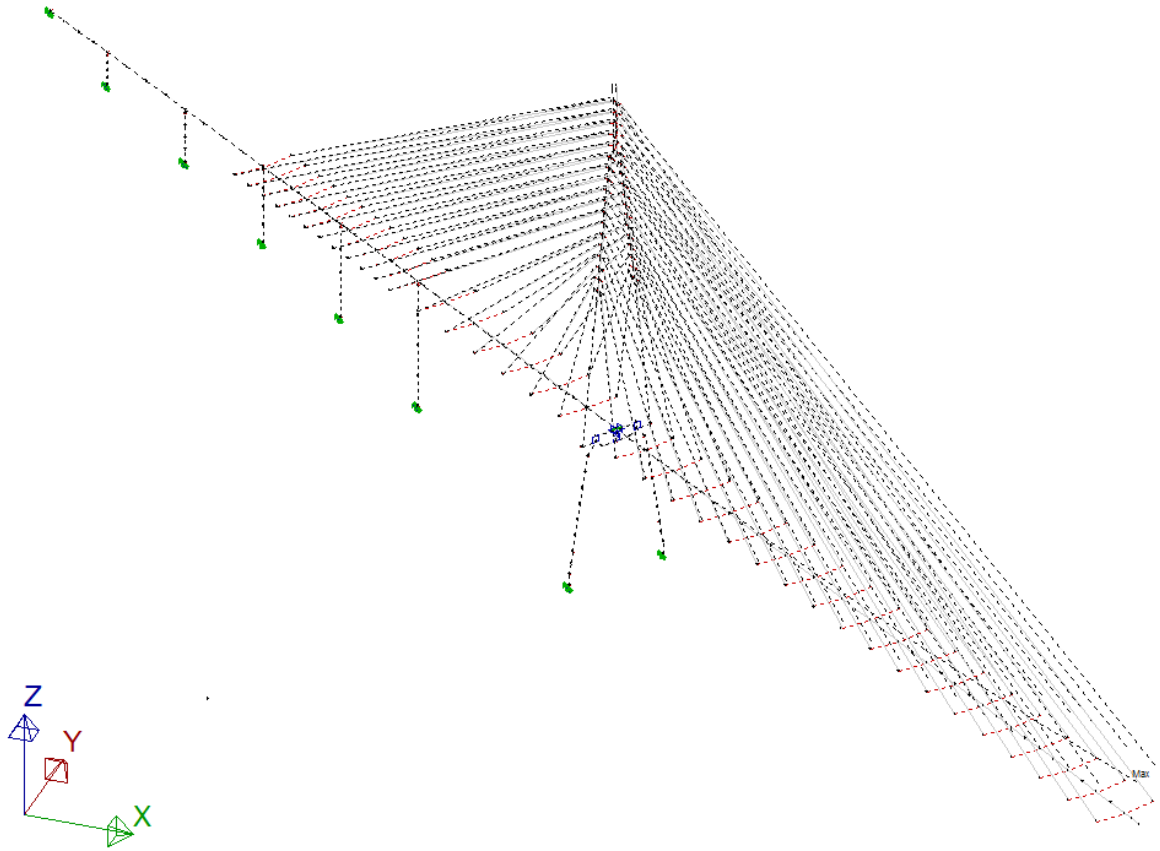
8.4 Stage C

Mode:	Freq. [Hz]	Omega [rad/s]	Period [sec.]
1	0.111	0.696	9.026
2	0.246	1.543	4.071
3	0.383	2.408	2.609
4	0.507	3.188	1.971
5	0.572	3.595	1.748
6	0.695	4.366	1.439
7	0.787	4.942	1.271
8	0.949	5.964	1.054
9	1.032	6.485	0.969
10	1.133	7.116	0.883
11	1.140	7.164	0.877
12	1.185	7.446	0.844
13	1.222	7.678	0.818
14	1.275	8.010	0.784
15	1.285	8.075	0.778
16	1.299	8.164	0.770
17	1.759	11.049	0.569
18	1.834	11.524	0.545
19	1.853	11.642	0.540
20	2.029	12.749	0.493
21	2.087	13.112	0.479
22	2.096	13.171	0.477
23	2.162	13.587	0.462
24	2.354	14.792	0.425
25	2.357	14.812	0.424
26	2.501	15.713	0.400
27	2.751	17.285	0.363
28	2.758	17.327	0.363
29	2.905	18.252	0.344
30	2.939	18.466	0.340
31	3.079	19.349	0.325
32	3.118	19.594	0.321
33	3.167	19.897	0.316
34	3.295	20.703	0.303
35	3.462	21.755	0.289
36	3.708	23.301	0.270
37	3.735	23.466	0.268
38	3.771	23.693	0.265
39	3.846	24.166	0.260
40	3.940	24.757	0.254
41	4.159	26.132	0.240
42	4.348	27.322	0.230
43	4.550	28.587	0.220
44	4.575	28.744	0.219
45	4.674	29.365	0.214
46	4.884	30.684	0.205
47	5.008	31.466	0.200
48	5.217	32.777	0.192
49	5.340	33.555	0.187
50	5.545	34.843	0.180

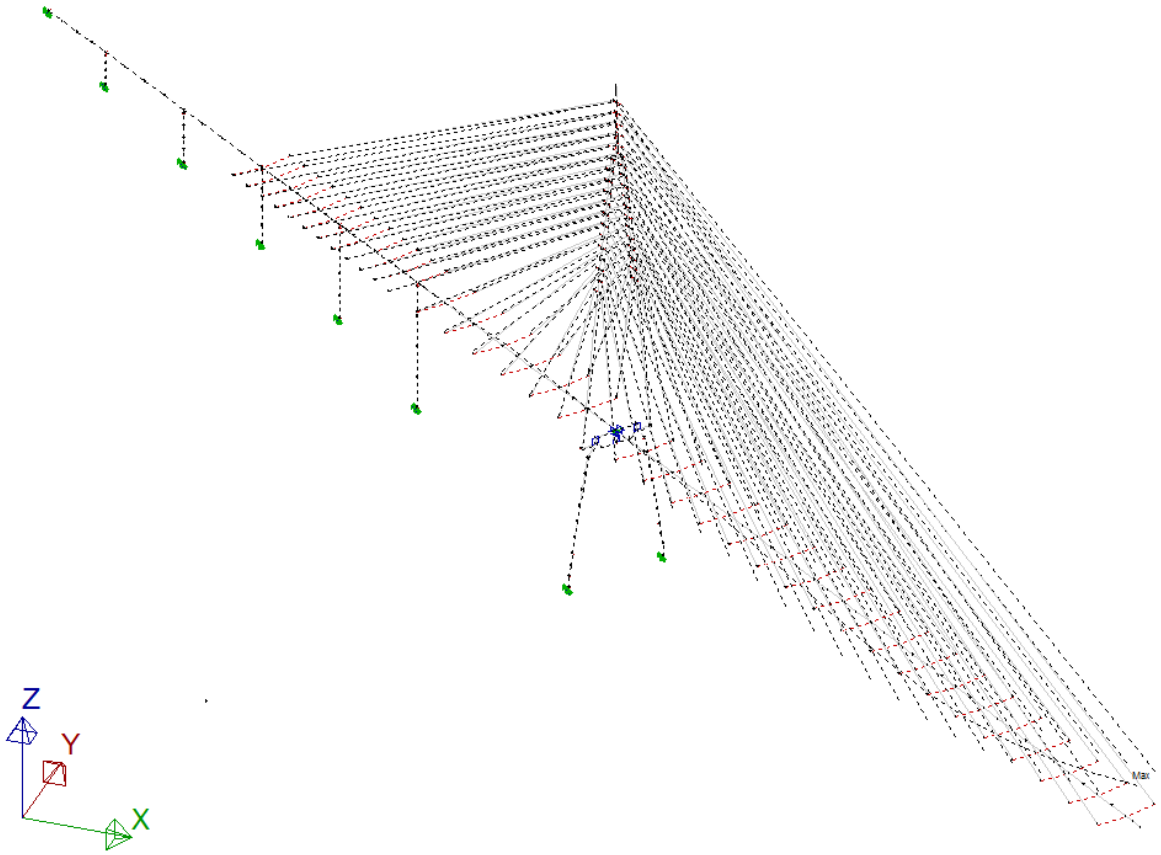
Mode 1 (transverse motion bridge girder):



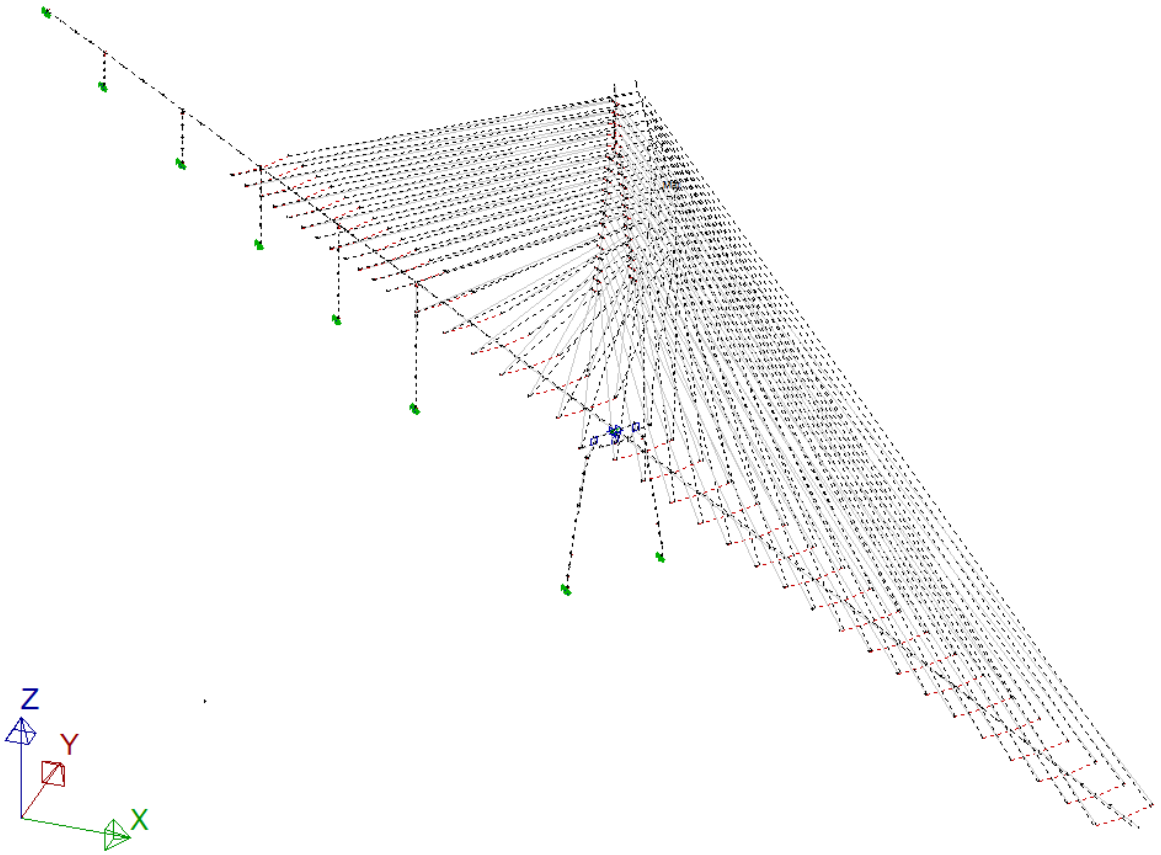
Mode 2 (longitudinal motion tower, vertical motion bridge girder):



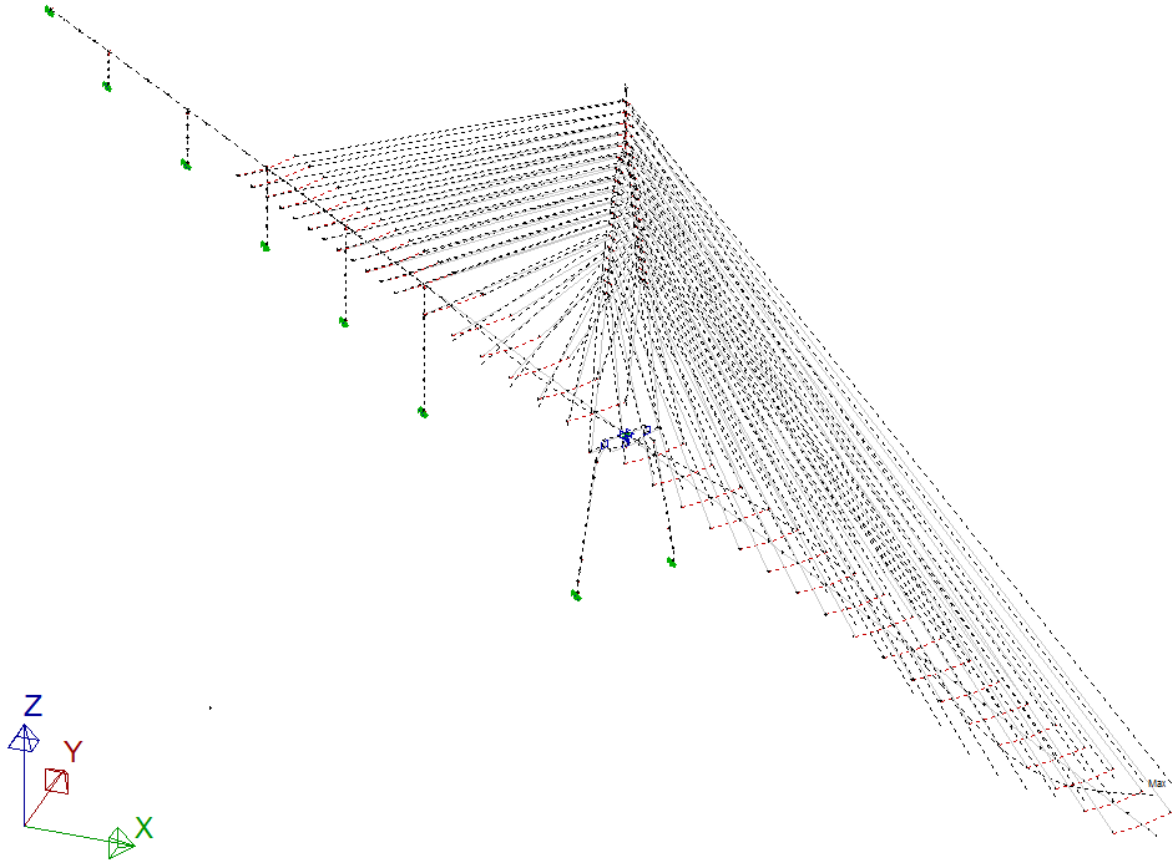
Mode 3 (longitudinal motion tower, vertical motion bridge girder):



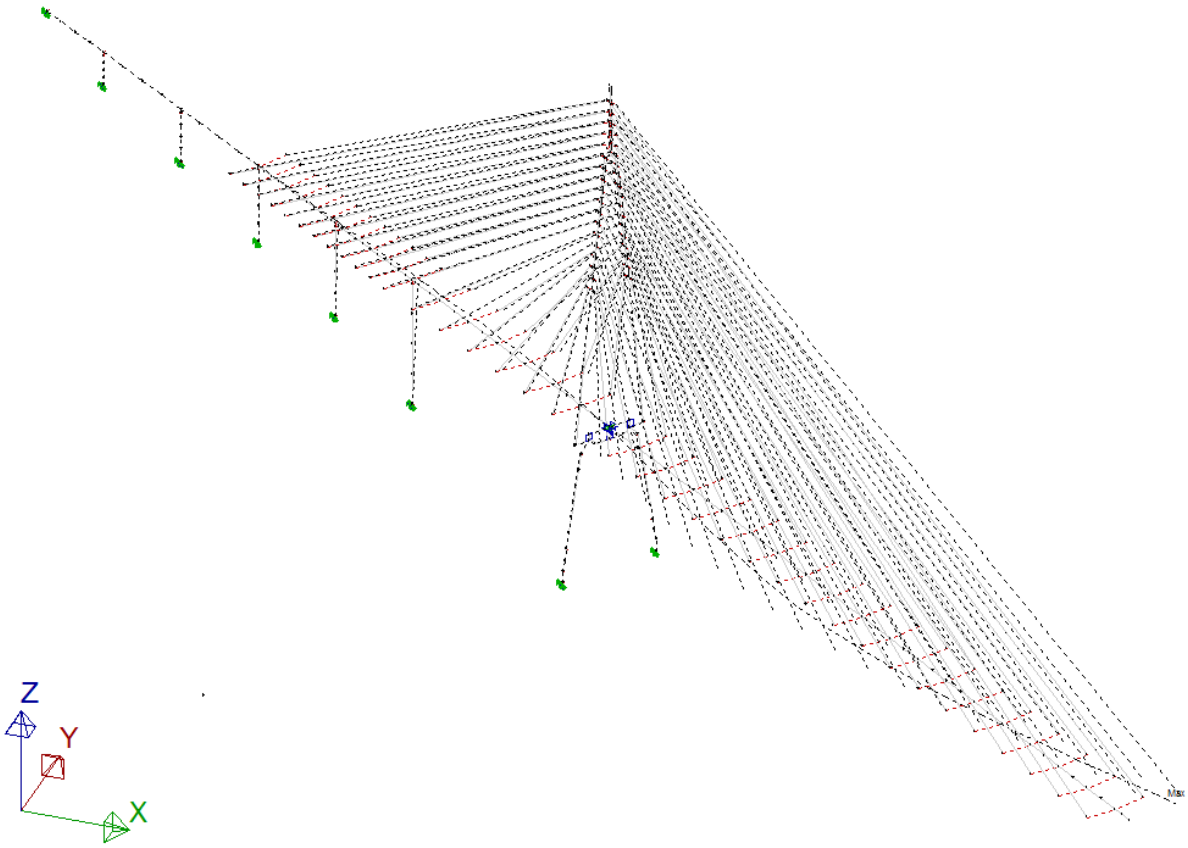
Mode 4 (transverse motion tower):



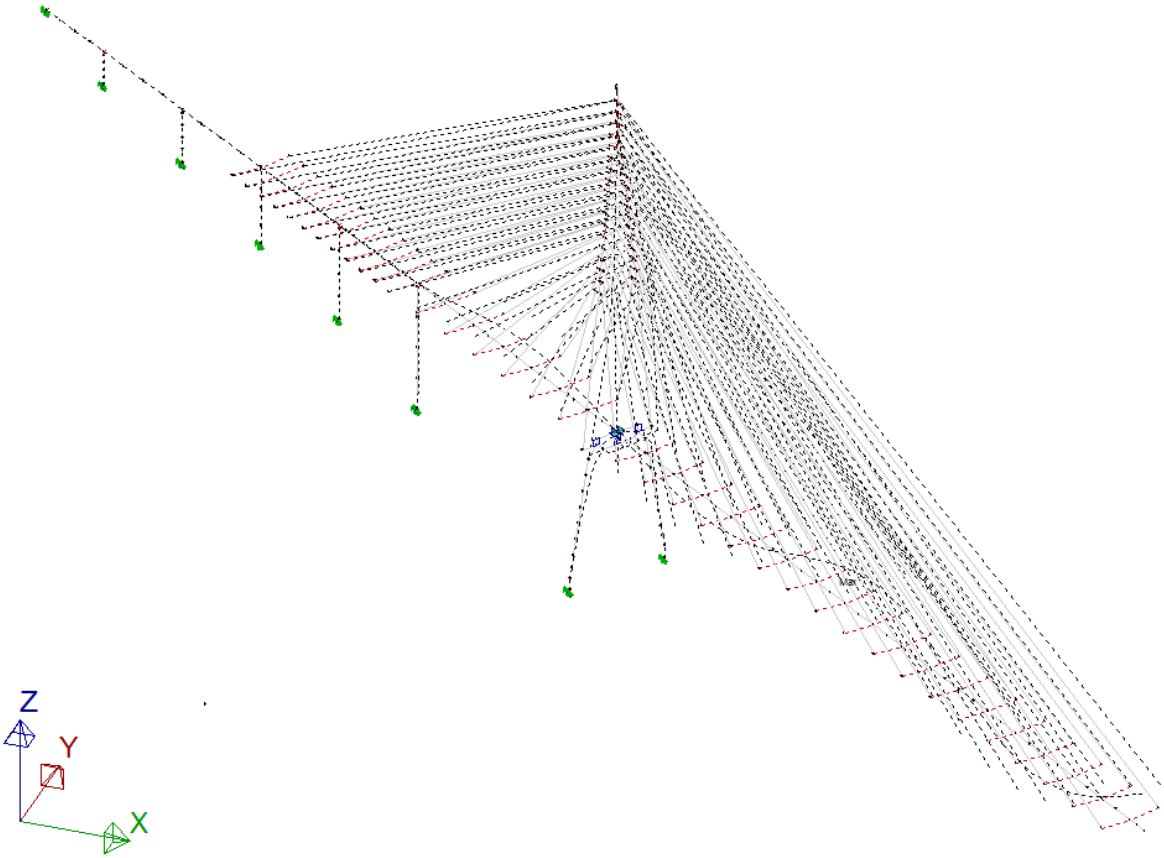
Mode 5 (longitudinal motion tower, vertical motion bridge girder):



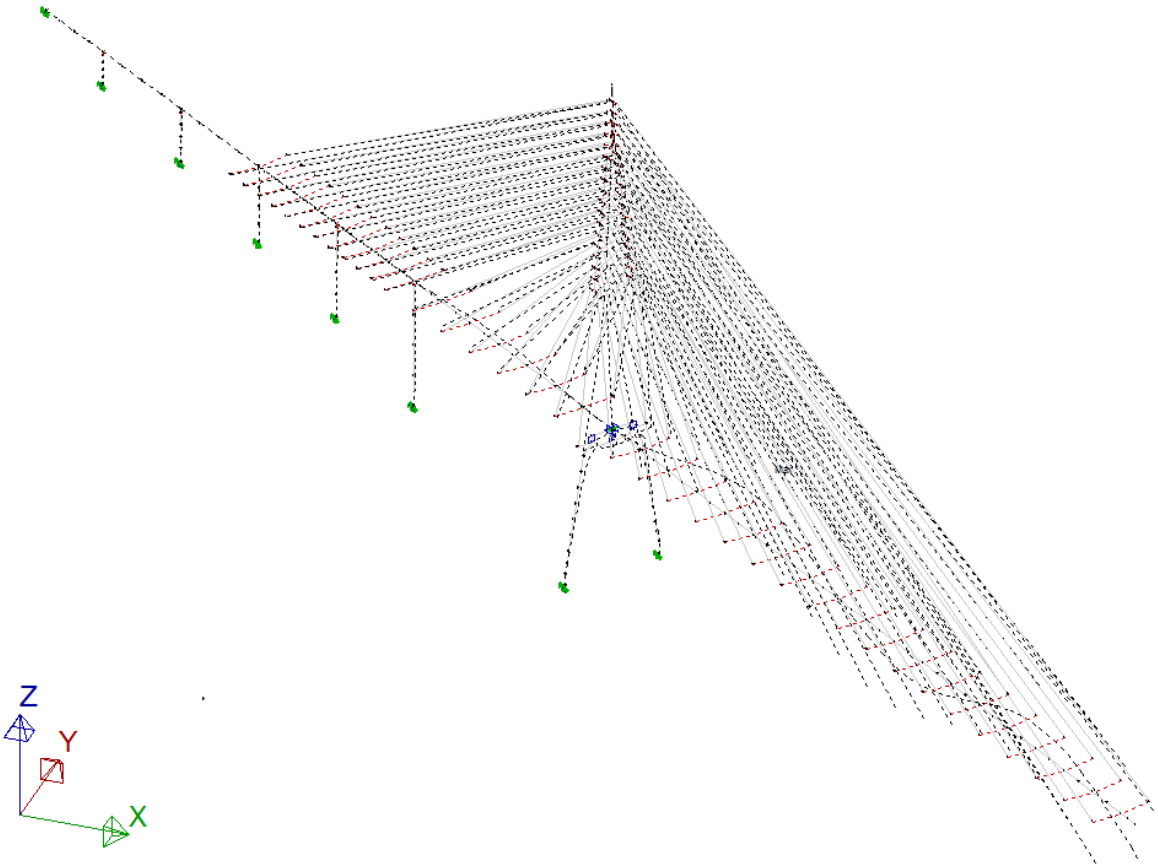
Mode 6 (transverse motion):



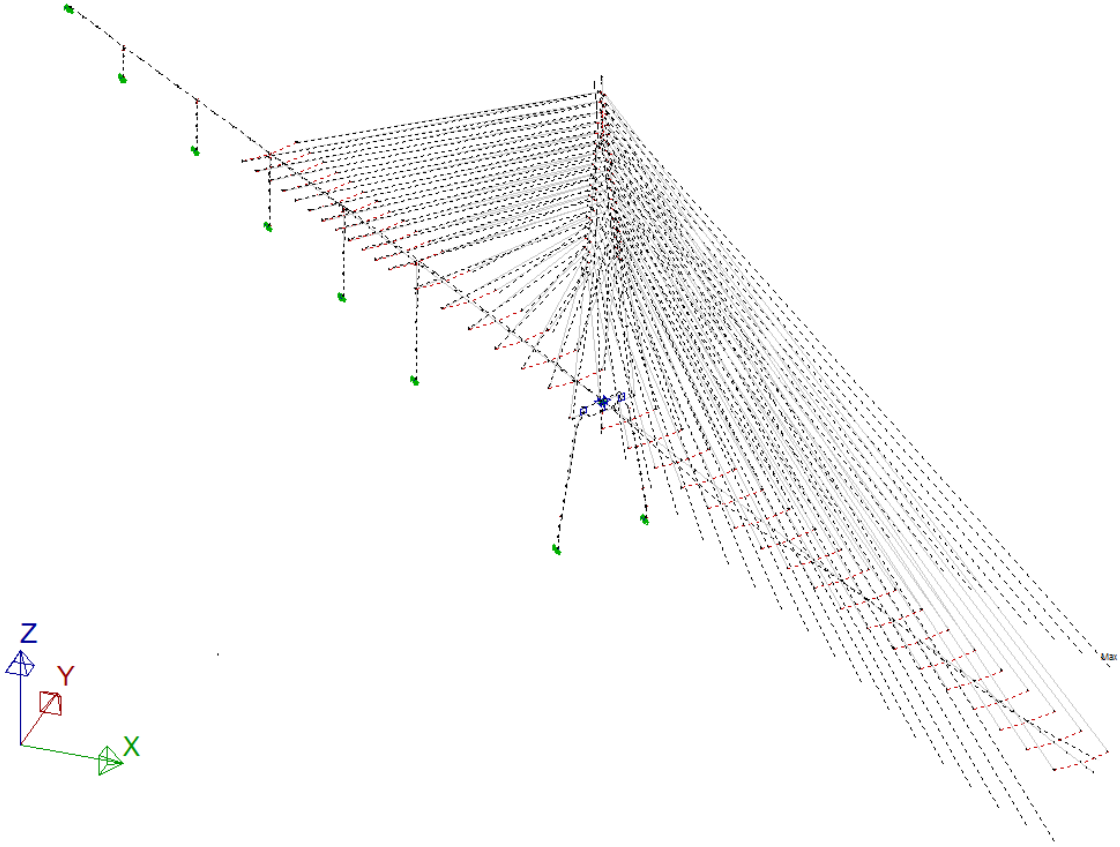
Mode 7 (longitudinal motion tower, vertical motion bridge girder):



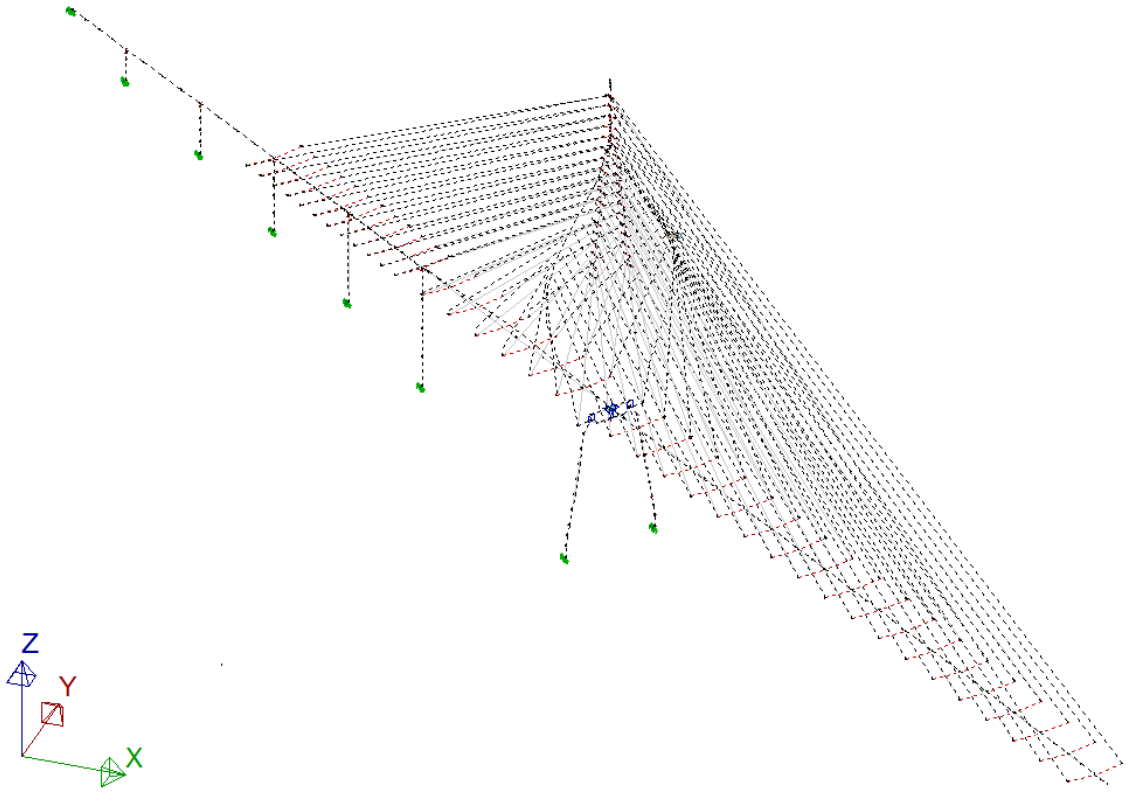
Mode 8 (longitudinal motion tower, vertical motion bridge girder):



Mode 9 (rotational motion tower/bridge girder):



Mode 10 (transverse motion tower):



Analysis of construction stages

9 Mode by mode response

Explanations:

D-Mech	=	Structural damping ratio
D-Aero	=	Aerodynamic damping ratio
D-Tot	=	Total damping ratio
Freq	=	Natural frequency
W-Stdv	=	Standard deviation of displacement
W-Peak	=	Peak factor of displacement
W-Max	=	Max displacement (W-Stdv x W-Peak)
A-Stdv	=	Standard deviation of acceleration
A-Peak	=	Peak factor of acceleration
A-Max	=	Max acceleration (W-Stdv x W-Peak)

9.1 Stage A1

The response of each mode at wind direction 210 deg is listed below.

Mode	D-Mech	D-Aero	D-Tot	Freq	W-Stdv	W-Peak	W-Max	A-Stdv	A-Peak	A-Max
1	0.0080	0.0038	0.0118	0.3436	0.0782	3.4002	0.2660	0.3156	3.4570	1.0911
2	0.0080	0.0004	0.0084	1.7639	0.0008	3.8037	0.0031	0.0727	3.8890	0.2828
3	0.0080	0.0005	0.0085	2.2106	0.0006	3.8661	0.0024	0.0863	3.9460	0.3405
4	0.0080	0.0002	0.0082	6.2116	0.0000	4.0341	0.0002	0.0348	4.1988	0.1459
5	0.0080	0.0001	0.0081	11.0757	0.0000	3.0000	0.0000	0.0150	4.3341	0.0651
6	0.0080	0.0001	0.0081	12.1917	0.0000	3.0000	0.0000	0.0181	4.3562	0.0790
7	0.0080	0.0000	0.0080	14.8980	0.0000	3.0000	0.0000	0.0000	3.0000	0.0000
8	0.0080	0.0001	0.0081	20.1764	0.0000	3.0000	0.0000	0.0110	4.4702	0.0492
9	0.0080	0.0000	0.0080	30.1667	0.0000	3.0000	0.0000	0.0074	4.5592	0.0337
10	0.0080	0.0000	0.0080	31.0386	0.0000	3.0000	0.0000	0.0057	4.5655	0.0258

9.2 Stage A2

The response of each mode at wind direction 210 deg is listed below.

Mode	D-Mech	D-Aero	D-Tot	Freq	W-Stdv	W-Peak	W-Max	A-Stdv	A-Peak	A-Max
1	0.0080	0.0079	0.0159	0.1769	0.2295	3.1939	0.7329	0.2403	3.2725	0.7863
2	0.0080	-0.0004	0.0076	0.5169	0.0057	3.5043	0.0200	0.0496	3.5626	0.1767
3	0.0080	0.0016	0.0096	0.7779	0.0057	3.6129	0.0207	0.1101	3.6775	0.4049
4	0.0080	0.0006	0.0086	1.1265	0.0006	3.7327	0.0023	0.0267	3.7732	0.1008
5	0.0080	-0.0004	0.0076	1.1385	0.0007	3.7541	0.0027	0.0342	3.7757	0.1291
6	0.0080	0.0004	0.0084	1.1736	0.0019	3.7098	0.0071	0.0796	3.7854	0.3011
7	0.0080	0.0007	0.0087	1.8420	0.0009	3.7673	0.0032	0.0691	3.9004	0.2696
8	0.0080	-0.0000	0.0080	1.9245	0.0004	3.8222	0.0014	0.0377	3.9113	0.1476
9	0.0080	0.0000	0.0080	2.6787	0.0001	3.8918	0.0003	0.0169	3.9938	0.0674
10	0.0080	0.0003	0.0083	2.8248	0.0001	3.9032	0.0003	0.0146	4.0067	0.0584
11	0.0080	-0.0001	0.0079	3.0941	0.0000	3.9669	0.0002	0.0142	4.0291	0.0572
12	0.0080	0.0004	0.0084	3.4474	0.0002	3.9031	0.0007	0.0428	4.0566	0.1735
13	0.0080	0.0000	0.0080	4.2856	0.0000	3.9961	0.0002	0.0211	4.1098	0.0867
14	0.0080	0.0002	0.0082	4.5328	0.0000	3.9788	0.0001	0.0125	4.1231	0.0514
15	0.0080	0.0000	0.0080	4.9083	0.0000	3.0000	0.0000	0.0016	4.1424	0.0065
16	0.0080	0.0002	0.0082	5.4901	0.0001	3.9549	0.0002	0.0249	4.1694	0.1036
17	0.0080	-0.0000	0.0080	6.0683	0.0000	3.0000	0.0000	0.0073	4.1932	0.0306
18	0.0080	-0.0000	0.0080	7.0260	0.0000	4.0734	0.0000	0.0113	4.2281	0.0480
19	0.0080	0.0001	0.0081	7.1454	0.0000	3.0000	0.0000	0.0087	4.2319	0.0369
20	0.0080	0.0000	0.0080	7.4309	0.0000	3.0000	0.0000	0.0032	4.2412	0.0136

9.3 Stage B

The response of each mode at wind direction 150 deg is listed below.

Mode	D-Mech	D-Aero	D-Tot	Freq	W-Stdv	W-Peak	W-Max	A-Stdv	A-Peak	A-Max
1	0.0080	0.0123	0.0203	0.1566	0.2477	3.1925	0.7907	0.2313	3.2718	0.7569
2	0.0080	0.0016	0.0096	0.3701	0.0128	3.4293	0.0438	0.0613	3.4732	0.2129
3	0.0080	0.0023	0.0103	0.5149	0.0146	3.4412	0.0502	0.1008	3.5623	0.3591
4	0.0080	0.0084	0.0164	0.6372	0.0474	3.5774	0.1697	0.6589	3.6285	2.3909
5	0.0080	0.0070	0.0150	0.6708	0.0365	3.5942	0.1311	0.5664	3.6410	2.0621
6	0.0080	0.0013	0.0093	0.7419	0.0071	3.6326	0.0259	0.1406	3.6637	0.5150
7	0.0080	0.0006	0.0086	1.0499	0.0016	3.6016	0.0059	0.0409	3.7548	0.1536
8	0.0080	0.0053	0.0133	1.0805	0.0080	3.7265	0.0298	0.3248	3.7648	1.2228
9	0.0080	0.0001	0.0081	1.1142	0.0003	3.6769	0.0013	0.0119	3.7704	0.0447
10	0.0080	0.0009	0.0089	1.1336	0.0013	3.7455	0.0047	0.0573	3.7751	0.2164
11	0.0080	0.0009	0.0089	1.2319	0.0022	3.7029	0.0080	0.0911	3.7965	0.3459
12	0.0080	0.0045	0.0125	1.3166	0.0059	3.7502	0.0220	0.3169	3.8155	1.2090
13	0.0080	0.0004	0.0084	1.4907	0.0007	3.7965	0.0027	0.0514	3.8460	0.1976
14	0.0080	0.0004	0.0084	1.8225	0.0006	3.8278	0.0022	0.0576	3.8972	0.2243
15	0.0080	0.0004	0.0084	1.9461	0.0007	3.7092	0.0024	0.0449	3.9137	0.1758
16	0.0080	0.0006	0.0086	2.0993	0.0005	3.8905	0.0019	0.0701	3.9330	0.2758
17	0.0080	0.0001	0.0081	2.2823	0.0004	3.8464	0.0014	0.0488	3.9538	0.1931
18	0.0080	0.0000	0.0080	2.3163	0.0001	3.8503	0.0004	0.0144	3.9576	0.0569
19	0.0080	0.0001	0.0081	2.3792	0.0002	3.8781	0.0010	0.0391	3.9642	0.1551
20	0.0080	0.0021	0.0101	2.4866	0.0012	3.9211	0.0046	0.2299	3.9755	0.9140
21	0.0080	0.0005	0.0085	2.5419	0.0003	3.9301	0.0011	0.0577	3.9808	0.2298
22	0.0080	0.0003	0.0083	2.6036	0.0003	3.8533	0.0011	0.0462	3.9866	0.1842
23	0.0080	0.0002	0.0082	2.8228	0.0001	3.9442	0.0005	0.0336	4.0066	0.1345
24	0.0080	0.0018	0.0098	2.9728	0.0008	3.9410	0.0031	0.2022	4.0195	0.8129
25	0.0080	0.0004	0.0084	3.0781	0.0001	3.9630	0.0004	0.0266	4.0279	0.1071
26	0.0080	0.0003	0.0083	3.1343	0.0001	3.9589	0.0005	0.0337	4.0324	0.1360
27	0.0080	0.0001	0.0081	3.2072	0.0001	3.9091	0.0003	0.0171	4.0379	0.0690
28	0.0080	0.0003	0.0083	3.4310	0.0002	3.9623	0.0006	0.0506	4.0553	0.2053
29	0.0080	0.0001	0.0081	3.6254	0.0000	3.9701	0.0001	0.0099	4.0688	0.0401
30	0.0080	0.0004	0.0084	3.8544	0.0002	3.9150	0.0007	0.0497	4.0839	0.2031
31	0.0080	0.0002	0.0082	4.3381	0.0001	3.9652	0.0003	0.0306	4.1125	0.1257
32	0.0080	0.0000	0.0080	4.4186	0.0000	3.9395	0.0002	0.0153	4.1173	0.0631
33	0.0080	0.0001	0.0081	4.6005	0.0000	3.9809	0.0001	0.0106	4.1268	0.0439
34	0.0080	0.0010	0.0090	4.6610	0.0002	4.0611	0.0009	0.1393	4.1302	0.5752
35	0.0080	0.0001	0.0081	4.9463	0.0000	4.0507	0.0001	0.0133	4.1444	0.0550

9.4 Stage C

The response of each mode at wind direction 150 deg is listed below.

Mode	D-Mech	D-Aero	D-Tot	Freq	W-Stdv	W-Peak	W-Max	A-Stdv	A-Peak	A-Max
1	0.0050	0.0104	0.0154	0.1108	0.5361	3.0635	1.6424	0.2341	3.1443	0.7361
2	0.0050	0.0292	0.0342	0.2456	0.3868	3.3051	1.2784	0.8155	3.4055	2.7772
3	0.0050	0.0178	0.0228	0.3832	0.1354	3.4437	0.4663	0.7084	3.5009	2.4799
4	0.0050	0.0039	0.0089	0.5074	0.0299	3.4741	0.1037	0.2284	3.5577	0.8127
5	0.0050	0.0109	0.0159	0.5720	0.0448	3.5634	0.1596	0.5314	3.5995	1.9129
6	0.0050	0.0013	0.0063	0.6948	0.0085	3.6054	0.0308	0.1433	3.6443	0.5221
7	0.0050	0.0060	0.0110	0.7862	0.0157	3.6520	0.0575	0.3535	3.6804	1.3011
8	0.0050	0.0052	0.0102	0.9489	0.0120	3.6921	0.0441	0.3754	3.7295	1.4002
9	0.0050	0.0002	0.0052	1.0329	0.0033	3.7105	0.0124	0.1227	3.7494	0.4599
10	0.0050	0.0019	0.0069	1.1323	0.0035	3.7461	0.0132	0.1612	3.7742	0.6082
11	0.0050	0.0044	0.0094	1.1398	0.0092	3.7387	0.0345	0.4142	3.7770	1.5645
12	0.0050	0.0003	0.0053	1.1852	0.0015	3.7178	0.0056	0.0646	3.7856	0.2444
13	0.0050	0.0021	0.0071	1.2219	0.0065	3.7320	0.0244	0.3058	3.7939	1.1603
14	0.0050	0.0007	0.0057	1.2751	0.0021	3.7674	0.0080	0.1188	3.8048	0.4520
15	0.0050	0.0026	0.0076	1.2853	0.0038	3.7671	0.0145	0.2164	3.8076	0.8241
16	0.0050	0.0035	0.0085	1.2990	0.0041	3.7750	0.0155	0.2411	3.8106	0.9188
17	0.0050	0.0038	0.0088	1.7580	0.0032	3.8576	0.0124	0.3498	3.8883	1.3600
18	0.0050	0.0006	0.0056	1.8341	0.0008	3.7991	0.0031	0.0750	3.8981	0.2925
19	0.0050	0.0004	0.0054	1.8530	0.0006	3.8265	0.0024	0.0650	3.9007	0.2535
20	0.0050	0.0003	0.0053	2.0291	0.0008	3.8664	0.0029	0.0989	3.9238	0.3881
21	0.0050	0.0014	0.0064	2.0866	0.0012	3.8930	0.0047	0.1777	3.9311	0.6984
22	0.0050	0.0003	0.0053	2.0965	0.0006	3.8768	0.0025	0.0905	3.9320	0.3560
23	0.0050	0.0007	0.0057	2.1625	0.0009	3.9023	0.0036	0.1478	3.9399	0.5822
24	0.0050	0.0020	0.0070	2.3539	0.0011	3.9312	0.0042	0.2057	3.9614	0.8147
25	0.0050	0.0005	0.0055	2.3573	0.0006	3.9104	0.0022	0.0998	3.9615	0.3952
26	0.0050	0.0016	0.0066	2.5007	0.0006	3.9421	0.0025	0.1389	3.9764	0.5522
27	0.0050	0.0003	0.0053	2.7509	0.0003	3.9076	0.0010	0.0538	3.9999	0.2150
28	0.0050	0.0014	0.0064	2.7574	0.0007	3.9615	0.0027	0.1753	4.0007	0.7012
29	0.0050	0.0002	0.0052	2.9052	0.0002	3.9585	0.0008	0.0564	4.0135	0.2265
30	0.0050	0.0004	0.0054	2.9392	0.0004	3.9782	0.0014	0.1051	4.0164	0.4220
31	0.0050	0.0004	0.0054	3.0790	0.0002	3.9909	0.0006	0.0501	4.0278	0.2018
32	0.0050	0.0004	0.0054	3.1185	0.0003	3.9687	0.0012	0.0932	4.0309	0.3756
33	0.0050	0.0014	0.0064	3.1663	0.0007	3.9863	0.0026	0.2151	4.0347	0.8680
34	0.0050	0.0004	0.0054	3.2950	0.0002	3.9972	0.0007	0.0618	4.0445	0.2500
35	0.0050	0.0003	0.0053	3.4625	0.0002	4.0015	0.0008	0.0726	4.0571	0.2946
36	0.0050	0.0000	0.0050	3.7087	0.0001	3.9694	0.0005	0.0450	4.0740	0.1835
37	0.0050	0.0002	0.0052	3.7350	0.0002	3.9803	0.0007	0.0625	4.0757	0.2545
38	0.0050	0.0001	0.0051	3.7709	0.0001	3.9659	0.0004	0.0371	4.0781	0.1512
39	0.0050	0.0006	0.0056	3.8463	0.0002	3.9889	0.0010	0.0963	4.0830	0.3934
40	0.0050	0.0014	0.0064	3.9397	0.0004	4.0424	0.0015	0.1827	4.0890	0.7472
41	0.0050	0.0000	0.0050	4.1592	0.0001	4.0329	0.0004	0.0466	4.1020	0.1913
42	0.0050	0.0003	0.0053	4.3483	0.0001	4.0011	0.0004	0.0503	4.1128	0.2069
43	0.0050	0.0002	0.0052	4.5496	0.0001	4.0284	0.0004	0.0519	4.1238	0.2139
44	0.0050	0.0012	0.0062	4.5740	0.0003	4.0618	0.0012	0.1906	4.1252	0.7864
45	0.0050	0.0002	0.0052	4.6760	0.0000	4.0690	0.0001	0.0203	4.1304	0.0838
46	0.0050	0.0004	0.0054	4.8833	0.0001	4.0852	0.0003	0.0577	4.1409	0.2390
47	0.0050	0.0007	0.0057	5.0076	0.0001	4.0824	0.0005	0.0860	4.1470	0.3564
48	0.0050	0.0000	0.0050	5.2168	0.0001	4.0820	0.0002	0.0436	4.1568	0.1811
49	0.0050	0.0001	0.0051	5.3406	0.0001	4.0689	0.0004	0.0816	4.1624	0.3396
50	0.0050	0.0001	0.0051	5.5454	0.0001	4.0660	0.0002	0.0412	4.1715	0.1720