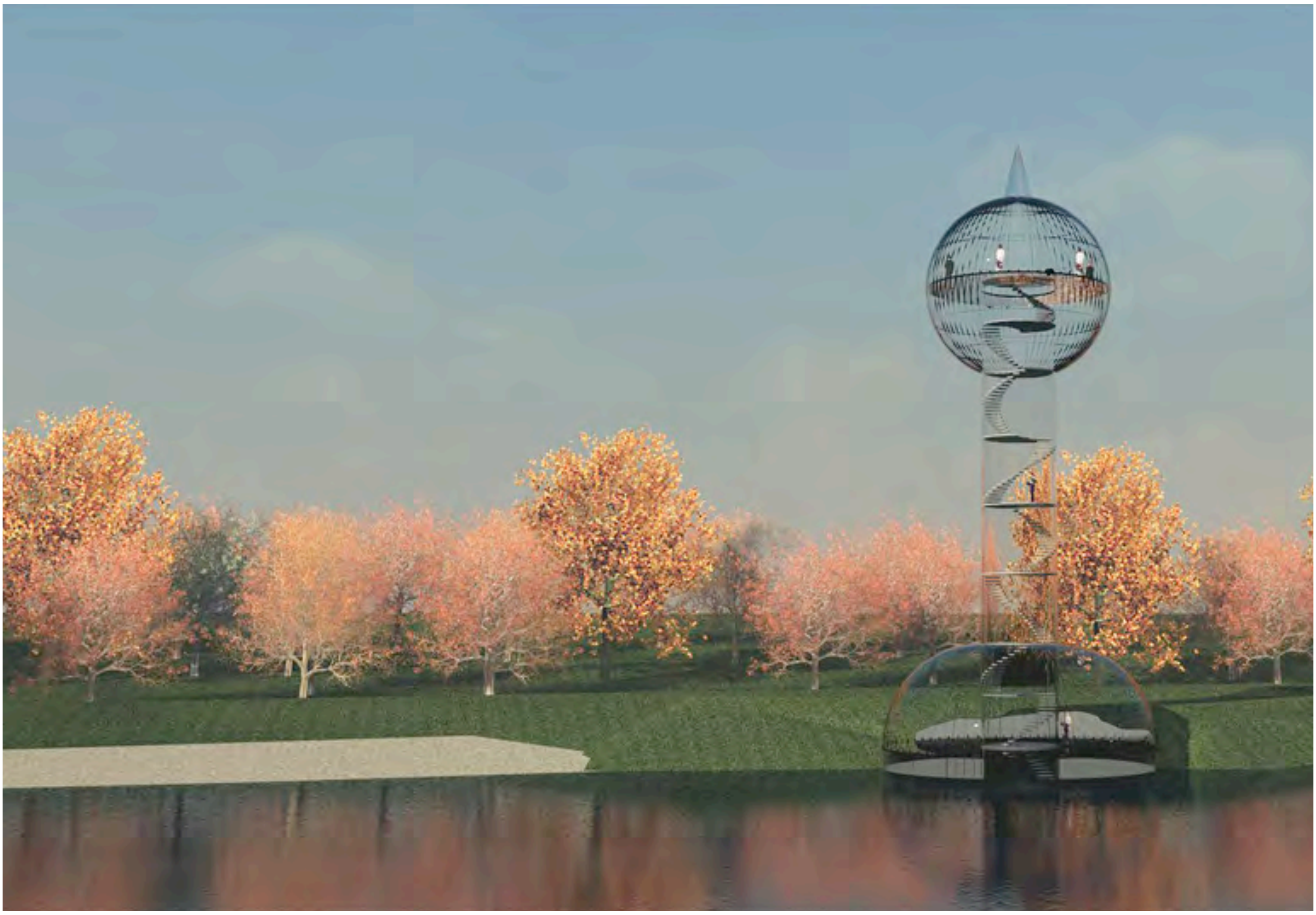
A search for structural applications of transparent plastics in the building industry

Appendices



M de Graaff

TU Delft Delft University of Technology

Challenge the future

Appendix A: Material sheet

	Acrylic	Polycarbonate	Soda-lime glass	Steel	Concrete	Softwood
Mechanical properties, GEMIDDELDE WAARDEN						
Density (kg/m3)	1190	1200	2500	7850	2400	520
Young's modulus (Mpa)	3300	2300	70000	210000	20000	9300
*Weighted Young's modulus (Mpa*dm3/kg)*	*2773*	*1917*	*28000*	*26752*	*8333*	*17885*
Shear modulus (Mpa)	1100	800	29000	81000	9000	700
Bulk modulus (Mpa)	4300	3800	41000		10000	390
Poisson's ratio	0,39	0,4	0,21		0,2	0,37
Yield strength (elastic limit) (N/mm2)	65	65	32	235	2	40
*Weighted yield strength (N/mm2 *dm3/kg)*	*55*	*54*	*13*	*30*	*1*	*77*
Tensile strength (N/mm2)	70	67	33	235	1,4	80
Compressive strength (N/mm2)	110	80	400		35	38
Flexural strength (rupture) (N/mm2)	100	90				
Elongation at break (%)	5	110	0	26	0	2,2
Hardness - Vickers (HV)	18	19	460		6	4
Hardness - Rockwell (M)	98	74				
Fatigue strength (10^7 cycles) (Mpa)	23	26	31		0,7	21
Fracture thoughness (Mpa m^0,5)	1,2	3,2	0,6		0,4	3,8
Mechanical loss coefficient (tan delta)	0,014	0,017	0,0008		0,02	0,008
Thermal properties						
Glass temperature(gr C)	105	170	500		x	90
Max service temperature	50	120	280		500	130
Min service temperature	-90	-100	-273		-160	-85
Coeff lineair thermal expansion (K-1)	0,00007	0,000065	0,000009	0,000012	0,00001	0,000009
Thermal conductivity (W/mK)	0,19	0,2	1	50	2,1	0,26
Specific heat capacity (J/gK)	1,49	1,6	0,72		0,9	1,68
Processing properties						
Linear mold shrinkage	0,6	0,6				
Melt temperature	275	260				
Mold temperature	85	85				
Molding pressure range	104	75				
Production						
Primary production energy (MJ/kg)	100	110	16		1,1	7,4
Primary production CO2 footprint (kg/kg)	3,6	5,7	0,8		0,14	0,43
Primary production water usage (l/kg)	200	300	15		3	630
Eco-indicator 99 (mpoints/kg)	506	463	76		4	42
Processing						
Molding energy (MJ/kg)	18,5	18,6	9,1			
Extrusion energy (MJ/kg)	6,1	6,1				
Grinding energy (per unit wt removed) (kg/kg)	16,5	13,4	27,0		2,2	16,4
Molding CO2 (kg/kg)	1,4	1,4	0,69			
Extrusion CO2 (kg/kg)	0,45	0,45				
Grinding CO2 (per unit wt removed) (kg/kg)	1,2	1,0	2,0		0,2	1,2
Recycling						
Embodied energy, recycling (MJ/kg)	42	46	7		0,015	x
CO2 footprint, recycling (kg/kg)	1,5	2,4	0,4		0,07	x
Heat of combustion (net) (MJ/kg)	26	31	x		x	21
Recycle fraction current supply (%)	0,7	0,7				
Recycle mark	7	7	x		x	x
Price (€/kg)	2	3	1,5	1,3	0,04	0,7
Price (€/m3)	2380	3600	3750	10205	96	364

Sources: (Carlowitz 1995) (CES-Database 2012) (Eyerer and Elsner 2005) (Wörner, Stahl and Eckhardt 2007)

Appendix B: Reference projects transparent plastics

Acrylic

Figure 230: Liszt Konzerthaus - realised

Figure 231: Showroom Italy - realised

Figure 232: Large aquarium around lift shaft, hotel lobby Berlin - realised

Figure 233: Acrylic house, Japan - realised

Figure 234: Acrylic dome - desing

Polycarbonate

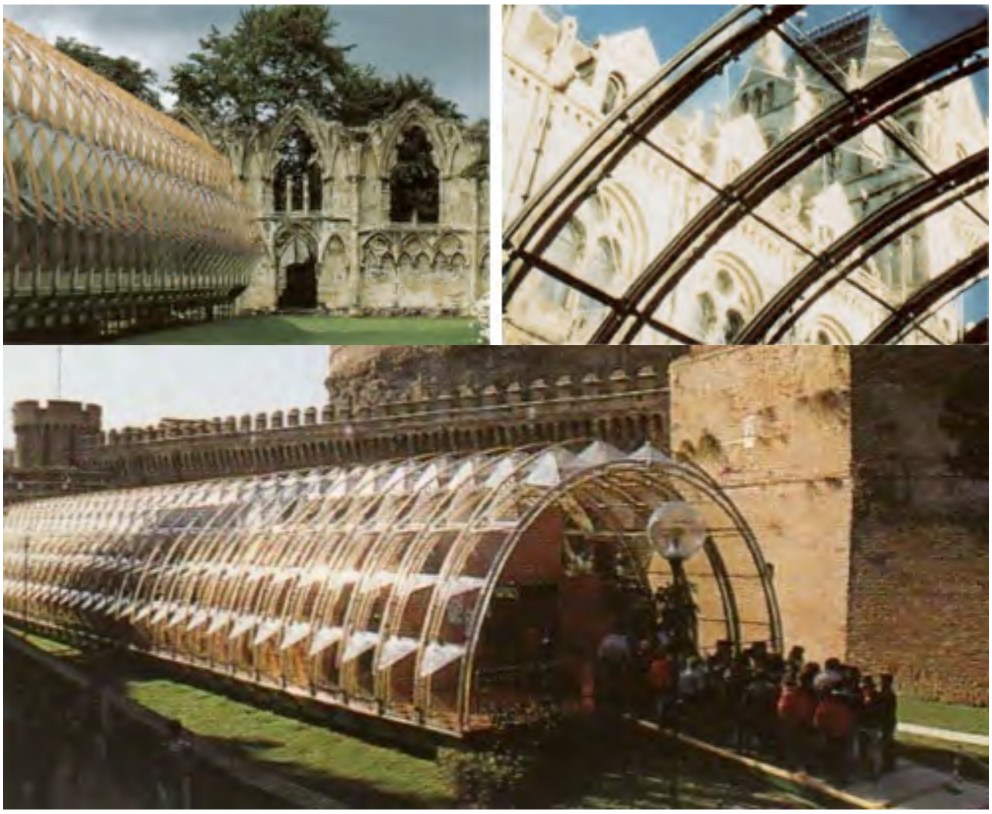


Figure 235: IBM travelling pavilion - realised

Figure 236: Polycarbonate sheet roofing, Aviav stadium, Dublin - realised

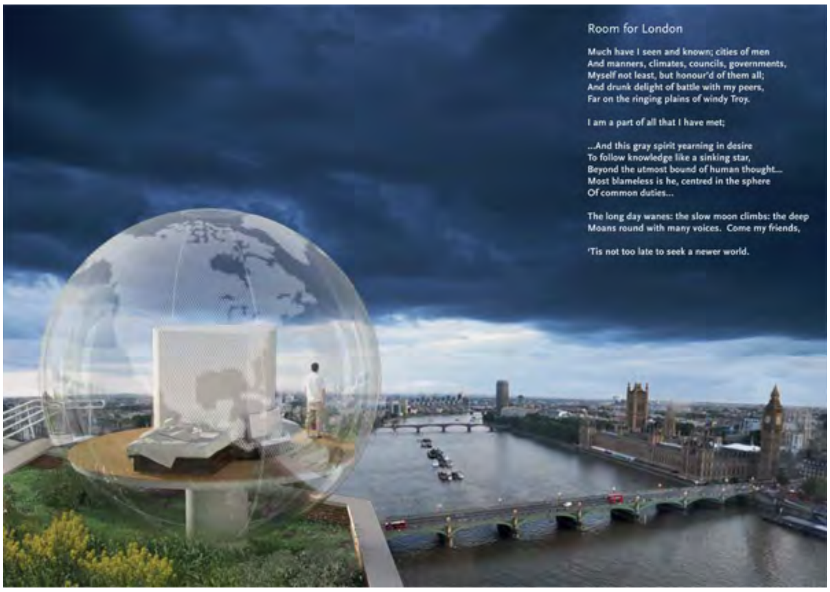


Figure 237: Transparent room above Londen, polycarbonate shell - design

Composite

Footbridge Darmstadt

The properties of a material sometimes can be utilized better by combining it with another material. For example a wooden composite girder consisting of a upper and lower flange of timber and a web of acrylate. This way the acrylate only takes the bending and shear stresses and the timber takes the tensional and compressive stresses.

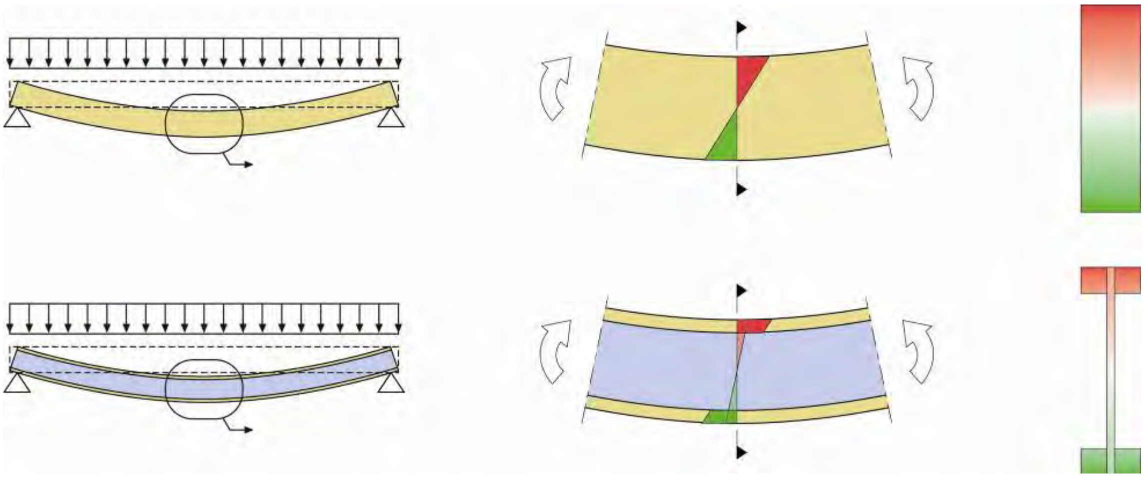


Figure 238: Flexural stress distribution in a simple beam and in the composite girder

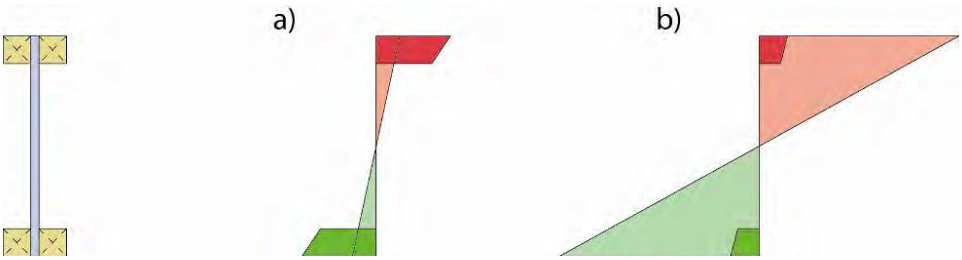


Figure 239: Flexural stress distribution: a) wood PMMA composite, b) wood glass composite

This girder has been developed by de university of Darmstadt, Germany and is used in practice to make a footbridge between two old buildings. (Wörner, Stahl and Eckhardt 2007)

Figure 240: Prototype – palace moat bridge in Darmstadt, Germany.

Composite façade element, Cardboard between two acrylic panels (Kim 2009)

Figure 241: Impact test set-up TCFS

Other materials

Figure 242: Glass shell without supporting substructure, Blandini & Sobek

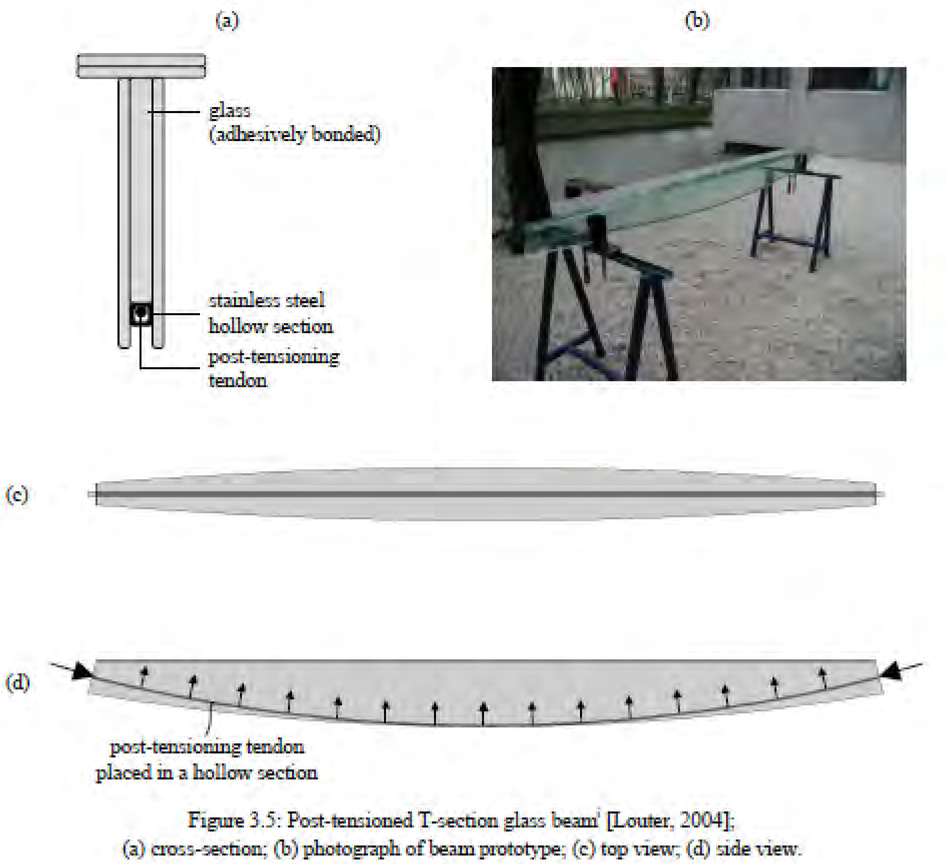


Figure 243: Reinforced glass beams, Christian Louter

Figure 244: Timber grind pavilion

Appendix C: Reference projects observatory tower

Observation towers exist in all kind of sizes and shapes. From towers rising high above the trees to small elevations above a hill, from towers with lifts and restaurants to clean structures, even without any shelter.
A few inspirational examples are shown here:

Figure 245: Transparent glass structure, Apple Store Shanghai

Figure 246: Pearl Tower Shanghai with observatory spheres

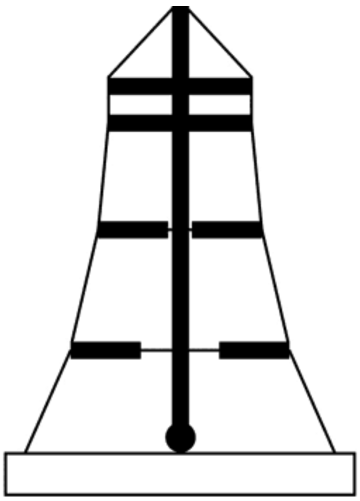


Figure 247: Killesberg tower, Jörg schlaich, Rudolf Bergermann, 40 meter high. The tensile net structure provides a lot transparency, and a light weight structure.

Figure 248: Bostoren Putten, 40 meter

Figure 249:Observatory tower Schossberg, spiral staircase in between columns

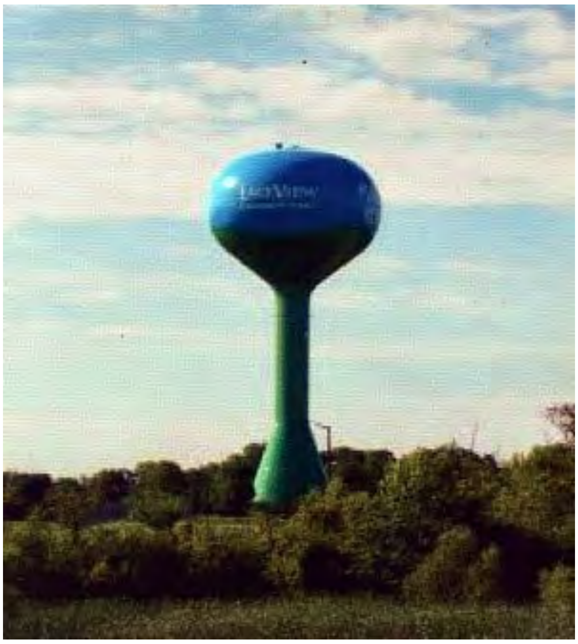


Figure 250: American water tower with spherical shape

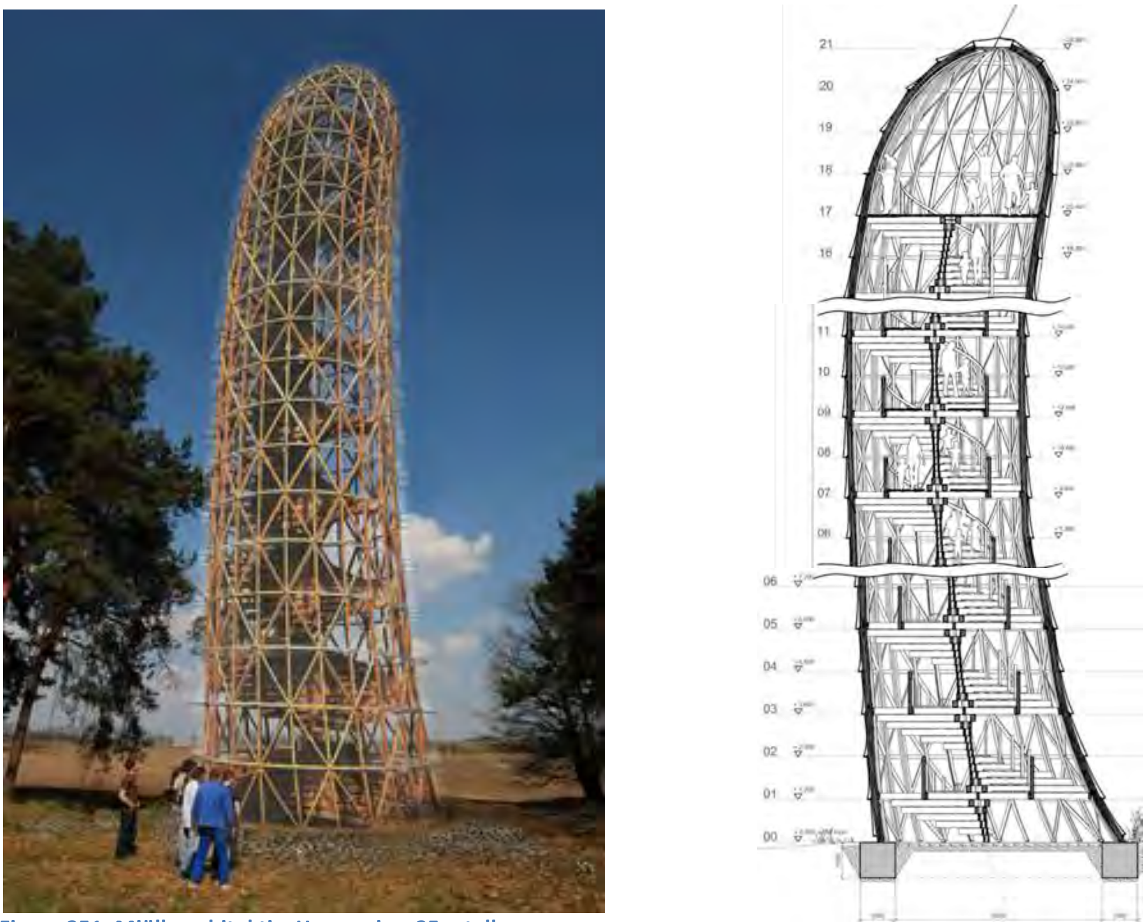


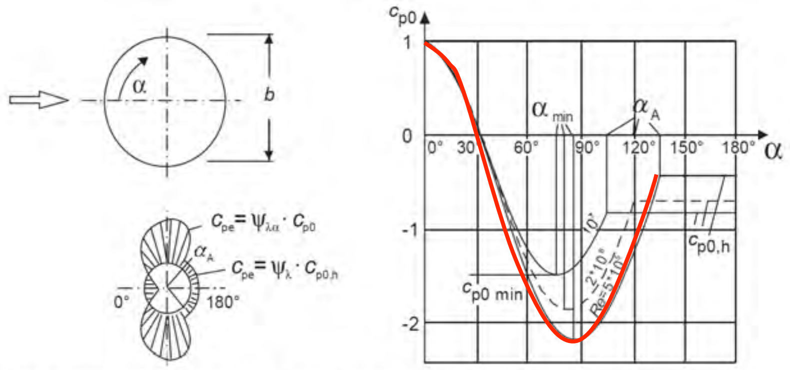
Figure 251: Mjölk architekti – Hermanice, 25m tall

Appendix D: Determination of wind loads

In this supplement for each structural element the wind load factors are determined.

Cylinder

Local



OPMERKING 1 Voor tussenliggende waarden mag lineair zijn geïnterpoleerd.

OPMERKING 2 Kenmerkende waarden in bovenstaande figuur zijn te vinden in tabel 7.12. Figuur en tabel zijn gebaseerd op het Reynoldsgetal met $v = \sqrt{\frac{2 \cdot q_p}{\rho}}$ en q_p gegeven in 4.5.

OPMERKING 3 De bovenstaande figuur is gebaseerd op een equivalente ruwheid k/b kleiner dan $5 \cdot 10^{-4}$. Kenmerkende waarden voor de ruwheidshoogte k zijn gegeven in tabel 7.13.

Figure 252: Determination of factor c_{pe} for local wind pressure on cylinders

In the figure above for each area around the cylinder it is shown how the applicable factor c_{pe} for local pressure can be computed . C_{p0} can be determined from the graph for each angle α, the ψ values can now be computed with the following formula's:

ψ_{λ} = 0,66 (from the Eurocode table)
$\psi_{\lambda\alpha} = 1$; 0 ≤ α ≤ 85
$\psi_{\lambda\alpha} = \psi_{\lambda} + (1 - \psi_{\lambda}) * \cos\left(\frac{\pi}{2} * \left(\frac{\alpha - \alpha_{min}}{\alpha_A - \alpha_{min}}\right)\right)$; 85 ≤ α ≤ 135
$\psi_{\lambda\alpha}$= 0,66 ; 135 ≤ α ≤ 180

The Reynolds number can be computed with the following formulas:

$Re = \frac{b * v(z_e)}{\nu}$ With: $v(z_e) = \sqrt{\frac{2 * q_p(z_e)}{\rho}}$

So for this cylinder:

$$v(z_e) = \sqrt{\frac{2 * 1{,}06}{1{,}25}} = 1{,}30 \qquad Re = \frac{4{,}5 * 1{,}3}{15 * 10^{-6}} = 3{,}9 * 10^5$$

As can be seen the maximum outward pressure takes place at an angle α of 85° for which a $\psi_{\lambda\alpha}$ of 1 results in the minimum factor (suction) for local pressure on the shell of:

$C_{p,min}$ = -2,2

The maximum local pressure takes place at an angle of α = 0°, from the graph can be read:

$C_{p,max}$ = 1,0

Global

The global wind force can be computed by adding all local factors multiplied with the concerned surface area. For a cylindrical cross section this is quite complicated. The largest local factors will compensate each other globally speaking as suction occurs on both sides perpendicular to the wind direction. The components of the wind factors in the direction of the wind are 1,0 and 0,4 on the central axis but decreasing towards the edges, at the front even changing into suction from α=30°. Therefore another figure is available to determine the wind force factor.

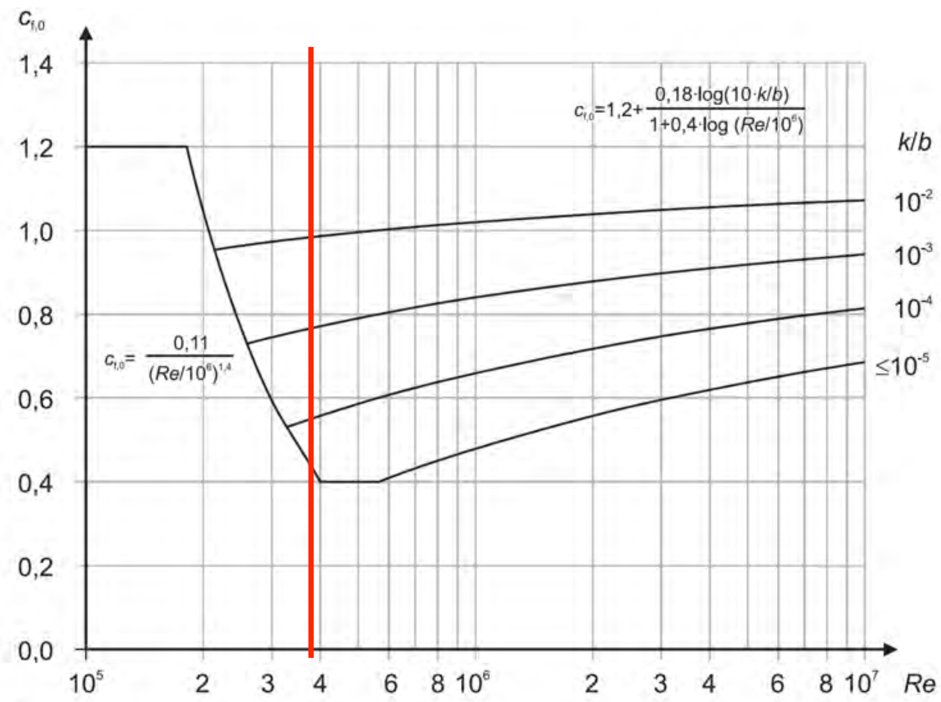


Figure 253: Force coefficient $c_{f,0}$ for circular cylinders for various equivalent roughnesses

The equivalent roughness k of several materials can be found in the table below. For transparent plastics no value is given.
It is assumed that plastics are rougher than glass, moreover over time scratches and other irregularities may occur. As the core will be assembled of two elements only two seams might disturb the wind flowing around the tube. These seems will be bonded with polymerized glue, which creates an almost invisible bond, the effect of these is ignorable.
If concerned conservatively, the surface could be comparable with smooth concrete, with k=0.2 mm.

$$\frac{k}{b} = \frac{0,2}{4500} = 4,4 * 10^{-5}$$

So for the computed Reynolds number, the global wind force factor will be:

$$Cf = 1{,}2 + \frac{0{,}18\log(10 * k/b)}{1 + 0{,}4\log(Re/10^6)} = 1{,}2 + \frac{0{,}18\log(10 * 4{,}4 * 10^{-5})}{1 + 0{,}4\log(3{,}9 * 10^5/10^6)} = 0{,}48$$

A value of C_f=0,5 will be used in the calculations.

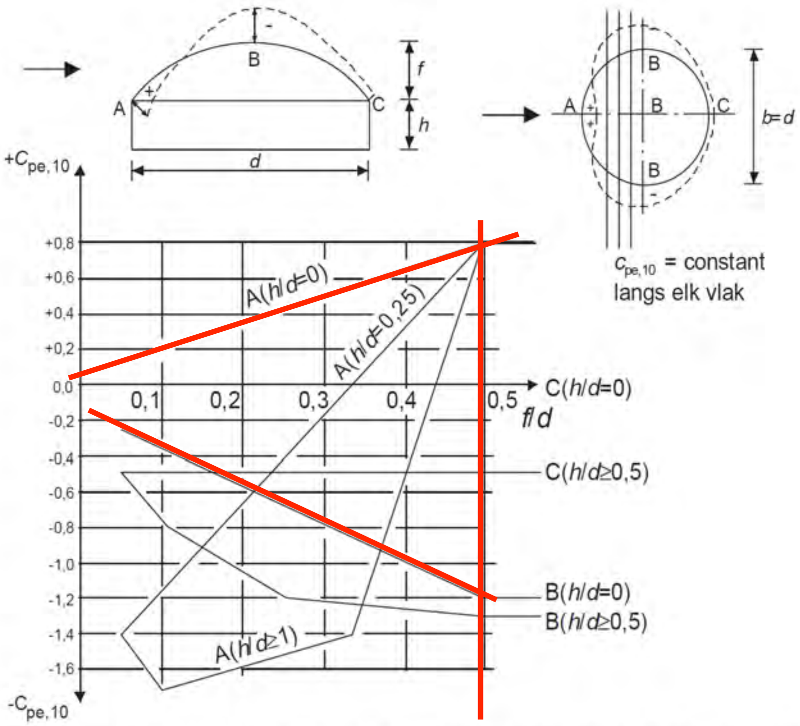
Tabel 7.13 — Ruwheidshoogte[*] k

Oppervlaktetype	Ruwheidshoogte[*] k mm	Oppervlaktetype	Ruwheidshoogte[*] k mm
Glas	0,0015	Glad beton	0,2
Gepolijst metaal	0,002	Geschaafd hout	0,5
Gladde verflaag	0,006	Ruw beton	1,0
Gespoten verflaag	0,02	Ruw hout	2,0
Blank staal	0,05	Roest	2,0
Gietijzer	0,2	Metselwerk	3,0
Gegalvaniseerd staal	0,2		

Figure 254: Roughness heights for various materials

Lower dome structure

Local



$c_{pe,10}$ is constant langs cirkelbogen, doorsneden van de bol en vlakken loodrecht op de wind; een eerste benadering van $c_{pe,10}$ kan zijn bepaald door lineaire interpolatie tussen de waarden in A, B en C langs de cirkelbogen parallel met de wind. Op dezelfde wijze kunnen de waarden van $c_{pe,10}$ in A indien 0 < h/d < 1 en in B of C indien 0 < h/d < 0,5 zijn bepaald door lineaire interpolatie in de figuur hierboven.

Figure 255: Local pressure coefficients c_{pe} for domes with a circular floorplan

The figure above shows the determination of the local pressure factors for wind pressure and suction on the lower dome structure. It is clearly visible in the top view that the suction effect is quite some smaller than for a cylindrical structure. With:

$$\frac{h}{d} = \frac{0}{12} = 0 \qquad \frac{f}{d} = \frac{5}{12} = 0{,}42$$

The factors concerned will become (on the safe side):

$C_{p,min}$ = -1,2

$C_{p,max}$ = 0,8

Global

The global wind pressure factor is not described in the Eurocode NEN-EN 1991-1-4, to compute this factor the ratio for the cylinder between local and global pressure ($C_f/C_{p,\,max}$ = 0,5) is used. This because the flow pattern at the front side of this structure is quite similar, the angle α for which the factor changes from pressure to suction is approximately the same, so :

*C_f = 0,5 * $C_{p,max}$= 0,5 *0,8 = 0,4*

Sphere

Global

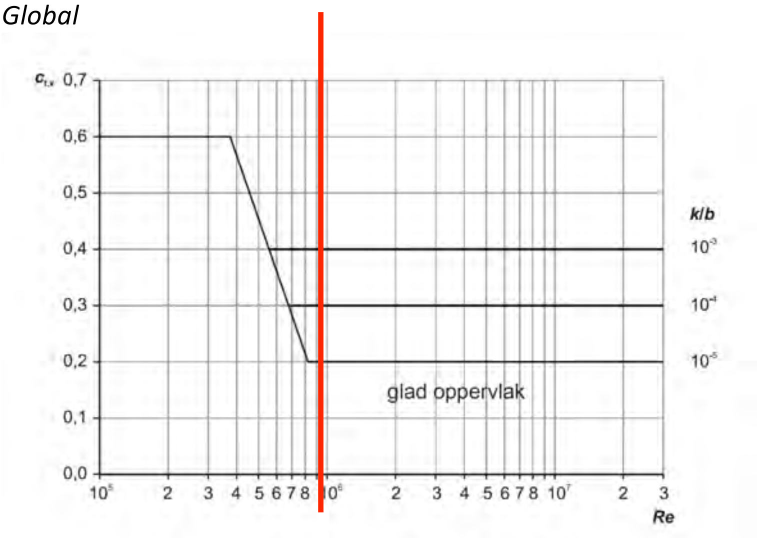


Figure 256: Determination of force coefficient c_f for a sphere

For this sphere:

$$v(z_e) = \sqrt{\frac{2 * 1{,}19}{1{,}25}} = 1{,}38 \quad , \quad Re = \frac{10 * 1{,}38}{15 * 10^{-6}} = 9{,}2 * 10^5$$

And:

$$\frac{k}{b} = \frac{0{,}002}{10000} = 2 * 10^{-7}$$

This means the lowest line of the graph is applicable. This leads to a global wind force factor of

C_f = 0,2

Local

The local factors for wind pressure and suction on spheres are not prescribed in the Eurocode NEN-EN 1991-1-4, therefore an assumption is made based on the global and local pressure for the cylinder and dome structure.

When the same ratio is used as was computed for the cylinder ($C_f/C_{p,\,max}$ = 0,5) the resulting factor is:

$C_{p,max} = C_f/0{,}5 = 0{,}2/0{,}5 = 0{,}4$

This is realistic as the angle α for which the factor changes from pressure to suction is approximately the same.

The ratio between pressure and suction is used from the lower dome structure ($C_{p,max}/C_{p,min}$ = -2/3) as the behaviour of wind along a spherical structure resembles the curved roof more than the cylinder.

$C_{p,min} = C_{p,max} * -3/2 = 0{,}4 * -3/2 = -0{,}6$

Appendix E: PMMA burning test

SUMMARY TEST REPORT

Cone Calorimeter

Test Ref: T5921

Test Date: 08-09-1993
Date Received: 08-09-1993

DETAILS OF MATERIAL TESTED

Sponsor : National Institute of Standards & Technology

Material: PMMA

DETAILS OF TEST PROCEDURE USED

Heat Flux	: 50.0 kW/m²	**Nominal Flow**	: 24.0 l/s
Orifice Constant	: 0.044311	**Heat per Unit Mole**	: 12.98000 kJ/gO2
Heater Orientation	: Horizontal	**Spark Ignitor Used**	: Y
Grid Used	: N	**Frame Used**	: N
Conditioning	: 50.0 RH @ 23.0°C	**Test Conditions**	: 50.0 RH @ 0.0°C
Specimen Thickness:	0.002540m	**Specimen Area**	: 0.010000 m²

TEST RESULTS

Initial Mass	: 295.7 g	**Time of Peak RHR**	: 585 s
Final Mass	: 0.0 g	**Peak RHR**	: 746.3 kW/m²
Mass Lost	: 29.73 kg/m²	**Peak Mass Loss**	: 30.05 g/s*m²
Ignition Time	: 29 s	**Peak Extinction Area:**	155.98 m²/kg
Flameout Time	: 1,152 s	**Total Heat Released**	: 716.02 MJ/m²

Summary Data From Ignition

		Test Mean	60S	180S	300s
Heat Release	kW/m²	642.21	530.53	583.08	605.51
Mass Loss Rate	g/s*m²	27.89	20.35	23.47	24.65
Heat of Combustion	MJ/kg	24.08	26.07	24.85	24.57
Specific Ext. Area	m²/kg	119.44	113.12	125.42	124.73
Carbon Dioxide	kg/kg	2.54311	2.90185	2.69888	2.64951
Carbon Monoxide	kg/kg	0.00761	0.00526	0.00729	0.00756

OBSERVATIONS AND COMMENTS

Flaming out time 19 minute 13 second/1152 seconds. Cardboard glued on side of PMMA. spark ignited used with pan holder and kao wool. TUH is off--Soot collected.

Tested by : Lee, Jack
Officer : Ohlemiller, Tom Dr.

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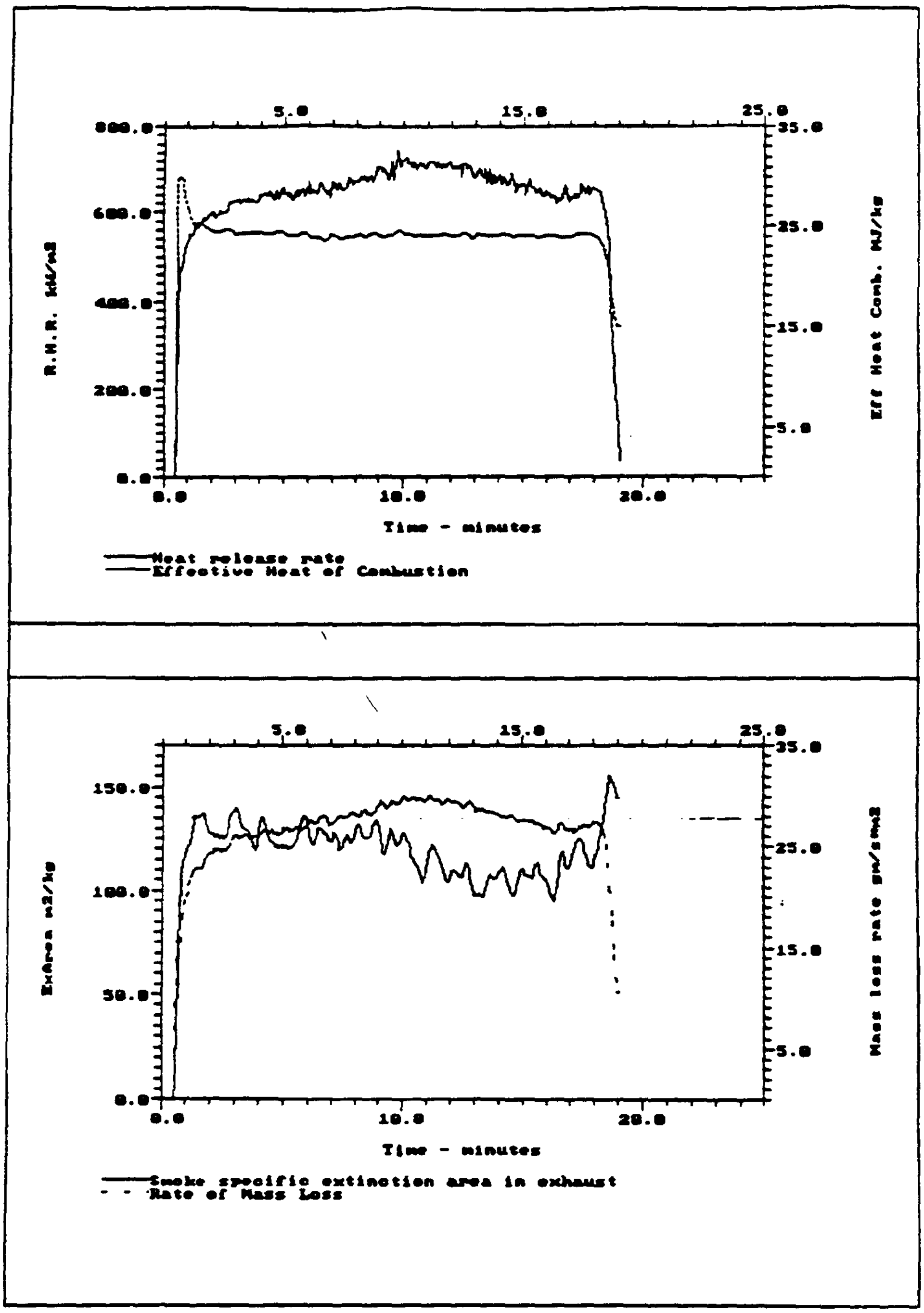
T5921 PMMA 25mm 50 kW/m2



Appendix F: Determination of Design factors

Design factors are determined for influence of time, temperature and environmental conditions.

Separate factors are determined for the design and the design strength, as these are not influenced equally by time, temperature and environment.

1. Time dependence

Time span is regarded for long term and short term separately. As short-term duration 24h is taken, as wind loads will not be just holding seconds it would not be sensible to use the ultimate short term values. As long term duration 20 years is used as tests and manufacturers guarantees are not available (yet) beyond this lifetime.

24 hours = 86.400 seconds
20 year = 7.300 days = 175.200 hours = 630.720.000 seconds

Stiffness

PMMA

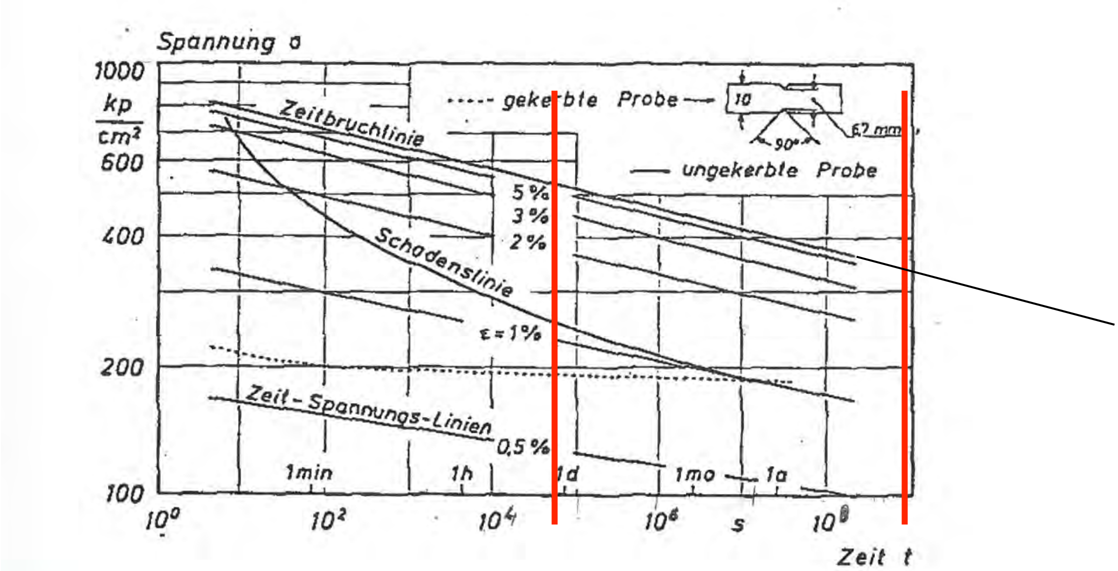


Figure 257: Reduction of modulus over time for PMMA, determination of reduction factor

24 hours: 700/540 = 1,3
20 years: 700/340 = 2,1

PC

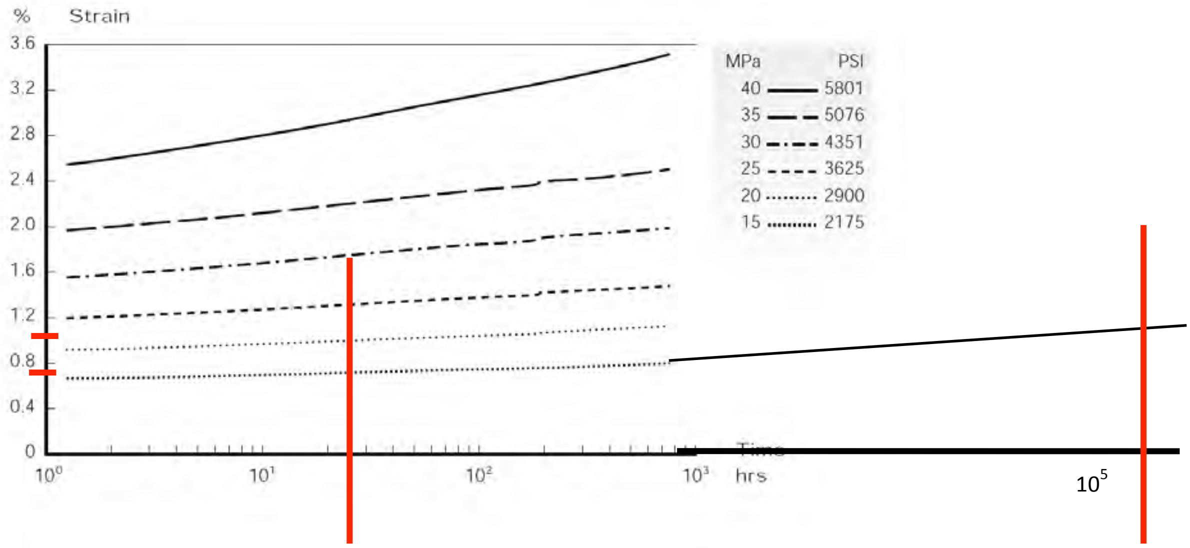


Figure 258: Long term deformation polycarbonate at 23°C [16]

24 hours: 0,73/0,65 = 1,1
20 years: 1,0/0,65 = 1,5

Strength

PMMA

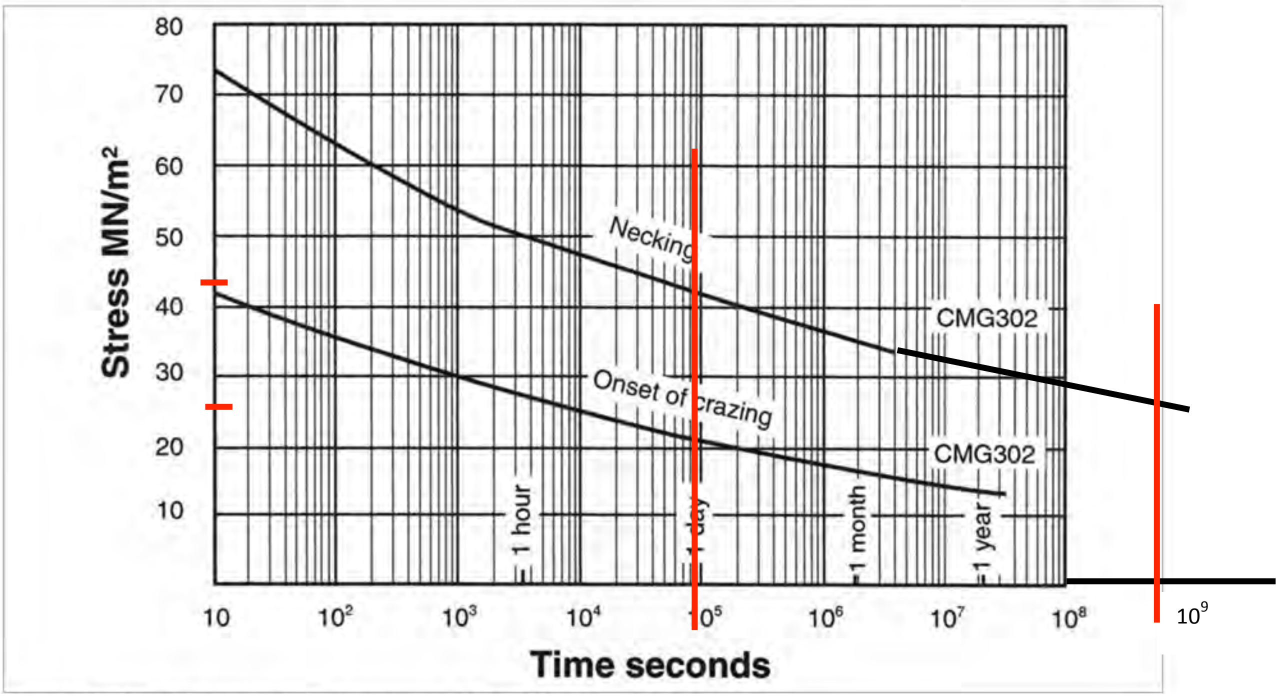


Figure 259: Long term maximal allowable stress Acrylic [15]

24 hours: 74/43 = 1,7
20 years: 74/25,5 = 2.9

PC

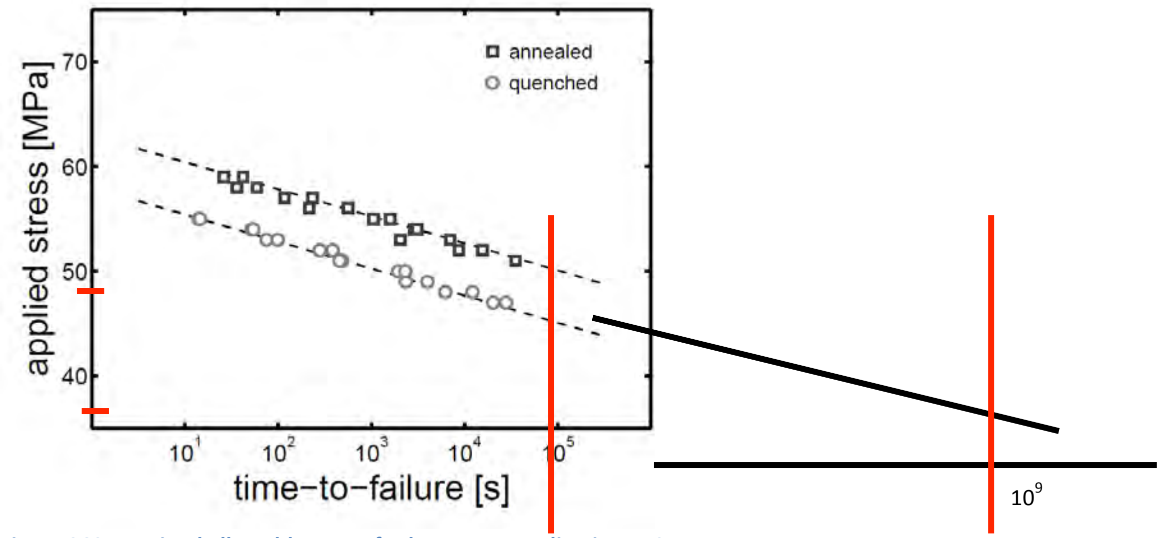


Figure 260: Maximal allowable stress for long-term applications PC

65/52 = 1,3
65/40 = 1,6

2. Temperature dependence

For the temperature influence the factors are determined for 40 °C and 60 °C, the first temperature for inside surfaces, the last one for surfaces in direct sunlight (inside and outside). Thereby the value for 20 degrees is taken to be the verification point with factor 1,0.

Stiffness

PMMA

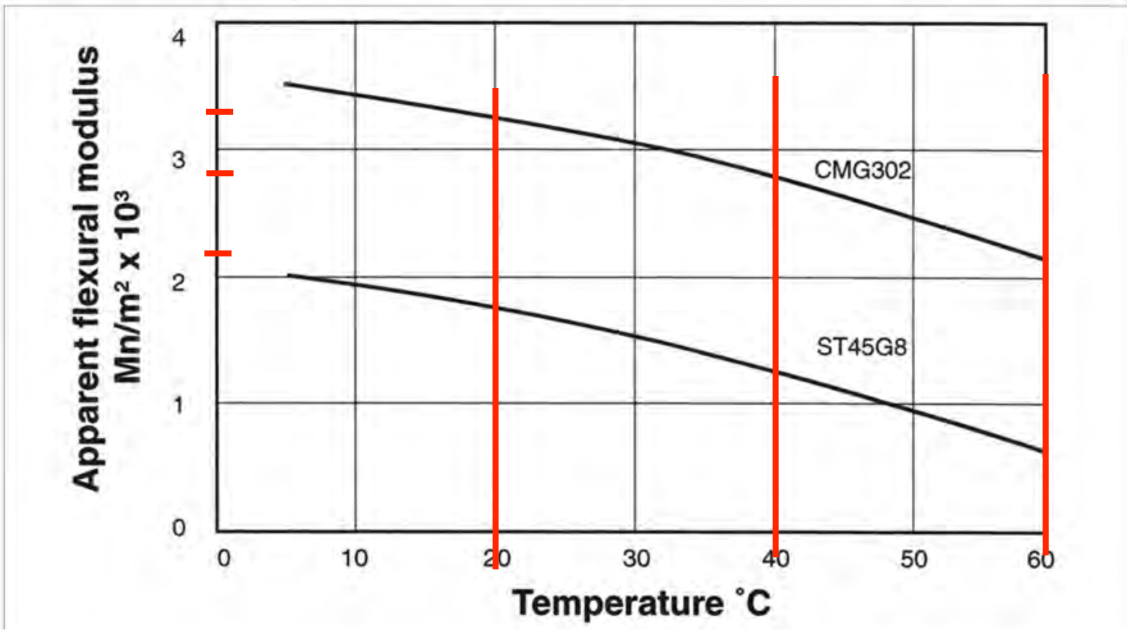


Figure 261: Relation between modulus and temperature for PMMA

40 °C: 3,3/2,8 = 1,2
60 °C: 3,3/2,2 = 1,5

PC

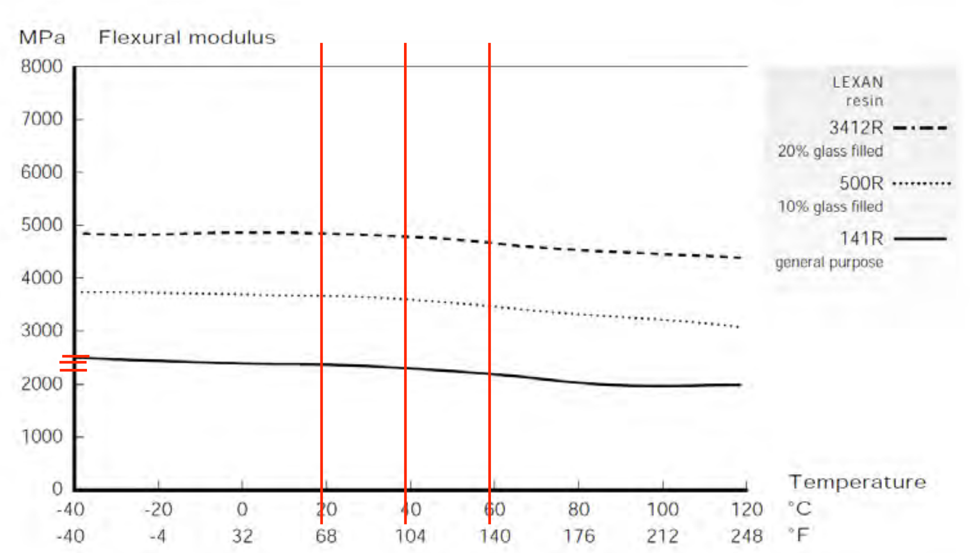


Figure 262: Relation between modulus and temperature for PC

40 °C: 2500/ 2350 = 1,05
60 °C: 2500/ 2200 = 1,1

Strength

PMMA

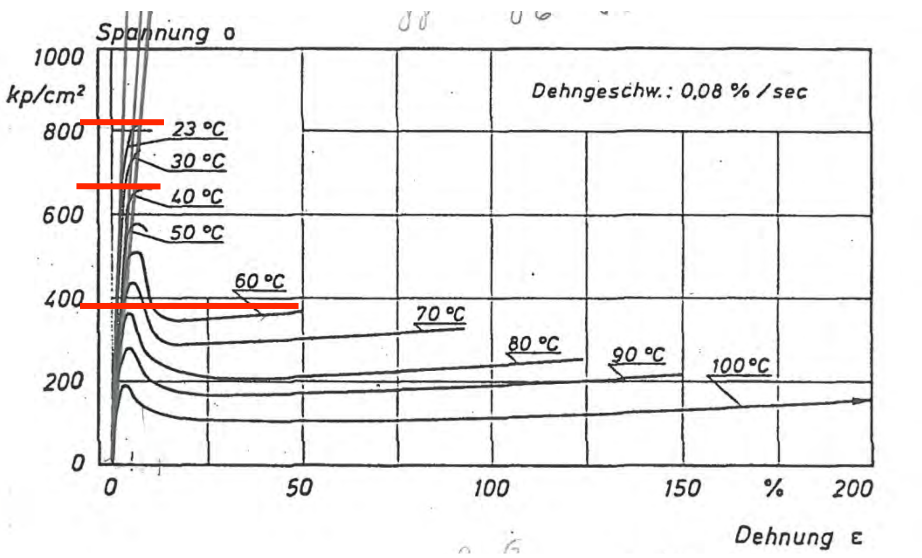


Figure 263: Failure stress at various temperatures for PMMA

40 °C: 820/ 650 = 1,3
60 °C: 820/ 390 = 2,1

PC

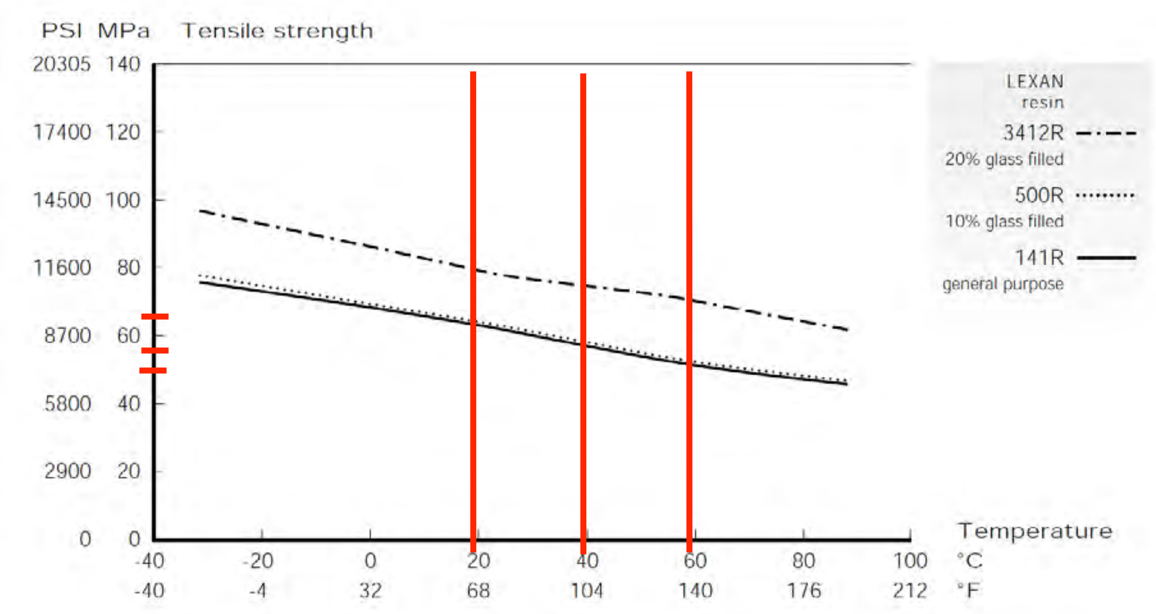


Figure 264: Relation between temperature and tensile strenght for PC

40 °C: 62/ 57 = 1,1
60 °C: 62/ 49 = 1,3

3. Environmental dependence

Stiffness

If stiffness is influenced by the environmental this is a favourable effect as it enbrittles by the influence of for instance UV radiation. This will not be taken into account.

This is also described in the NEN 1778 norm.

Strength

Test results on the subject of environmental influences are scarce. The ETAG010 did prescribe a certain factor but with 1,10 only a very low one. Probably because this guideline is only used for the design of secondary structures as roof panels. From the indicative test results available it is clear that environmental circumstances have a significant influence on thermoplastics. Therefore the load factor mentioned by Uwe Gleiter in his dissertation was used. This factor included the influence of temperature up to 60 degrees Celsius, the factor only for environmental effects becomes now:

5,4/2,1 = 2,6

As the material will be less affected when in compression, a lower factor is used to compute the design value for compressive stress: 2,3

For polycarbonate no value is available but that from the ETAG010, the ratio between the values for PMMA and PC in the ETAG010 is used to compute the factor for PC:

2,6*1,05 = 2,7

4. Concluding design values

The determined load factors are used to determine the design values for strength and stiffness. If these design values are used no crazing or cracking will occur for at least 20 years

Calc. design factors (temp *time *environment)	Material factor				Design factors inside		Design factors inside - direct sun		Design factors outside		Design factors under water	
Long term	**PMMA**		**PC**		**PMMA**	**PC**	**PMMA**	**PC**	**PMMA**	**PC**	**PMMA**	**PC**
E-modulus Bending (MPa)		1,1		1,1	1,2 * 2,5 * 1	1,05 * 1,5 * 1	1,5 * 2,5 * 1	1,1 * 1,5 * 1	1,5 * 2,5 * 1	1,1 * 1,5 * 1	1,2 * 2,5 * 1	1,05 * 1,5 * 1
E-modulus Buckling (MPa)	1,4	1,2	1,4	1,2								
Max. tensile strength (MPa)		1,5		1,5	1,3 * 2,9 * 1	1,1 * 1,6 * 1	2,1 * 2,9 * 1	1,3 * 1,6 * 1	2,1 * 2,9 * 2,6 2,1* 2,9 * 2,3	1,3 * 1,6 * 2,7	1,3 * 2,9 * 2 1,3 * 2,9 *1,8	1,1 * 1,6 * 2,1
Max. Compressive strength (MPa)		1,2		1,2								
Short term	**PMMA**		**PC**		**PMMA**	**PC**	**PMMA**	**PC**	**PMMA**	**PC**	**PMMA**	**PC**
E-modulus Bending (MPa)					1,2 * 1,2 * 1	1,05 * 1,1 * 1	1,5 * 1,2 * 1	1,1 * 1,1 * 1	1,5 * 1,2 * 1	1,1 * 1,1 * 1	1,2 * 1,2 * 1	1,05 * 1,1 * 1
E-modulus Buckling (MPa)												
Max. tensile strength (MPa)					1,3 * 1,7 *1	1,1 * 1,3 * 1	2,1 * 1,7 *1	1,3 * 1,3 * 1	2,1 * 1,7 *2,6 2,1 * 1,7 *2,3	1,3 * 1,3 * 2,7	1,3 * 1,7 *2 1,3 * 1,7 *1,8	1,1 * 1,3 * 2,1
Max. Compressive strength (MPa)												

Figure 265: Load factor calculation

Design factors	Material factor				Design factors inside		Design factors inside - direct sun		Design factors outside		Design factors under water	
Long term	**PMMA**		**PC**		**PMMA**	**PC**	**PMMA**	**PC**	**PMMA**	**PC**	**PMMA**	**PC**
E-modulus Bending (MPa)		1,1		1,1	3,00	1,58	3,75	1,65	3,75	1,65	3,00	1,58
E-modulus Buckling (MPa)	1,4	1,2	1,4	1,2								
Max. tensile strength (MPa)		1,5		1,5	3,77	1,76	6,09	2,08	15,83 14,01	5,62	7,54 6,79	3,70
Max. Compressive strength (MPa)		1,2		1,2								
Short term	**PMMA**		**PC**		**PMMA**	**PC**	**PMMA**	**PC**	**PMMA**	**PC**	**PMMA**	**PC**
E-modulus Bending (MPa)					1,44	1,16	1,80	1,21	1,80	1,21	1,44	1,16
E-modulus Buckling (MPa)												
Max. tensile strength (MPa)					2,21	1,43	3,57	1,69	9,28 8,21	4,56	4,42 3,98	3,00
Max. Compressive strength (MPa)												

Figure 266: Load factors

Used design values	**Material factor**		**Design values inside**				**Design values inside - direct sun**				**Design values outside**				**Design values under water**			
Long term	**PMMA/PC**		**PMMA**		**PC**		**PMMA**		**PC**		**PMMA**		**PC**		**PMMA**		**PC**	
E-modulus Bending (MPa)	1,1		909		1270		727		1212		727		1212		909		1270	
E-modulus Buckling (local/global) (MPa)	1,4	1,2	714	833	998	1164	571	667	952	1111	571	667	952	1111	714	833	998	1164
Max. tensile strength (MPa)	1,5		12,4		20,8		7,7		17,6		2,9		6,5		6,2		9,9	
Max. Compressive strength (MPa)	1,2		24,3		35,5		15,1		30,0		6,5		11,1		13,5		16,9	
Short term	**PMMA/PC**		**PMMA**		**PC**		**PMMA**		**PC**		**PMMA**		**PC**		**PMMA**		**PC**	
E-modulus Bending (MPa)	1,1		1894		1732		1515		1653		1515		1653		1894		1732	
E-modulus Buckling (local/global) (MPa)	1,4	1,2	1488	1736	1361	1587	1190	1389	1299	1515	1190	1389	1299	1515	1488	1736	1361	1587
Max. tensile strength (MPa)	1,5		21,1		25,6		13,1		21,7		5,0		8,0		10,6		12,2	
Max. Compressive strength (MPa)	1,2		41,5		43,7		25,7		37,0		11,2		13,7		23,0		20,8	

Figure 267: Design values

Appendix G: Dynamical Effects

The standard deviation for the acceleration according to the Eurocode 1: (NEN-EN1991-1-1 2002)

$$\sigma_{a,x}(y,z) = c_f \cdot \rho \cdot I_v(z_s) \cdot v_m^2(z_s) \cdot R \cdot \frac{K_y \cdot K_z \cdot \Phi(y,z)}{\mu_{ref} \cdot \Phi_{max}}$$

With c_f	the force coefficient for wind, on average this is assumed to be **0,4**
ρ	the density of air, prescribed to be **1,25** kg/m^3
$I_v(z_s)$	the turbulence intensity at height z_s above the ground
$v_m(z_s)$	the characteristic average wind speed at height z_s above the ground
R	the square root of the resonance factor
K_y and K_z	factors depending on the vibration mode, in this case 1 and 3/2 respectively
μ_{ref}	the reference mass per surface area of the core, total mass/(h*D_{core}) = (974000/9,81)/(35*4) = **709** kg/m^2
Φ(y,z)	the vibration mode, for slender buildings clamped at the foot: Φ(y,z)=$(z/h)^{1,5}$
Φ_{max}	the value for the vibration mode at the point with the highest amplitude, for the natural frequency this will be the top: Φ(y,z)=$(35/35)^{1,5}$= 1

$$v_m(z) = c_r(z) * c_0(z) * v_b = k_r * \ln\left(\frac{z}{z_0}\right) * c_0(z) * v_b$$

With

z_0	the roughness height, taken to be 0,05 for areas with low cover
c_0	the orography factor, 1 conform the national supplements
v_b	the fundamental wind velocity, equal to $v_{b,0}$ which is 27 m/s conform the national supplements
k_r	terrainfactor, calculated with:

$$k_r = 0,19 * \left(\frac{z_0}{0,05}\right)^{0,07} = 0,19 * 1^{0,07} = 0,19$$

z_s	the reference height, 0,6h, for buildings with an approximately even distribution of the load over the height: 0,6*35= 21 m

Now $v_m(z_s)$ can be calculated:

$$v_m(z_s) = k_r * \ln\left(\frac{z_s}{z_0}\right) * c_0(z_s) * v_b = 0,19 * \ln\left(\frac{21}{0,05}\right) * 0 * 27 = 31\ m/s$$

With v_m the turbulence intensity can be calculated:

$$I_v(z_s) = \frac{\sigma_v}{v_m(z_s)} = \frac{k_r * v_b * k_1}{31} = \frac{0,19 * 27 * 1}{31} = 0,165$$

The resonance factor R^2 is computed with the following formula:

$$R^2 = \frac{\pi^2}{2 \cdot \delta} \cdot S_L(z_s, n_{1,x}) \cdot K_s(n_{1,x})$$

With

δ	the damping
S_L	A dimensionless spectral density function
$n_{1,x}$	First natural frequency of the structure, computed earlier as **0,55**
K_s	Measurement reduction function

The damping is a combination of aerodynamic damping and structural damping. The structural damping (δ_s) is empirically determined for all materials. Transparent plastics however are not among the conventional building materials. Visco-elastic materials are sometimes used for building damping devices for buildings so it is not expected that they fall in the lower damping categories. The mean value for bridges of fibre reinforced polymers is used for the calculations, which is **0,06**.

$$\delta = \delta_s + \delta_a = 0{,}06 + \frac{c_f * \rho * v_m(z_s)}{2 * n_1 * \mu_e} = 0{,}06 + \frac{0{,}4 * 1{,}25 * 31}{2 * 0{,}55 * 709} = 0{,}080$$

Dimensionless coefficient S_L is computed with the formula:

$$S_L(z,n) = \frac{n \cdot S_v(z,n)}{\sigma_v^2} = \frac{6{,}8 \cdot f_L(z,n)}{(1 + 10{,}2 \cdot f_L(z,n))^{5/3}}$$

$$L(z_s) = L_t * \left(\frac{z_s}{z_t}\right)^{\alpha} = 300 * \left(\frac{21}{200}\right)^{0{,}52} = 92{,}9$$

$$f_L(z_s, n_1) = \frac{n_1 * L(z_s)}{v_m(z_s)} = \frac{0{,}55 * 92{,}9}{31} = 1{,}65$$

Now S_L becomes:

$$S_L(z_s, n_1) = \frac{6{,}8 * 1{,}65}{(1 + 10{,}2 * 1{,}65)^{5/3}} = 0.092$$

$$K_s(n) = \frac{1}{1 + \sqrt{(G_y \cdot \varphi_y)^2 + (G_z \cdot \phi_z)^2 + \left(\frac{2}{\pi} \cdot G_y \cdot \phi_y \cdot G_z \cdot \phi_z\right)^2}}$$

With

G_y and G_z	factors depending on the vibration mode, in this case 1/2 and 3/8 respectively

$$\varphi_y(n_1) = \frac{c_y * b * n_1}{v_m(z_s)} = \frac{11{,}5 * 7 * 0{,}55}{31} = 1{,}43 \; and \; \varphi_x(n_1) = \frac{c_z * h * n_1}{v_m(z_s)} = \frac{11{,}5 * 35 * 0{,}55}{31} = 7{,}14$$

Thus $K_s(n_1)$= 0,248

Now R^2 becomes:

$$R^2 = \frac{\pi^2}{2\delta} * S_L(z_s, n_1) * K_s(n_1) = \frac{\pi^2}{2 * 0{,}08} * 0{,}092 * 0{,}248 = 1{,}41 \quad and \quad R = \sqrt{1{,}41} = 1{,}19$$

Now finally the standard deviation of the acceleration can be calculated, this is done for the platform level, the largest height that visitors can reach. At 27 meters.

$$\sigma_{a,x}(y,z) = c_f * \rho * I_v(z_s) * v_m{}^2(z_s) * R * \frac{K_y * K_z * \Phi(\mathrm{y},\mathrm{z})}{\mu_{ref} * \Phi_{\max}}$$

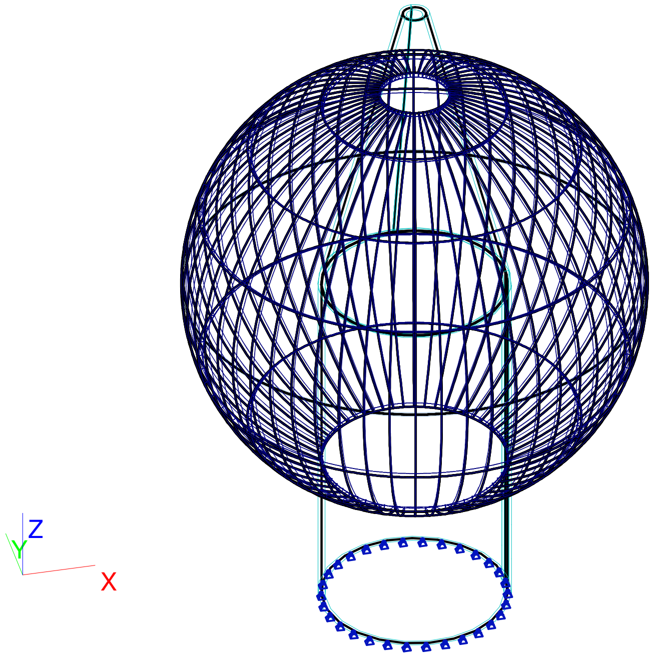
$$= 0{,}4 * 1{,}25 * 0{,}165 * 31^2 * 1{,}19 * \frac{1 * \frac{3}{2} * \left(\frac{27}{35}\right)^{1{,}5}}{709 * 1} = 0{,}135 \ {}^{m}/_{s^2}$$

Now the highest occurring acceleration can be computed by multiplying the standard deviation with a certain peak factor, k_p, computed for the natural frequency n_1=0,55. With T as the average time of the reference wind speed is 600 s.

$$k_p(n_1) = \sqrt{2 * \ln(n_1 * T)} + \frac{0{,}6}{\sqrt{2 * \ln(n_1 * T)}} = 3{,}58$$

Appendix H: Calculations

1. Overzicht constructie

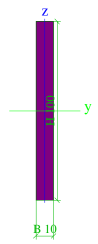


2. Materialen

Naam	Acrylic Short term
Type	Algemeen materiaal
E-mod [MPa]	1,8940e+03
Poisson - nu	0,4
G-mod [MPa]	6,7643e+02
Massa eenheid [kg/m³]	1200,0
Thermisch uitz. [m/mK]	0,00
Log. decrement	0,15
Specifieke hitte [J/gK]	1,4700e+00
Naam	Acrylic Long term
Type	Algemeen materiaal
E-mod [MPa]	9,0900e+02
Poisson - nu	0,4
G-mod [MPa]	3,2464e+02
Massa eenheid [kg/m³]	1200,0
Thermisch uitz. [m/mK]	0,00
Log. decrement	0,15
Specifieke hitte [J/gK]	1,4700e+00
Naam	Polycarbonate Short term
Type	Algemeen materiaal
E-mod [MPa]	1,7320e+03
Poisson - nu	0,4
G-mod [MPa]	6,1857e+02
Massa eenheid [kg/m³]	1200,0
Thermisch uitz. [m/mK]	0,00
Log. decrement	0,15
Specifieke hitte [J/gK]	1,2000e+00

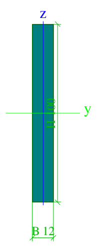
3. Doorsneden

Naam	CS3	
Type	Rechthoek	
Uitgebreid	100; 10	
Onderdeelmateriaal	Polycarbonate Short term	
Bouwwijze	Algemeen	
Knik y-y, z-z	b	b
EEM berekening	✓	



A [m²]	1,0000e-03	
A y, z [m²]	8,3660e-04	8,3333e-04
I y, z [m⁴]	8,3333e-07	8,3333e-09
I w [m⁶], t [m⁴]	0,0000e+00	3,0918e-08
Wel y, z [m³]	1,6667e-05	1,6667e-06
Wpl y, z [m³]	2,5000e-05	2,5000e-06
d y, z [mm]	0	0
c YLCS, ZLCS [mm]	5	50
alpha [deg]	0,00	
AL [m²/m]	2,2000e-01	

Naam	CS4	
Type	Rechthoek	
Uitgebreid	100; 12	
Onderdeelmateriaal	Polycarbonate Short term	
Bouwwijze	Algemeen	
Knik y-y, z-z	b	b
EEM berekening	×	



A [m²]	1,2000e-03	
A y, z [m²]	1,0000e-03	1,0000e-03
I y, z [m⁴]	1,0000e-06	1,4400e-08
I w [m⁶], t [m⁴]	0,0000e+00	5,2762e-08
Wel y, z [m³]	2,0000e-05	2,4000e-06
Wpl y, z [m³]	3,0000e-05	3,6000e-06
d y, z [mm]	0	0
c YLCS, ZLCS [mm]	6	50
alpha [deg]	0,00	
AL [m²/m]	2,2400e-01	

4. 2D-element

Naam	Materiaal	D. [mm]	Dikte type	Type	Laag
S2	Acrylic Long term	155	konstant	schaal (98)	Laag1
E4	Acrylic Long term	155	konstant	schaal (98)	Laag1

5. Belastingsgevallen

Naam	Omschrijving	Actie type	Lastgroep	Belastingtype	Spec	Richting	Duur	'Master' belastingsgeval
BG1		Permanent	LG1	Eigen gewicht		-Z		
BG2	Vloerlast BG	Variabel	LG2	Statisch	Standaard		Kort	Geen
BG3	Wind	Variabel	LG3	Statisch	Standaard		Kort	Geen
BG4	Sneeuw - evenly	Variabel	LG4	Statisch	Sneeuw			Geen
BG5	Sneeuw - unevenly	Variabel	LG4	Statisch	Standaard		Kort	Geen

6. Combinaties

Naam	Type	Belastingsgevallen	Coëff. [-]
UGT1-Long term	Lineair - UGT	BG1	1,35
		BG2 - Vloerlast BG	0,38
UGT2-Short term	Lineair - UGT	BG1	1,20
		BG2 - Vloerlast BG	1,50
UGT3-Short term- wi	Lineair - UGT	BG1	1,20
		BG2 - Vloerlast BG	0,38
		BG3 - Wind	1,50
UGT4a-Short term- sn -ev	Lineair - UGT	BG1	1,20
		BG2 - Vloerlast BG	0,38
		BG4 - Sneeuw - evenly	1,50
UGT4b-Short term- sn- un	Lineair - UGT	BG1	1,20
		BG2 - Vloerlast BG	0,38
		BG5 - Sneeuw - unevenly	1,50
BGT1-Long term	Lineair - BGT	BG1	1,00
		BG2 - Vloerlast BG	0,60
BGT2-Short term	Lineair - BGT	BG1	1,00
		BG2 - Vloerlast BG	1,00
BGT3-Short term- wi	Lineair - BGT	BG1	1,00
		BG2 - Vloerlast BG	0,25
		BG3 - Wind	1,00
BGT4a-Short term- sn- ev	Lineair - BGT	BG1	1,00
		BG2 - Vloerlast BG	0,25
		BG4 - Sneeuw - evenly	1,00
BGT4b-Short term- sn- un	Lineair - BGT	BG1	1,00
		BG2 - Vloerlast BG	0,25
		BG5 - Sneeuw - unevenly	1,00

7. Vrije oppervlakte last

Naam	Belastingsgeval	Rich	Type	Verdeling	q [kN/m²]	Geldigheid	Selecteer	Systeem	Locatie
FF1	BG4 - Sneeuw - evenly								
FF2	BG3 - Wind								
FF3	BG3 - Wind								
FF4	BG3 - Wind								
FF7	BG5 - Sneeuw - unevenly	Z	Kracht	Gelijkmatig	-0,2100	Alle	Selecteer	GCS	Lengte
FF8	BG5 - Sneeuw - unevenly	Z	Kracht	Gelijkmatig	-0,6300	Alle	Selecteer	GCS	Lengte
FF9	BG5 - Sneeuw - unevenly	Z	Kracht	Gelijkmatig	-0,2400	Alle	Selecteer	GCS	Lengte
FF10	BG5 - Sneeuw - unevenly	Z	Kracht	Gelijkmatig	-0,4200	Alle	Selecteer	GCS	Lengte
FF11	BG5 - Sneeuw - unevenly	Z	Kracht	Gelijkmatig	-1,2600	Alle	Selecteer	GCS	Lengte
FF12	BG5 - Sneeuw - unevenly	Z	Kracht	Gelijkmatig	-0,4200	Alle	Selecteer	GCS	Lengte

8. Lasten op oppervlak

Naam	Rich	Type	Waarde [kN/m²]	2D-element	Belastingsgeval	Systeem
SF1	Z	Kracht	-3,0000	E741	BG2 - Vloerlast BG	LCS

9. 2D element - Spanningen

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Klasse : Alle UGT
Hoofd grootheden. In knopen, gem. op elem..

BG	Staaf	elem	sig1+ [MPa]	sig2+ [MPa]	alfa+ [deg]	sigE+ [MPa]	sig1- [MPa]	sig2- [MPa]	alfa- [deg]	sigE- [MPa]	taumaxb [MPa]
Alle UGT	E516	23245	**-5,1**	-6,6	-49,35	3,1	1,7	-2,2	-8,57	2,6	0,1
Alle UGT	E510	22579	**6,6**	3,0	89,53	5,7	**5,8**	2,5	-87,60	5,0	0,1
Alle UGT	E733	49202	-4,2	**-8,2**	-1,92	3,7	0,0	-0,4	19,87	0,3	0,1
Alle UGT	E503	21626	5,4	**3,6**	-73,18	4,7	3,9	1,1	-79,32	3,5	0,1
Alle UGT	E406	10378	0,2	-0,6	**-90,00**	0,6	0,0	-1,2	**-90,00**	0,7	0,0
Alle UGT	E399	9407	0,7	0,2	**90,00**	0,9	0,5	-0,3	**90,00**	1,4	0,0
Alle UGT	S2	1350	0,0	0,0	-75,85	**0,0**	0,0	0,0	-83,40	0,0	0,0
Alle UGT	E733	49202	-2,1	-4,2	3,11	**7,1**	0,6	0,0	47,02	0,6	0,1
Alle UGT	E509	22278	0,3	-2,5	-0,44	1,4	**-3,5**	-4,6	-1,72	2,0	0,0

BG	Staaf	elem	sig1+ [MPa]	sig2+ [MPa]	alfa+ [deg]	sigE+ [MPa]	sig1- [MPa]	sig2- [MPa]	alfa- [deg]	sigE- [MPa]	taumaxb [MPa]
Alle UGT	E516	23222	-2,1	-6,4	8,51	2,9	-3,2	**-6,9**	-12,12	3,1	0,1
Alle UGT	E517	23547	4,4	2,0	89,85	3,8	4,4	**2,9**	89,73	3,9	0,0
Alle UGT	S2	1334	0,0	0,0	-88,77	0,0	0,0	0,0	-89,71	**0,0**	0,0
Alle UGT	E509	22266	-1,8	-3,9	-5,21	6,6	0,0	-3,2	-3,53	**6,1**	0,0
Alle UGT	S2	371	0,0	-0,1	-0,61	0,1	0,0	-0,1	-0,79	0,1	**0,0**
Alle UGT	S2	1366	2,6	0,9	2,56	2,3	-0,5	-1,1	-86,43	1,8	**6,1**

10. 2D element - Spanningen

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Combinaties : UGT1-Long term
Hoofd grootheden. In knopen, gem. op elem..

BG	Staaf	elem	sig1+ [MPa]	sig2+ [MPa]	alfa+ [deg]	sigE+ [MPa]	sig1- [MPa]	sig2- [MPa]	alfa- [deg]	sigE- [MPa]	taumaxb [MPa]
UGT1-Long term	E516	23245	**-2,9**	-3,7	-40,93	3,4	1,7	-1,2	-8,51	2,6	0,1
UGT1-Long term	E510	22579	**3,6**	1,7	87,83	3,1	**3,1**	1,4	-88,63	2,7	0,0
UGT1-Long term	E509	22261	-2,3	**-4,6**	-2,27	**4,0**	0,0	-0,3	16,89	0,3	0,1
UGT1-Long term	E503	21626	2,9	**2,0**	-74,35	2,6	2,1	0,6	-80,17	1,9	0,1
UGT1-Long term	E629	37098	0,3	-0,6	**-90,00**	0,8	0,3	-0,8	-90,00	1,0	0,0
UGT1-Long term	E681	42358	0,3	0,1	**90,00**	0,2	0,1	-0,4	**90,00**	0,4	0,0
UGT1-Long term	S2	1350	0,0	0,0	-75,85	**0,0**	0,0	0,0	-81,82	0,0	0,0
UGT1-Long term	E509	22278	0,3	-1,4	-0,43	1,6	**-1,9**	-2,6	-1,62	2,3	0,0
UGT1-Long term	E516	23222	-1,1	-3,6	8,51	3,2	-1,8	**-3,9**	-11,32	3,4	0,1
UGT1-Long term	E517	23547	2,4	1,1	89,85	2,1	2,4	**1,6**	89,73	2,1	0,0
UGT1-Long term	E637	38256	0,3	-0,3	-89,98	0,5	0,1	-0,8	**-90,00**	0,8	0,0
UGT1-Long term	S2	1331	0,0	0,0	89,98	0,0	0,0	0,0	-89,31	**0,0**	0,0
UGT1-Long term	E509	22266	-2,0	-4,3	-6,01	3,7	-0,2	-3,6	-3,98	**3,5**	0,0
UGT1-Long term	S2	371	0,0	-0,1	0,01	0,1	0,0	-0,1	0,02	0,1	**0,0**
UGT1-Long term	S2	1366	1,4	0,5	2,29	1,2	-0,5	-1,1	-86,43	1,0	**3,3**

11. 2D element - Interne krachten

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Klasse : Alle UGT
Basis grootheden. In knopen, gem. op elem..

BG	Staaf	elem	mx [kNm/m]	my [kNm/m]	mxy [kNm/m]	vx [kN/m]	vy [kN/m]	nx [kN/m]	ny [kN/m]	nxy [kN/m]
Alle UGT	E741	60931	**-9,4358**	-3,8994	-0,0006	-14,8745	-0,0588	-1,2661	1,6008	-0,3892
Alle UGT	E741	59945	**3,4162**	1,2586	0,0000	0,4585	0,0001	0,2949	1,8419	0,1132
Alle UGT	E741	60908	-3,9520	**-9,4900**	-0,0063	0,0102	-14,9171	0,8023	-1,0908	-2,4667
Alle UGT	S2	1515	1,4743	**3,5368**	-0,0199	0,2486	-34,3792	34,9643	9,2090	1,0998
Alle UGT	E741	60918	-6,1328	-6,1449	**-2,6466**	-4,1935	-4,0753	-2,7023	0,5205	-1,6519
Alle UGT	E741	60895	-2,7034	-2,6994	**2,6452**	4,0850	-1,8410	1,7591	0,7482	1,7352
Alle UGT	S2	870	-3,1259	-1,5904	-0,1180	**-217,1300**	-18,9802	14,1426	-13,3051	-2,4900
Alle UGT	S2	1366	-5,0476	-2,0275	-0,1393	**628,2318**	66,9899	**38,6807**	0,3380	0,7493
Alle UGT	S2	911	-0,3579	-1,4677	0,1846	32,3685	**-144,9129**	12,8457	-27,1980	2,4982
Alle UGT	S2	1389	1,8364	3,3138	0,1933	113,2176	**86,2737**	34,1084	7,3598	3,9440
Alle UGT	E4	3112	-0,3646	-1,8864	-0,0268	3,2197	-2,6569	**-49,3102**	-60,5636	-0,6428
Alle UGT	E4	3096	-0,0370	-0,0913	0,0052	0,0379	2,1459	-26,5730	**-66,8895**	-0,4383
Alle UGT	E510	22579	-0,0007	-0,0010	-0,0002	0,2722	-0,0179	16,7083	**36,9170**	0,1691
Alle UGT	S2	1050	0,2313	-0,3332	-0,4639	-2,8230	-40,1399	13,9985	-19,5278	**-5,5989**
Alle UGT	S2	1385	0,4940	2,2344	0,4767	49,6892	-13,9603	33,2598	2,7368	**5,1906**

12. Verplaatsing van knopen

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Klasse : Alle BGT

BG	Staaf	Knoop	Ux [mm]	Uy [mm]	Uz [mm]	Fix [mrad]	Fiy [mrad]	Fiz [mrad]
Alle BGT	E634	K914	**-4,0063**	0,6188	-11,8585	-0,3	-0,2	0,1
Alle BGT	E639	37437	**4,2423**	0,3454	-5,8556	0,0	0,1	0,0
Alle BGT	E768	K3314	-0,4260	**-3,9529**	-11,7186	0,0	0,7	-1,4
Alle BGT	E564	K644	0,2879	**4,0055**	-6,7179	-0,2	0,2	0,1
Alle BGT	E741	57382	-0,0079	-0,0340	**-17,3265**	0,0	-0,6	0,0

BG	Staaf	Knoop	Ux [mm]	Uy [mm]	Uz [mm]	Fix [mrad]	Fiy [mrad]	Fiz [mrad]
Alle BGT	E4	K244	0,0000	0,0000	**0,0000**	0,0	0,4	0,0
Alle BGT	E754	49996	0,1055	-2,6816	-10,9829	**-13,5**	-0,7	-0,1
Alle BGT	E698	43327	0,3308	-0,0591	-1,5272	**13,3**	0,4	-3,1
Alle BGT	E600	31980	-0,1290	0,1111	-2,6425	-0,1	**-13,3**	-4,9
Alle BGT	E509	21570	0,5392	0,2412	-1,8534	0,3	**13,3**	5,0
Alle BGT	E688	42263	-0,0465	-0,1767	-12,2470	-1,1	-1,4	**-12,5**
Alle BGT	E611	33718	2,1098	0,3803	-5,6086	1,1	-0,2	**12,5**

13. Spanning

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Combinaties : UGT2-Short term

Staaf	BG	dx [m]	Normaal - [MPa]	Normaal + [MPa]	Afschuiving [MPa]	Von Mises [MPa]	Vermoeiïng [MPa]	Kappa [-]
S826	UGT2-Short term	12,883	**-6,3**	5,0	0,9	6,3	0,0	0,00
S101	UGT2-Short term	6,823	**0,0**	0,4	0,1	0,4	0,0	0,00
S101	UGT2-Short term	0,338	-2,5	**0,0**	0,7	2,5	0,0	0,00
S811	UGT2-Short term	0,000	-5,3	**8,0**	1,3	**8,0**	0,0	0,00
S546	UGT2-Short term	0,201	-0,8	0,0	**0,0**	0,8	0,0	0,00
S283	UGT2-Short term	0,000	-5,3	8,0	**1,3**	8,0	0,0	0,00
S101	UGT2-Short term	7,064	0,0	0,2	0,0	**0,2**	0,0	0,00
S101	UGT2-Short term	0,000	-5,4	7,5	1,2	7,5	**0,0**	**0,00**

14. Spanning

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Combinaties : UGT1-Long term

Staaf	BG	dx [m]	Normaal - [MPa]	Normaal + [MPa]	Afschuiving [MPa]	Von Mises [MPa]	Vermoeiïng [MPa]	Kappa [-]
S826	UGT1-Long term	12,883	**-3,5**	2,8	0,5	3,5	0,0	0,00
S101	UGT1-Long term	6,823	**0,0**	0,1	0,0	0,1	0,0	0,00
S101	UGT1-Long term	0,338	-1,4	**0,0**	0,4	1,4	0,0	0,00
S811	UGT1-Long term	0,000	-3,0	**4,5**	0,7	**4,5**	0,0	0,00
S546	UGT1-Long term	0,201	-0,4	0,0	**0,0**	0,4	0,0	0,00
S319	UGT1-Long term	0,000	-3,0	4,5	**0,7**	4,5	0,0	0,00
S101	UGT1-Long term	7,004	0,0	0,1	0,0	**0,1**	0,0	0,00
S101	UGT1-Long term	0,000	-3,1	4,3	0,7	4,3	**0,0**	**0,00**

15. Interne krachten in staaf

Lineaire berekening, Extreem : Globaal, Systeem : Hoofd
Selectie : Alle
Klasse : Alle UGT

Staaf	BG	dx [m]	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
S101	UGT2-Short term/1	0,918	**-3,4694**	0,0000	-0,0107	0,0000	-0,0254	0,0000
S629	UGT2-Short term/1	0,201	**2,4413**	-0,0014	-0,0028	0,0000	0,0024	-0,0003
S829	UGT4b-Short term- sn- un/2	0,224	-2,0716	**-0,0859**	0,0536	-0,0007	-0,0006	-0,0010
S105	UGT4b-Short term- sn- un/2	0,000	0,3547	**0,0874**	-0,0359	0,0002	-0,0004	-0,0003
S101	UGT2-Short term/1	0,000	1,2598	0,0013	**-0,9396**	-0,0001	**0,1289**	0,0000
S101	UGT2-Short term/1	1,932	-1,7692	-0,0006	**0,2046**	0,0000	0,0119	0,0000
S692	UGT3-Short term- wi/3	0,000	-0,6478	-0,0244	-0,0319	**-0,0008**	-0,0050	0,0004
S747	UGT3-Short term- wi/3	0,520	-0,6478	0,0244	0,0320	**0,0008**	-0,0050	0,0004
S101	UGT4b-Short term- sn- un/2	12,881	-0,9308	-0,0020	-0,6429	0,0000	**-0,1134**	0,0000
S620	UGT4b-Short term- sn- un/2	0,000	-2,0028	0,0870	-0,0640	0,0007	0,0000	**-0,0010**
S791	UGT2-Short term/1	0,000	2,2800	-0,0606	0,1127	-0,0005	-0,0055	**0,0008**

16. Vervormingen van staaf

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Klasse : Alle BGT

BG	Staaf	dx [m]	ux [mm]	uy [mm]	uz [mm]	fix [mrad]	fiy [mrad]	fiz [mrad]
BGT2-Short term/4	S247	5,796	**-12,5671**	-0,0008	-0,1797	0,0	7,1	0,0

BG	Staaf	dx [m]	ux [mm]	uy [mm]	uz [mm]	fix [mrad]	fiy [mrad]	fiz [mrad]
BGT3-Short term- wi/5	S799	0,056	**2,3065**	-1,6540	-5,3348	1,0	0,3	-0,2
BGT3-Short term- wi/5	S813	0,112	0,0986	**-3,9204**	-4,6965	1,0	0,0	0,0
BGT2-Short term/4	S848	0,260	-0,0133	**10,9051**	-5,2944	1,1	0,0	0,0
BGT2-Short term/4	S101	11,034	-4,4249	-0,0006	**-11,2168**	0,0	-1,0	0,0
BGT2-Short term/4	S101	2,449	-6,1954	0,0100	**10,4636**	0,2	-1,4	0,0
BGT3-Short term- wi/5	S247	7,003	-4,9361	-1,9498	-3,9669	**-10,4**	-1,4	-0,1
BGT3-Short term- wi/5	S187	7,003	-4,9358	1,9486	-3,9649	**10,4**	-1,4	0,1
BGT2-Short term/4	S101	0,483	-0,9989	-0,0002	4,6703	0,0	**-10,0**	0,0
BGT2-Short term/4	S355	5,796	-12,5542	-0,0012	0,5033	0,0	**7,1**	0,0
BGT3-Short term- wi/5	S747	0,455	-1,5692	4,2716	-3,4934	0,4	1,3	**-2,1**
BGT3-Short term- wi/5	S692	0,065	1,5678	4,2717	-3,4912	0,4	-1,3	**2,1**

Pictures belonging to the calculation report of the sphere structure

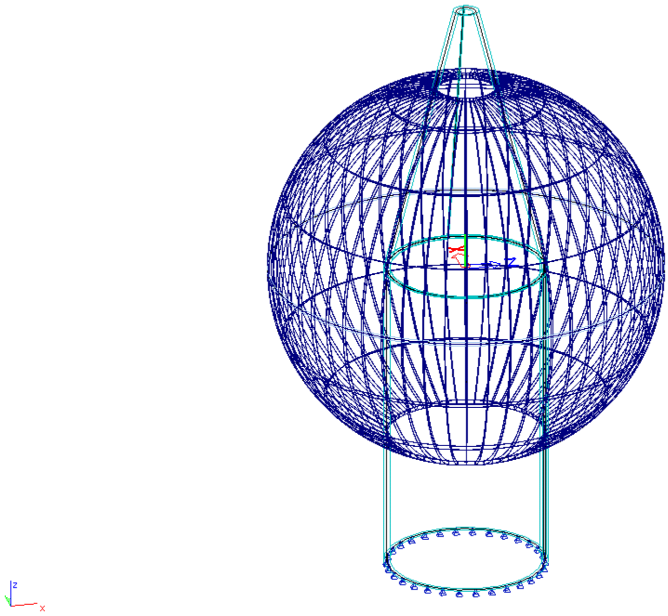


Figure 1: Overview structure

2 D Elements, stresses

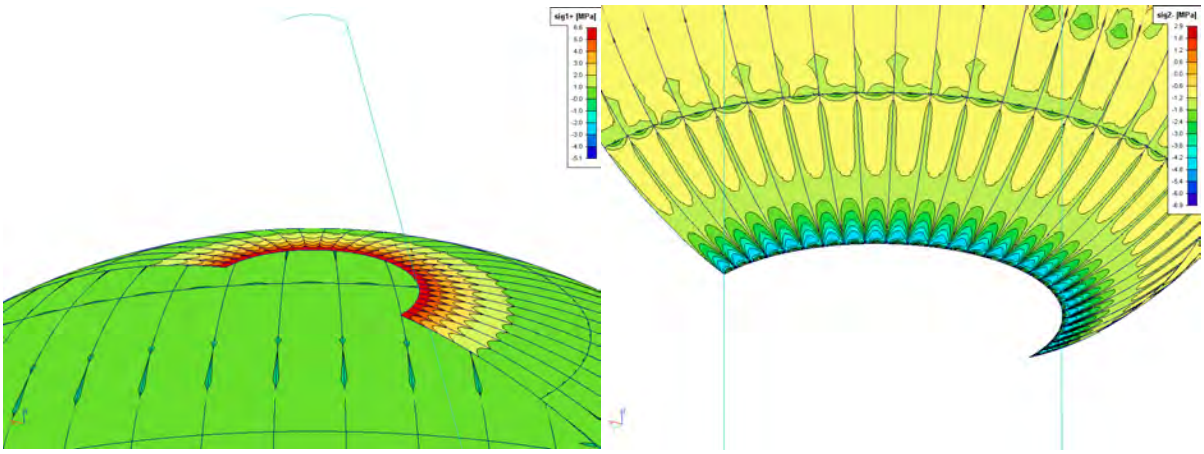
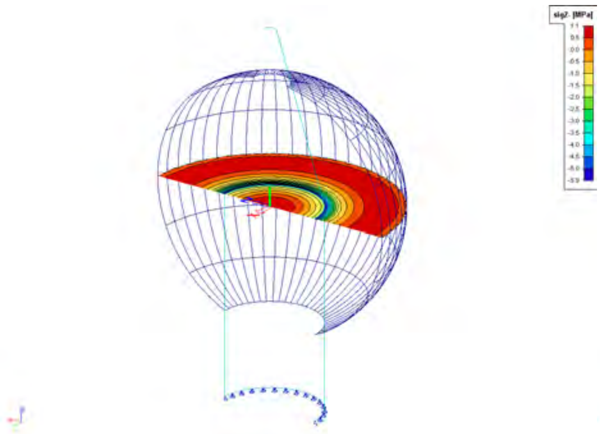


Figure 2: Maximal occurring principal stresses around the support edges, load case UGT2



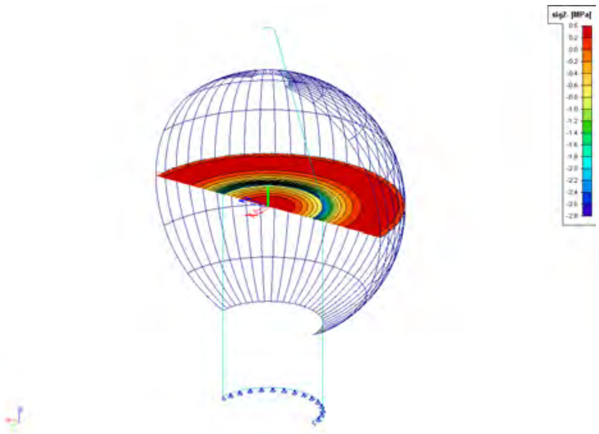


Figure 3: Maximal principal stress floor, UGT2 (short-term)

Figure 4: Maximal principal stress floor UGT1 (long-term)

2 D Elements, internal forces

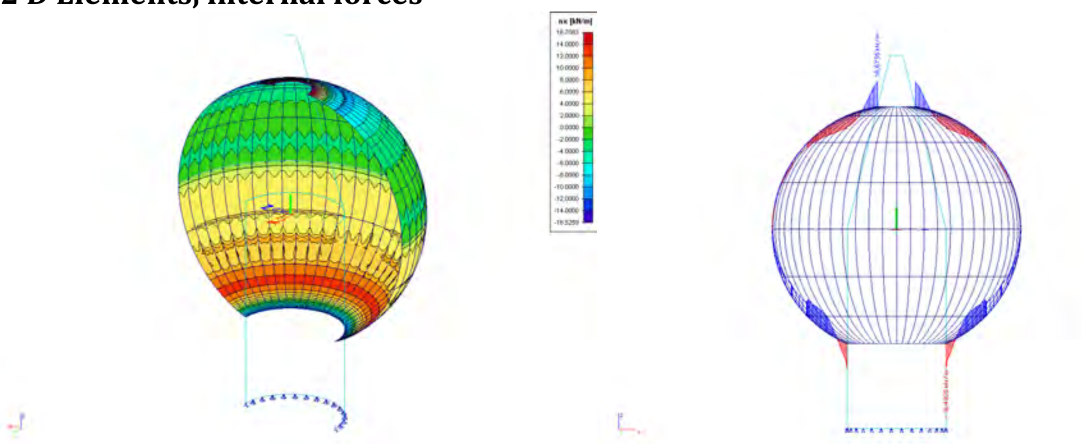


Figure 5: Ring forces nx for governing load case, UGT2

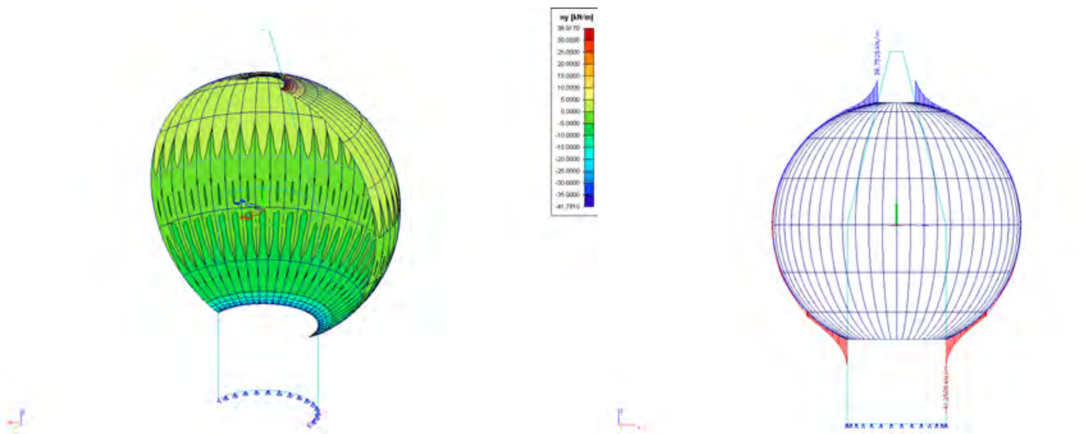


Figure 6: Meridional forces ny for governing load case, UGT2

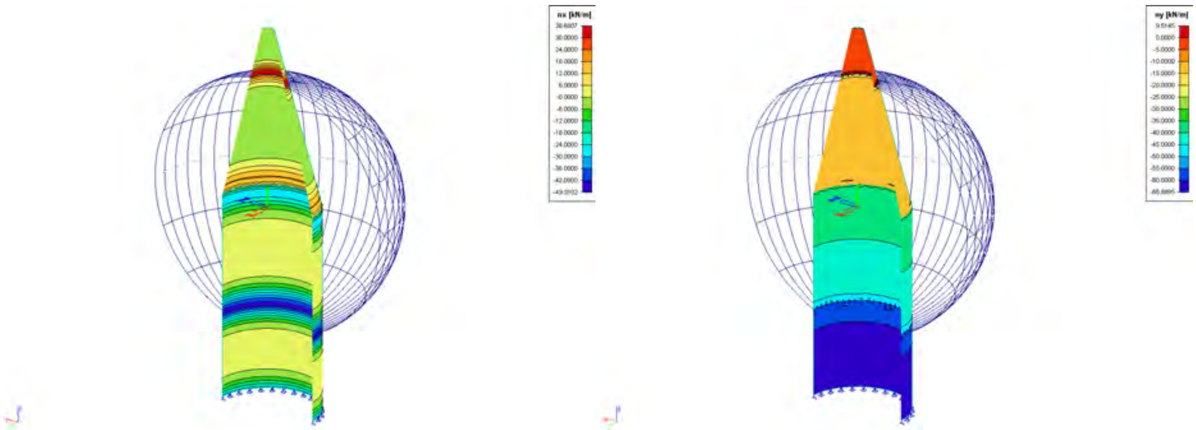


Figure 7: Ring forces nx (left) and mericional forces ny (right) core structure, for governing load case UGT2

2D elements, deformations

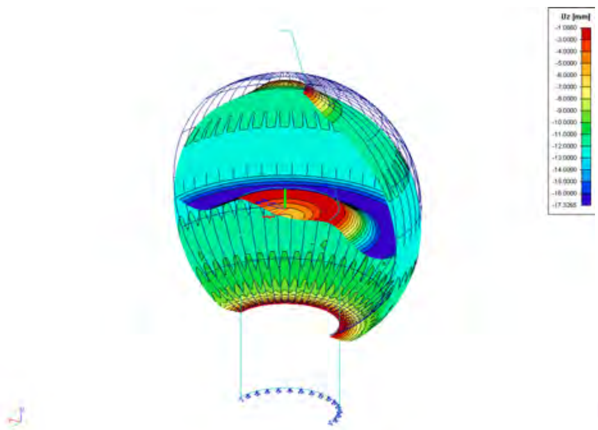


Figure 8: Vertical deformations for BGT2

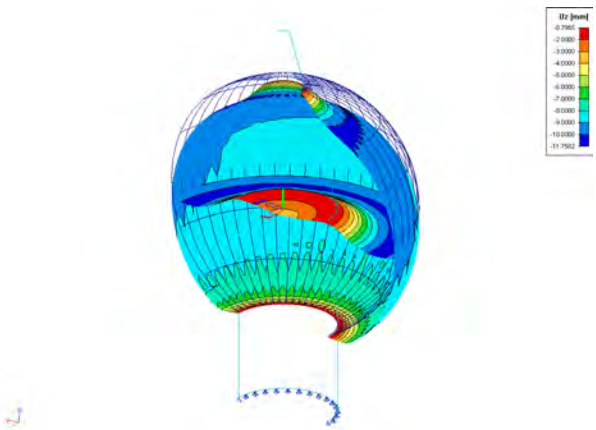


Figure 9: Vertical deformations for BGT4b

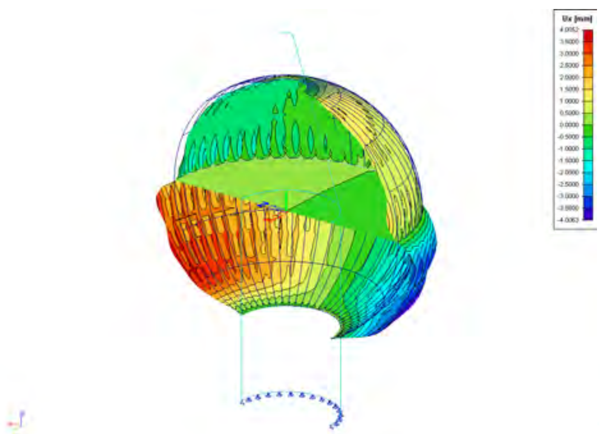


Figure 10: Deformations in x direction for BGT2

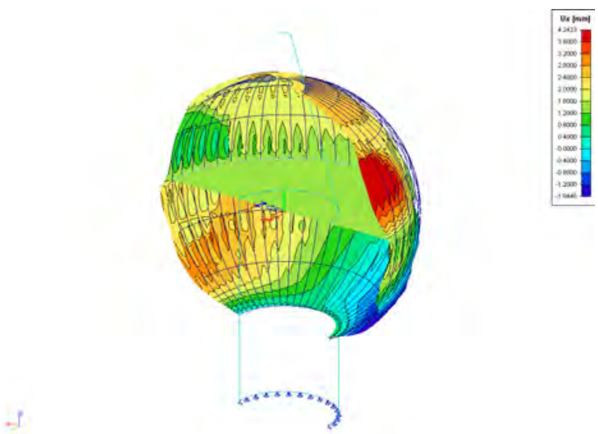


Figure 11: Deformations in x direction for BGT3

Ribs, internal forces

Figure 12: Normal forces for UGT2

Figure 13: Normal forces for UGT4b

Deformed structure

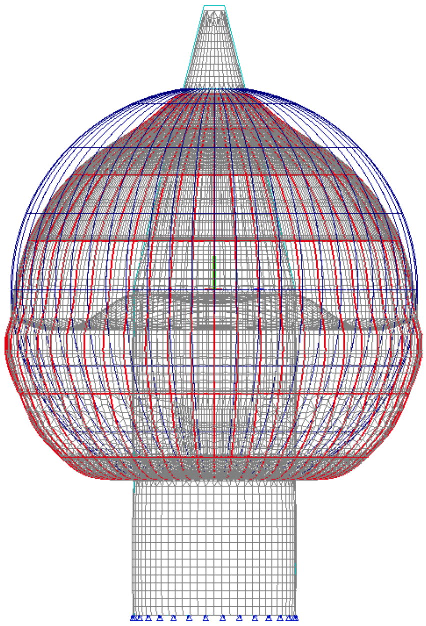


Figure 14: Deformed structure for BGT2

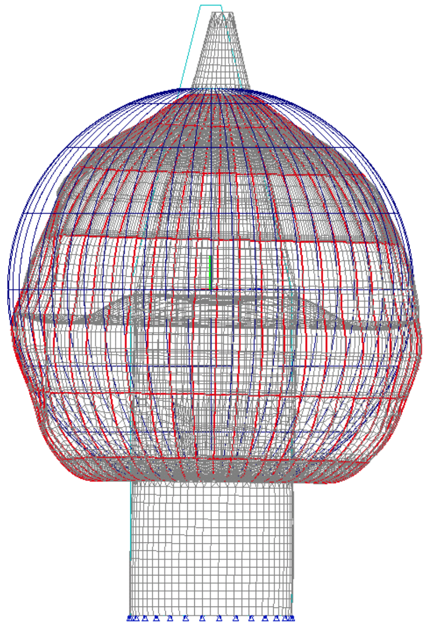
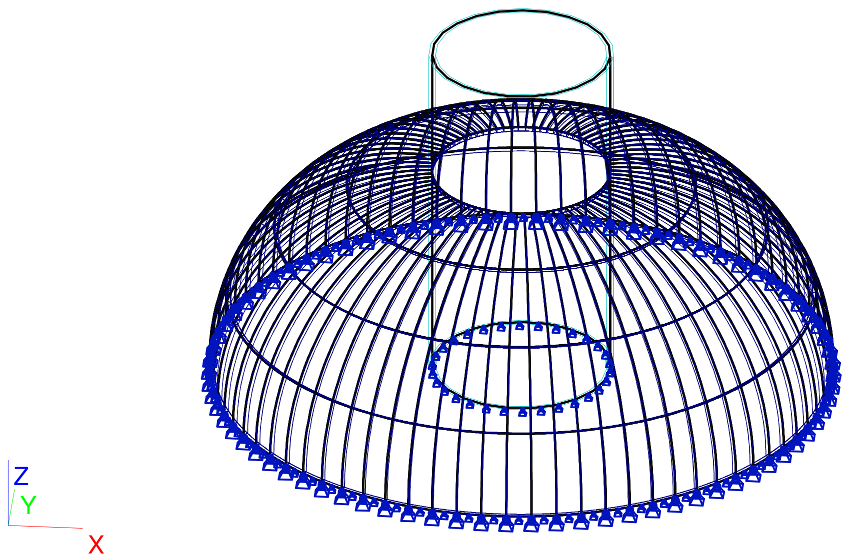


Figure 15: Deformed structure for BGT3

1. Overzicht constructie

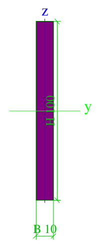


2. Materialen

Naam	Acrylic Short term
Type	Algemeen materiaal
E-mod [MPa]	1,8940e+03
Poisson - nu	0,4
G-mod [MPa]	6,7643e+02
Massa eenheid [kg/m³]	1200,0
Thermisch uitz. [m/mK]	0,00
Log. decrement	0,15
Specifieke hitte [J/gK]	1,4700e+00
Naam	Acrylic Long term
Type	Algemeen materiaal
E-mod [MPa]	9,0900e+02
Poisson - nu	0,4
G-mod [MPa]	3,2464e+02
Massa eenheid [kg/m³]	1200,0
Thermisch uitz. [m/mK]	0,00
Log. decrement	0,15
Specifieke hitte [J/gK]	1,4700e+00
Naam	Polycarbonate Short term
Type	Algemeen materiaal
E-mod [MPa]	1,7320e+03
Poisson - nu	0,4
G-mod [MPa]	6,1857e+02
Massa eenheid [kg/m³]	1200,0
Thermisch uitz. [m/mK]	0,00
Log. decrement	0,15
Specifieke hitte [J/gK]	1,2000e+00

3. Doorsneden

Naam	CS3	
Type	Rechthoek	
Uitgebreid	100; 10	
Onderdeelmateriaal	Polycarbonate Short term	
Bouwwijze	Algemeen	
Knik y-y, z-z	b	b
EEM berekening	✓	



A [m²]	1,0000e-03	
A y, z [m²]	8,3660e-04	8,3333e-04
I y, z [m⁴]	8,3333e-07	8,3333e-09
I w [m⁶], t [m⁴]	0,0000e+00	3,0918e-08
Wel y, z [m³]	1,6667e-05	1,6667e-05
Wpl y, z [m³]	2,5000e-05	2,5000e-06
d y, z [mm]	0	0
c YLCS, ZLCS [mm]	5	50
alpha [deg]	0,00	
AL [m²/m]	2,2000e-01	

4. 2D-element

Naam	Materiaal	D. [mm]	Dikte type	Type	Laag
E4	Acrylic Long term	155	konstant	schaal (98)	Laag1

5. Belastingsgevallen

Naam	Omschrijving	Actie type	Lastgroep	Belastingtype	Spec	Richting	Duur	'Master' belastingsgeval
BG1		Permanent	LG1	Eigen gewicht		-Z		
BG3	Wind	Variabel	LG3	Statisch	Standaard		Kort	Geen
BG4	Sneeuw - evenly	Variabel	LG4	Statisch	Sneeuw			Geen
BG5	Sneeuw - unevenly	Variabel	LG4	Statisch	Standaard		Kort	Geen

6. Combinaties

Naam	Type	Belastingsgevallen	Coëff. [-]
UGT1-Long term	Lineair - UGT	BG1	1,35
UGT3-Short term- wi	Lineair - UGT	BG1	1,20
		BG3 - Wind	1,50
UGT4a-Short term- sn -ev	Lineair - UGT	BG1	1,20
		BG4 - Sneeuw - evenly	1,50
UGT4b-Short term- sn- un	Lineair - UGT	BG1	1,20
		BG5 - Sneeuw - unevenly	1,50
BGT1-Long term	Lineair - BGT	BG1	1,00
BGT3-Short term- wi	Lineair - BGT	BG1	1,00
		BG3 - Wind	1,00
BGT4a-Short term- sn- ev	Lineair - BGT	BG1	1,00
		BG4 - Sneeuw - evenly	1,00
BGT4b-Short term- sn- un	Lineair - BGT	BG1	1,00
		BG5 - Sneeuw - unevenly	1,00

7. Vrije oppervlakte last

Naam	Belastingsgeval	Rich	Type	Verdeling	q [kN/m²]	Geldigheid	Selecteer	Systeem	Locatie
FF7	BG5 - Sneeuw - unevenly	Z	Kracht	Gelijkmatig	-0,2100	Alle	Selecteer	GCS	Lengte
FF8	BG5 - Sneeuw - unevenly	Z	Kracht	Gelijkmatig	-0,6300	Alle	Selecteer	GCS	Lengte
FF9	BG5 - Sneeuw - unevenly	Z	Kracht	Gelijkmatig	-0,2400	Van-tot	Selecteer	GCS	Lengte
FF10	BG5 - Sneeuw - unevenly	Z	Kracht	Gelijkmatig	-0,4200	Alle	Selecteer	GCS	Lengte
FF11	BG5 - Sneeuw - unevenly	Z	Kracht	Gelijkmatig	-1,2600	Alle	Selecteer	GCS	Lengte
FF12	BG5 - Sneeuw - unevenly	Z	Kracht	Gelijkmatig	-0,4200	Alle	Selecteer	GCS	Lengte
FF13	BG3 - Wind								
FF14	BG3 - Wind								

Naam	Belastingsgeval	Rich	Type	Verdeling	q [kN/m²]	Geldigheid	Selecteer	Systeem	Locatie
FF15	BG3 - Wind								
FF16	BG4 - Sneeuw - evenly								

8. Vlaklast

9. 2D element - Spanningen

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Klasse : Alle UGT
Hoofd grootheden. In knopen, gem. op elem..

BG	Staaf	elem	sig1+ [MPa]	sig2+ [MPa]	alfa+ [deg]	sigE+ [MPa]	sig1- [MPa]	sig2- [MPa]	alfa- [deg]	sigE- [MPa]	taumaxb [MPa]
Alle UGT	E774	10218	**-1,2**	-1,6	-89,90	0,7	-0,5	-0,7	3,07	0,5	0,0
Alle UGT	E988	54375	**2,2**	0,3	45,64	**2,2**	0,8	0,6	15,05	1,0	0,0
Alle UGT	E757	6303	-0,1	**-1,8**	-1,32	1,6	-0,1	-0,6	-3,46	0,5	0,0
Alle UGT	E852	26140	0,8	**0,8**	47,26	1,1	0,8	0,3	52,77	1,0	0,0
Alle UGT	E933	43018	0,2	-0,2	**-90,00**	0,2	0,2	-0,3	-85,39	0,2	0,0
Alle UGT	E806	16673	1,1	0,4	**90,00**	0,9	0,6	0,1	-0,25	0,6	0,0
Alle UGT	E4	2857	0,0	0,0	-0,59	**0,0**	0,0	0,0	-77,79	0,0	0,0
Alle UGT	E774	10259	-0,5	-1,0	2,86	0,8	**-1,2**	-1,4	6,13	0,8	0,0
Alle UGT	E800	15330	1,0	0,2	0,58	1,0	**2,2**	0,4	1,16	2,0	0,0
Alle UGT	E801	15791	-0,6	-1,0	-26,61	0,2	0,2	**-2,0**	-5,94	0,3	0,0
Alle UGT	E912	38603	1,1	0,0	43,23	1,1	1,3	**0,9**	75,69	1,3	0,0
Alle UGT	E4	2830	0,0	0,0	-8,13	0,0	0,0	0,0	**-90,00**	0,0	0,0
Alle UGT	E885	33283	0,2	0,1	0,00	1,0	1,0	0,4	**90,00**	0,9	0,0
Alle UGT	E4	2845	0,0	0,0	-87,69	0,0	0,0	0,0	-2,28	**0,0**	0,0
Alle UGT	E801	15791	1,8	0,1	39,28	1,8	1,0	-0,1	62,63	**2,1**	0,0
Alle UGT	E4	31	0,0	-0,1	-3,26	0,1	0,0	-0,1	-3,06	0,1	**0,0**
Alle UGT	E4	1558	0,3	0,1	86,42	0,2	0,2	0,1	67,73	0,3	**0,5**

10. 2D element - Spanningen

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Combinaties : UGT1-Long term
Hoofd grootheden. In knopen, gem. op elem..

BG	Staaf	elem	sig1+ [MPa]	sig2+ [MPa]	alfa+ [deg]	sigE+ [MPa]	sig1- [MPa]	sig2- [MPa]	alfa- [deg]	sigE- [MPa]	taumaxb [MPa]
UGT1-Long term	E749	5000	**-0,2**	-0,2	-24,75	0,2	0,2	-0,1	-6,87	0,2	0,0
UGT1-Long term	E745	3906	**0,3**	0,0	-1,59	**0,2**	0,0	-0,1	-6,77	0,1	0,0
UGT1-Long term	E749	5030	-0,1	**-0,3**	0,00	0,2	0,1	**0,0**	-89,99	0,1	0,0
UGT1-Long term	E958	48247	0,0	**0,0**	-72,24	0,0	0,0	0,0	13,35	0,0	0,0
UGT1-Long term	E910	38278	0,0	0,0	**-89,95**	0,0	0,0	0,0	-0,13	0,0	0,0
UGT1-Long term	E1038	64867	0,0	0,0	**89,92**	0,0	0,0	0,0	-0,11	0,0	0,0
UGT1-Long term	E4	2831	0,0	0,0	-0,02	**0,0**	0,0	0,0	-0,02	0,0	0,0
UGT1-Long term	E746	4425	0,0	-0,1	1,50	0,1	**-0,1**	-0,1	-78,16	0,1	0,0
UGT1-Long term	E745	4145	-0,1	-0,2	-23,85	0,2	**0,2**	0,0	-5,05	0,3	0,0
UGT1-Long term	E749	5025	-0,1	-0,2	-5,10	0,2	-0,1	**-0,2**	-10,94	0,2	0,0
UGT1-Long term	E953	47409	-0,1	-0,3	0,00	0,2	0,1	0,0	**-90,00**	0,1	0,0
UGT1-Long term	E809	17495	-0,1	-0,3	0,00	0,2	0,1	0,0	**90,00**	0,1	0,0
UGT1-Long term	E4	2884	0,0	0,0	0,08	0,0	0,0	0,0	0,07	**0,0**	0,0
UGT1-Long term	E745	4157	-0,1	-0,2	-26,62	0,2	0,2	-0,1	-5,84	**0,3**	0,0
UGT1-Long term	E4	31	0,0	-0,1	0,00	0,1	0,0	-0,1	0,00	0,1	**0,0**
UGT1-Long term	E4	2908	0,0	0,0	-17,98	0,0	0,0	-0,1	11,51	0,1	**0,1**

11. 2D element - Interne krachten

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Klasse : Alle UGT
Basis grootheden. In knopen, gem. op elem..

BG	Staaf	elem	mx [kNm/m]	my [kNm/m]	mxy [kNm/m]	vx [kN/m]	vy [kN/m]	nx [kN/m]	ny [kN/m]	nxy [kN/m]
Alle UGT	E4	1649	**-0,8055**	-1,1387	0,0000	-15,9301	-22,1741	-7,2525	-9,3988	-0,4401
Alle UGT	E4	1761	**0,5291**	0,8192	0,0366	16,3936	20,3688	8,9305	-5,8079	0,9460
Alle UGT	E4	1558	-0,5317	**-1,3107**	-0,0600	-13,8411	**-45,1342**	-8,5209	-10,1363	-0,6326

BG	Staaf	elem	mx [kNm/m]	my [kNm/m]	mxy [kNm/m]	vx [kN/m]	vy [kN/m]	nx [kN/m]	ny [kN/m]	nxy [kN/m]
Alle UGT	E4	1669	0,4223	**0,8698**	0,0404	14,8357	23,4315	10,8308	-6,4145	0,8443
Alle UGT	E4	1514	-0,1370	-0,1285	**-0,2001**	-12,3727	-22,0979	-5,8550	-7,6920	-0,2481
Alle UGT	E4	2962	0,1958	0,3686	**0,1897**	7,6538	-0,4852	9,1172	-4,3387	0,9826
Alle UGT	E4	1603	-0,7281	-1,1041	-0,0495	**-36,0418**	-22,2246	-8,4009	-9,4741	-0,8667
Alle UGT	E4	1548	0,4480	0,7940	0,0478	**35,6722**	12,6757	9,1939	-5,5080	0,8949
Alle UGT	E4	3036	0,2097	0,6971	0,0984	10,1804	**43,2383**	10,8345	-3,7283	0,5498
Alle UGT	E4	1579	-0,1919	-0,5375	-0,0139	-0,0193	-4,8354	**-8,8347**	-7,8162	-0,0065
Alle UGT	E4	1515	0,0297	0,4354	0,0223	0,5860	0,0856	**11,2389**	-6,7277	0,5082
Alle UGT	E4	1431	-0,0107	-0,0269	-0,0043	-0,0011	-0,8173	-7,9506	**-19,8850**	-0,1004
Alle UGT	E753	5597	0,0012	0,0005	0,0000	0,0080	-0,0001	4,1191	**6,0562**	0,0009
Alle UGT	E757	6675	-0,0005	-0,0004	-0,0008	-0,0192	-0,0071	-0,6411	-3,5951	**-4,8509**
Alle UGT	E801	15826	0,0003	0,0003	0,0008	0,0106	0,0071	0,1548	2,0022	**4,8515**

12. Verplaatsing van knopen

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Klasse : Alle BGT

BG	Staaf	Knoop	Ux [mm]	Uy [mm]	Uz [mm]	Fix [mrad]	Fiy [mrad]	Fiz [mrad]
Alle BGT	E765	7874	**-3,0568**	-0,6080	-0,3637	-0,1	0,0	0,0
Alle BGT	E773	9470	**3,8090**	0,2905	-0,0312	0,1	0,7	0,1
Alle BGT	E853	25970	-0,1214	**-3,0120**	-0,0172	-0,1	0,0	0,0
Alle BGT	E1013	58838	0,0215	**3,5775**	0,2146	0,2	0,1	0,0
Alle BGT	E1010	58584	0,0000	-1,4828	**-7,1964**	-1,0	-0,1	0,0
Alle BGT	E775	10111	0,1994	0,0026	**2,8623**	0,1	3,0	0,1
Alle BGT	E1013	59156	0,0000	0,0686	-0,0059	**-9,2**	0,0	0,0
Alle BGT	E857	27098	0,0022	-0,0686	0,0101	**7,8**	0,0	0,0
Alle BGT	E772	9371	-1,7350	0,0264	-1,3913	-1,9	**-13,4**	-0,2
Alle BGT	E801	15578	0,8618	0,3386	-0,0015	3,3	**9,2**	0,0
Alle BGT	E805	16179	-2,3861	-1,2680	-0,0107	-1,4	-2,3	**-13,8**
Alle BGT	E753	5503	1,3807	1,4212	0,0865	1,4	-0,1	**13,8**

13. Spanning

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Klasse : Alle UGT

Staaf	BG	dx [m]	Normaal - [MPa]	Normaal + [MPa]	Afschuiving [MPa]	Von Mises [MPa]	Vermoeiïng [MPa]	Kappa [-]
S372	Alle UGT	7,855	**-2,7**	0,8	0,2	**2,7**	3,4	-0,29
S3	Alle UGT	0,000	**0,0**	0,8	0,1	0,8	0,8	0,06
S42	Alle UGT	3,055	-0,9	**0,0**	0,2	0,9	0,8	0,11
S90	Alle UGT	0,687	-1,3	**1,9**	0,1	1,9	3,3	-0,69
S191	Alle UGT	0,282	-0,1	0,1	**0,0**	0,1	0,0	0,23
S90	Alle UGT	0,000	-0,9	1,0	**0,4**	1,0	1,9	-0,87
S209	Alle UGT	0,282	-0,1	0,1	0,0	**0,1**	0,0	0,23
S209	Alle UGT	0,094	0,0	0,0	0,1	0,2	**0,0**	0,20
S66	Alle UGT	7,855	-2,6	1,4	0,2	2,6	**3,9**	-0,53
S132	Alle UGT	5,727	-0,3	0,6	0,0	0,6	0,6	**-1,00**
S209	Alle UGT	0,517	0,0	0,0	0,1	0,1	0,0	**0,25**
S1	Alle UGT	0,000	-0,1	0,2	0,0	0,2	0,3	-0,58

14. Spanning

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Combinaties : UGT1-Long term

Staaf	BG	dx [m]	Normaal - [MPa]	Normaal + [MPa]	Afschuiving [MPa]	Von Mises [MPa]	Vermoeiïng [MPa]	Kappa [-]
S468	UGT1-Long term	0,785	**-0,3**	0,0	0,0	**0,3**	0,0	0,00
S1	UGT1-Long term	0,000	**0,0**	0,0	0,0	0,0	**0,0**	**0,00**
S2	UGT1-Long term	0,000	0,0	**0,0**	0,0	0,0	0,0	0,00
S196	UGT1-Long term	0,000	0,0	**0,1**	0,0	0,1	0,0	0,00
S293	UGT1-Long term	0,282	0,0	0,0	**0,0**	0,0	0,0	0,00
S6	UGT1-Long term	0,000	-0,2	0,1	**0,0**	0,2	0,0	0,00
S29	UGT1-Long term	0,282	0,0	0,0	0,0	**0,0**	0,0	0,00

15. Interne krachten in staaf

Lineaire berekening, Extreem : Globaal, Systeem : Hoofd
Selectie : Alle
Klasse : Alle UGT

Staaf	BG	dx [m]	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
S402	UGT4b-Short term- sn- un/1	0,835	**-1,0320**	0,0000	-0,0008	0,0000	-0,0097	0,0000
S406	UGT4b-Short term- sn- un/1	0,267	**1,2780**	0,0000	0,0003	0,0000	0,0012	0,0000
S18	UGT3-Short term- wi/2	0,000	0,2238	**-0,0247**	0,1924	0,0002	-0,0102	**0,0003**
S278	UGT4b-Short term- sn- un/1	0,000	-0,8188	**0,0308**	-0,0231	0,0001	-0,0036	-0,0002
S402	UGT4b-Short term- sn- un/1	0,000	-0,2881	0,0000	**-0,1640**	0,0000	0,0129	0,0000
S90	UGT3-Short term- wi/2	0,000	0,2239	0,0247	**0,1924**	-0,0002	-0,0102	-0,0003
S90	UGT3-Short term- wi/2	1,375	0,5572	-0,0077	-0,0563	**-0,0005**	0,0010	0,0000
S18	UGT3-Short term- wi/2	1,375	0,5576	0,0077	-0,0562	**0,0005**	0,0011	0,0000
S288	UGT4a-Short term- sn -ev/3	7,854	-0,9162	0,0000	-0,1292	0,0000	**-0,0277**	0,0000
S90	UGT3-Short term- wi/2	0,687	0,9608	0,0048	-0,0073	0,0004	**0,0155**	0,0001
S89	UGT3-Short term- wi/2	0,564	0,0072	-0,0224	0,0043	-0,0001	0,0001	**-0,0004**

16. Vervormingen van staaf

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Klasse : Alle BGT

BG	Staaf	dx [m]	ux [mm]	uy [mm]	uz [mm]	fix [mrad]	fiy [mrad]	fiz [mrad]
BGT4b-Short term- sn- un/4	S402	4,418	**-2,8994**	-0,0048	-2,2243	0,0	3,7	0,0
BGT3-Short term- wi/5	S54	3,109	**1,8106**	0,0013	-0,5378	0,0	-3,5	0,0
BGT4b-Short term- sn- un/4	S405	0,000	-0,0134	**-2,8108**	-0,4996	-2,7	0,0	0,0
BGT3-Short term- wi/5	S51	0,279	-0,0393	**1,5394**	2,0716	2,7	0,0	0,0
BGT4b-Short term- sn- un/4	S396	5,891	-1,3093	-0,0067	**-7,2120**	0,0	-0,5	0,0
BGT4b-Short term- sn- un/4	S408	1,325	-0,8760	0,0014	**3,4656**	0,0	-0,2	0,0
BGT3-Short term- wi/5	S90	1,031	0,4130	-1,0469	-1,7519	**-9,9**	-1,3	-0,2
BGT3-Short term- wi/5	S18	1,031	0,4129	1,0468	-1,7526	**9,9**	-1,3	0,2
BGT4b-Short term- sn- un/4	S414	6,922	-0,0379	0,0012	-3,7696	0,0	**-5,1**	0,0
BGT3-Short term- wi/5	S84	0,098	-0,2328	-0,0297	-0,4948	0,4	**4,9**	-0,3
BGT3-Short term- wi/5	S90	0,442	0,0142	-0,4845	-1,4894	-3,6	2,4	**-1,2**
BGT3-Short term- wi/5	S18	0,442	0,0141	0,4845	-1,4896	3,6	2,4	**1,2**

Pictures belonging to the calculation report of the dome structure

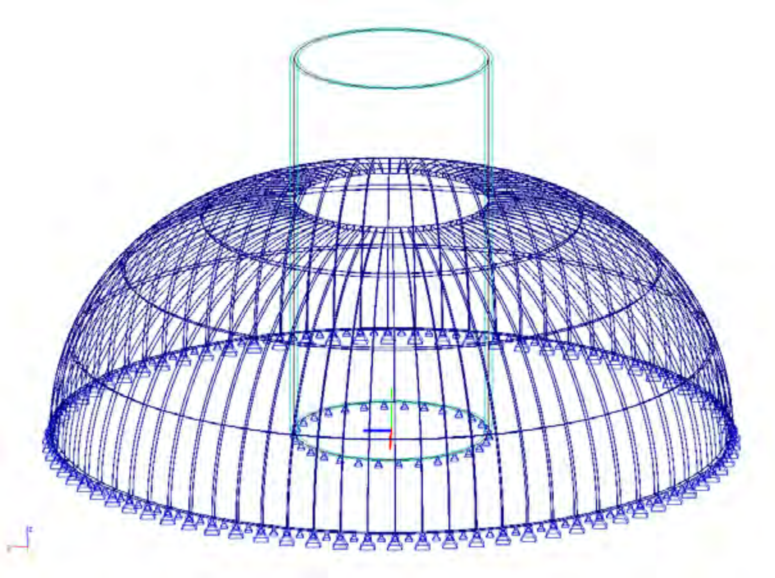


Figure 1: Overview structure

2 D Elements, stresses

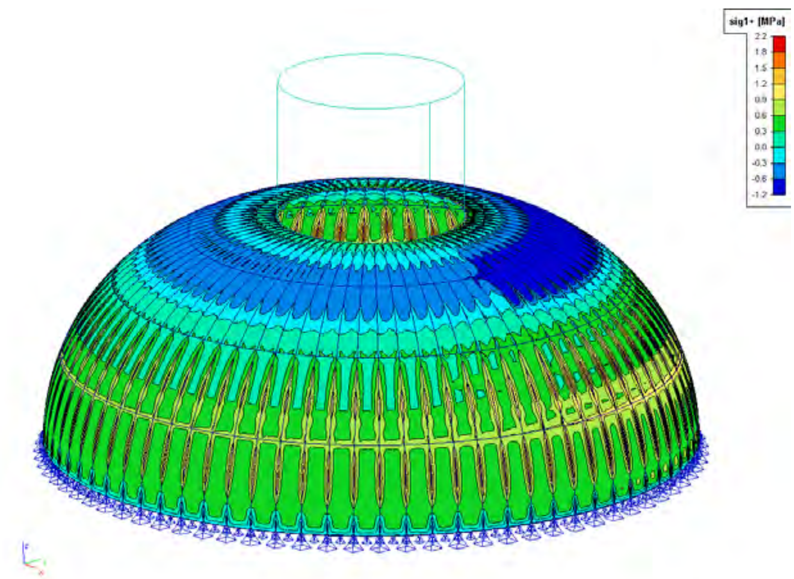


Figure 2: Maximal occurring principal stresses, load case UGT4b

2 D Elements, internal forces

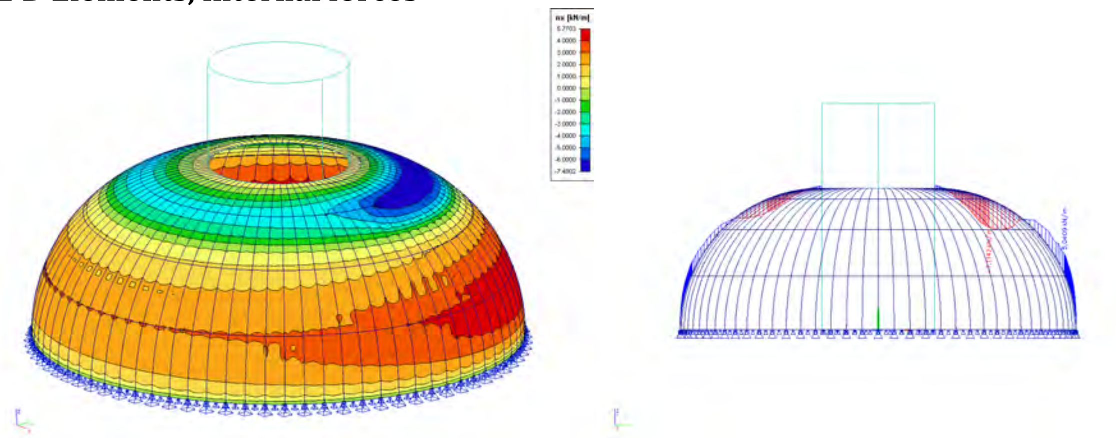


Figure 3: Ring forces nx for governing load case, UGT4b

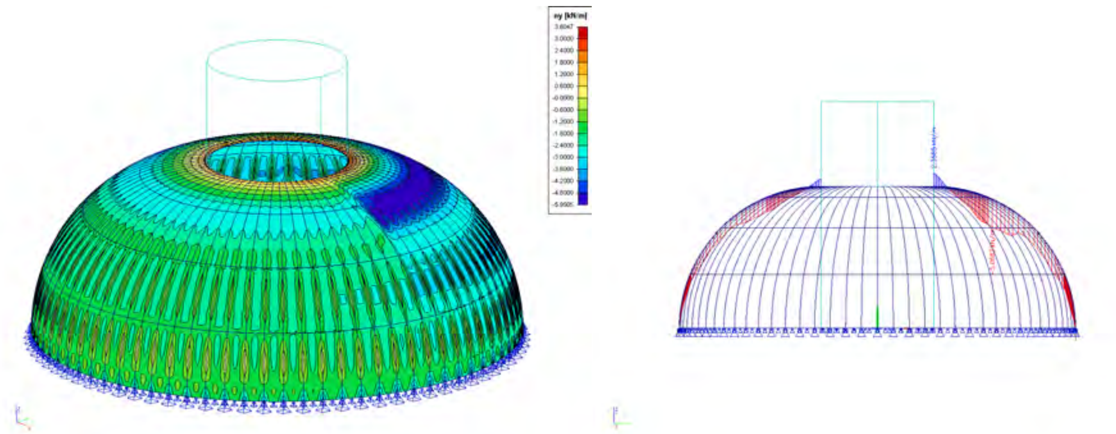


Figure 4: Meridional forces ny for governing load case, UGT4b

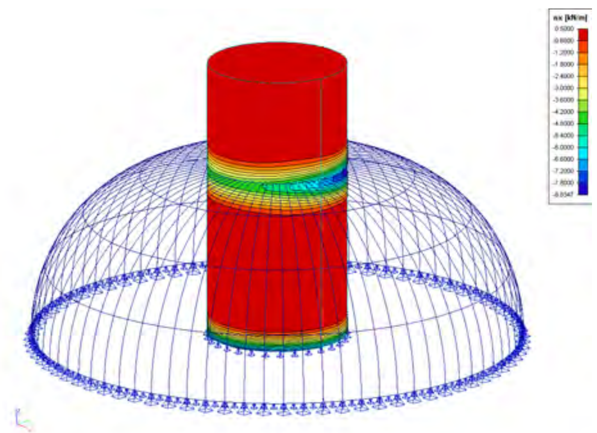


Figure 5: Ring forces nx on core structure, for governing load case UGT4b

2D elements, deformations

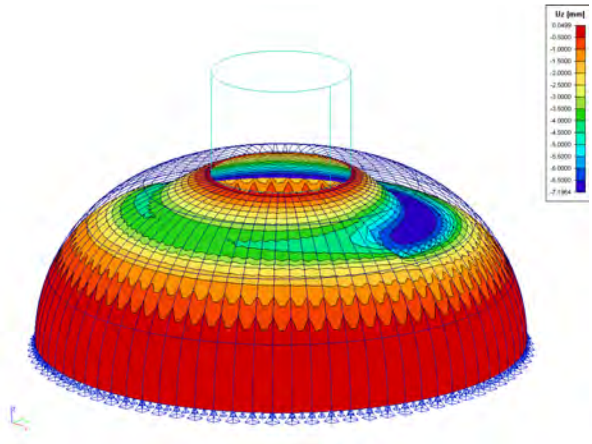


Figure 6: Vertical deformations for BGT4b

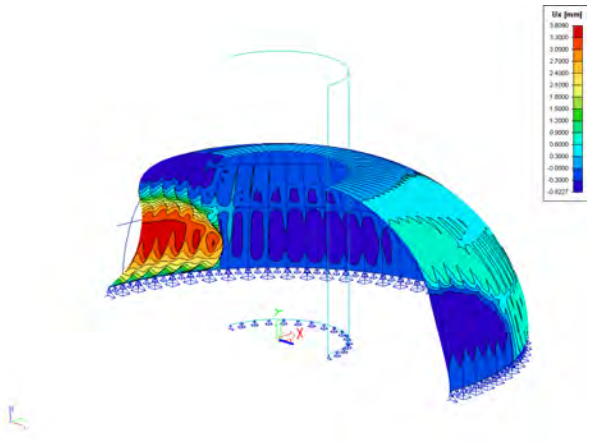


Figure 7: Deformations in x direction for BGT3

Ribs, internal forces

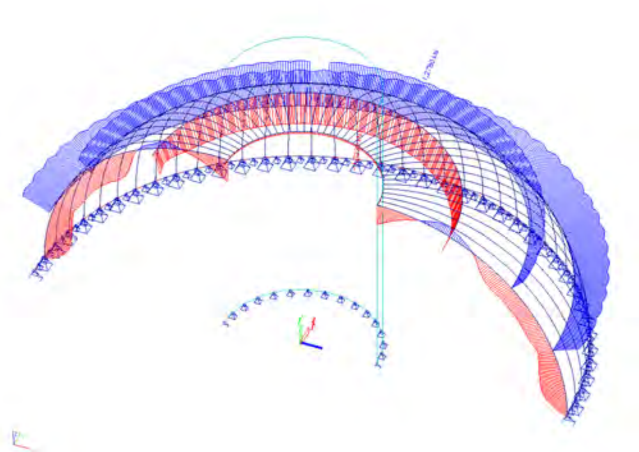


Figure 8: Normal forces for UGT4b

Deformed structure

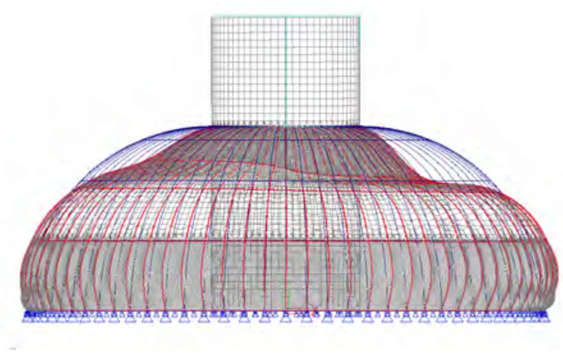


Figure 9: Deformed structure for BGT4b

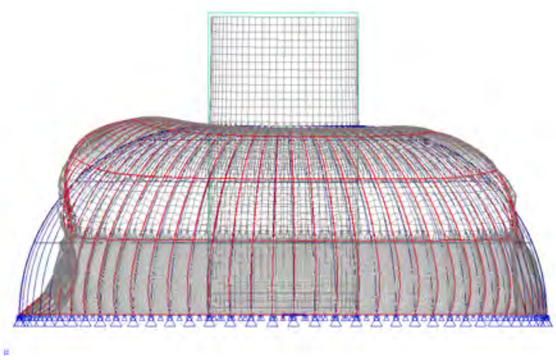
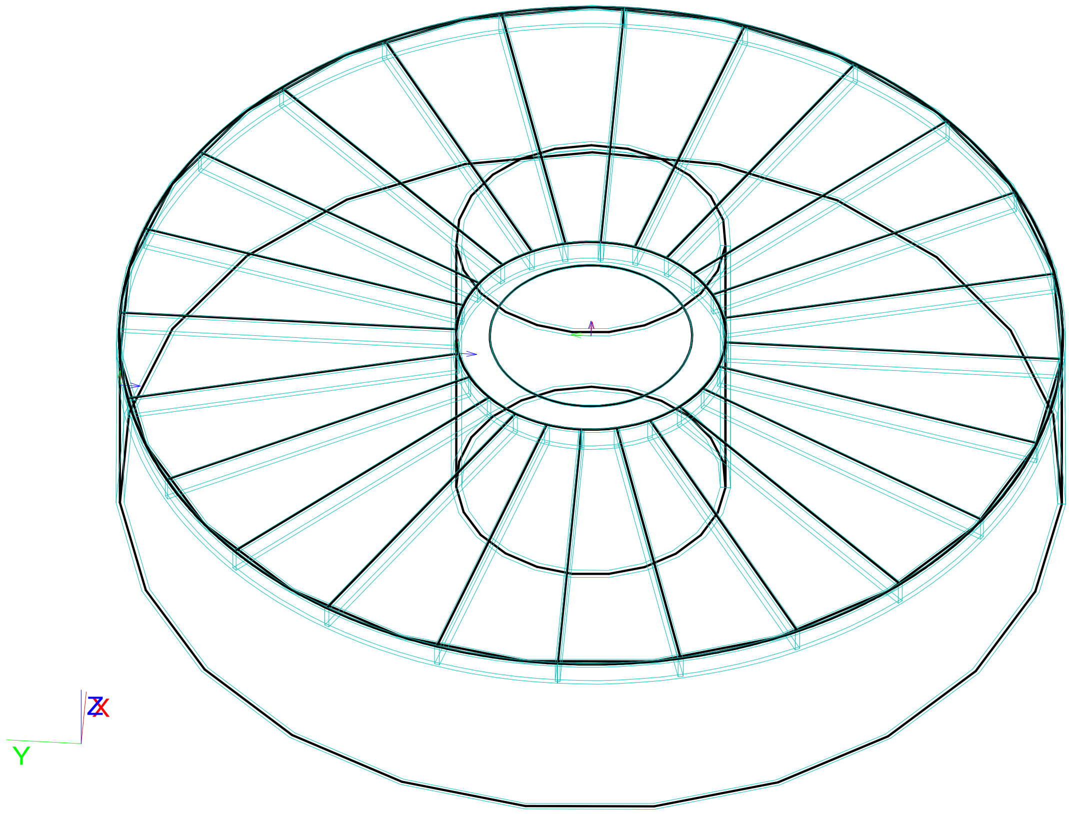


Figure 10: Deformed structure for BGT3

1. Overzicht constructie-def

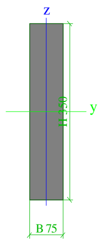


2. Materialen

Naam	Acrylic Long term
Type	Algemeen materiaal
E-mod [MPa]	9,0900e+02
Poisson - nu	0,4
G-mod [MPa]	3,2464e+02
Massa eenheid [kg/m³]	1200,0
Thermisch uitz. [m/mK]	0,00
Log. decrement	0,15
Specifieke hitte [J/gK]	1,4700e+00

3. Doorsneden

Naam	CS1	
Type	Rechthoek	
Uitgebreid	350; 75	
Onderdeelmateriaal	Acrylic Long term	
Bouwwijze	Algemeen	
Knik y-y, z-z	b	b
EEM berekening	✓	



A [m²]	2,6250e-02	
A y, z [m²]	2,1961e-02	2,1875e-02

I y, z [m^4]	2,6797e-04	1,2305e-05
I w [m^6], t [m^4]	0,0000e+00	4,2114e-05
Wel y, z [m^3]	1,5313e-03	3,2813e-04
Wpl y, z [m^3]	2,2969e-03	4,9219e-04
d y, z [mm]	0	0
c YLCS, ZLCS [mm]	38	175
alpha [deg]	0,00	
AL [m^2/m]	8,5000e-01	

4. Belastingsgevallen

Naam	Omschrijving	Actie type	Lastgroep	Belastingtype	Spec	Richting	Duur	'Master' belastingsgeval
BG1		Permanent	LG1	Eigen gewicht		-Z		
BG2	Vloerlast BG	Variabel	LG2	Statisch	Standaard		Kort	Geen
BG3	Gronddruk	Permanent	LG3	Standaard				
BG4	Waterdruk	Permanent	LG3	Standaard				

5. Combinaties

Naam	Type	Belastingsgevallen	Coëff. [-]
UGT-Short term	Lineair - UGT	BG1	1,20
		BG2 - Vloerlast BG	1,50
		BG3 - Gronddruk	1,20
		BG4 - Waterdruk	1,20
UGT2-Long term	Lineair - UGT	BG1	1,35
		BG2 - Vloerlast BG	0,38
		BG3 - Gronddruk	1,20
		BG4 - Waterdruk	1,20
BGT1-Short term	Lineair - BGT	BG1	1,00
		BG2 - Vloerlast BG	1,00
		BG3 - Gronddruk	1,00
		BG4 - Waterdruk	1,00
BGT1-Long term	Lineair - BGT	BG1	1,00
		BG2 - Vloerlast BG	0,60
		BG3 - Gronddruk	1,00
		BG4 - Waterdruk	1,00
BGT1-Long term_icm wind	Lineair - BGT	BG1	1,00
		BG2 - Vloerlast BG	0,25
		BG3 - Gronddruk	1,00
		BG4 - Waterdruk	1,00

6. Lasten op oppervlak

Naam	Rich	Type	Waarde [kN/m^2]	2D-element	Belastingsgeval	Systeem
SF1	Z	Kracht	-3,00	E3	BG2 - Vloerlast BG	GCS

7. Vrije oppervlakte last

Naam	Belastingsgeval	Rich	Type	Verdeling	q1 [kN/m^2]	q2 [kN/m^2]	Geldigheid	Selecteer	Systeem	Locatie
FF1	BG4 - Waterdruk	Z	Kracht	Richting Y	20,00	0,00	Alle	Selecteer	Element LCS	Lengte
FF2	BG3 - Gronddruk	Z	Kracht	Richting Y	18,00	8,00	-Z (incl. 0)	Selecteer	Element LCS	Lengte
FF3	BG3 - Gronddruk	Z	Kracht	Richting Y	8,00	0,00	-Z (incl. 0)	Selecteer	Element LCS	Lengte
FF4	BG2 - Vloerlast BG	Z	Kracht	Richting Y	1,50	1,50	-Z (incl. 0)	Selecteer	Element LCS	Lengte

8. 2D-element

Naam	Materiaal	D. [mm]	Dikte type	Type	Laag
E1	Acrylic Long term	130	variabel	schaal (98)	Laag1
		80			
E2	Acrylic Long term	155	konstant	schaal (98)	Laag1
E3	Acrylic Long term	45	konstant	vloer (90)	Laag1

9. Resultante

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Combinaties : UGT-Short term

BG	Rx [kN]	Ry [kN]	Rz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
UGT-Short term/1	**-504,00**	**-0,05**	**1153,01**	**0,11**	**-538,60**	**0,00**

Centraalpunt:

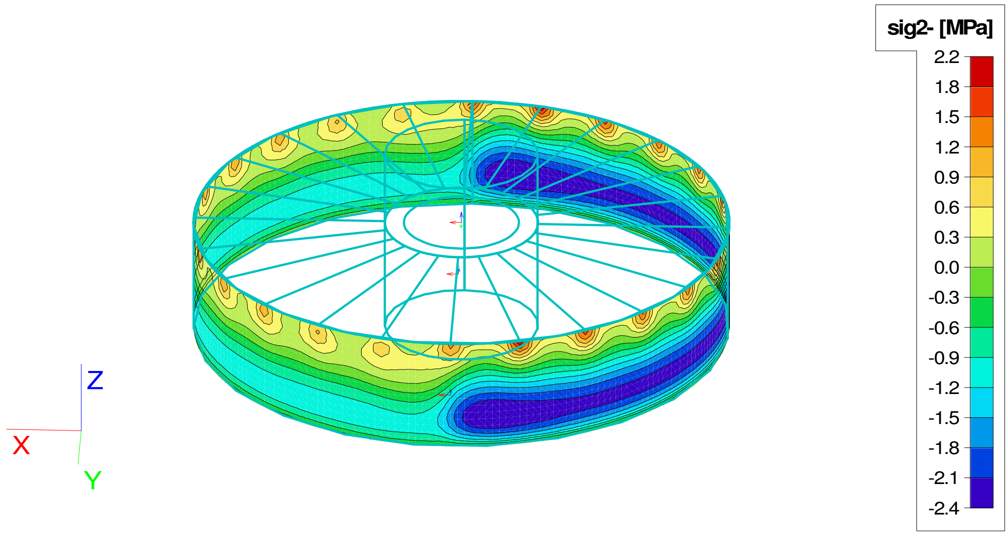
X [m]	Y [m]	Z [m]
7,000	7,000	0,000

10. 2D element - Spanningen

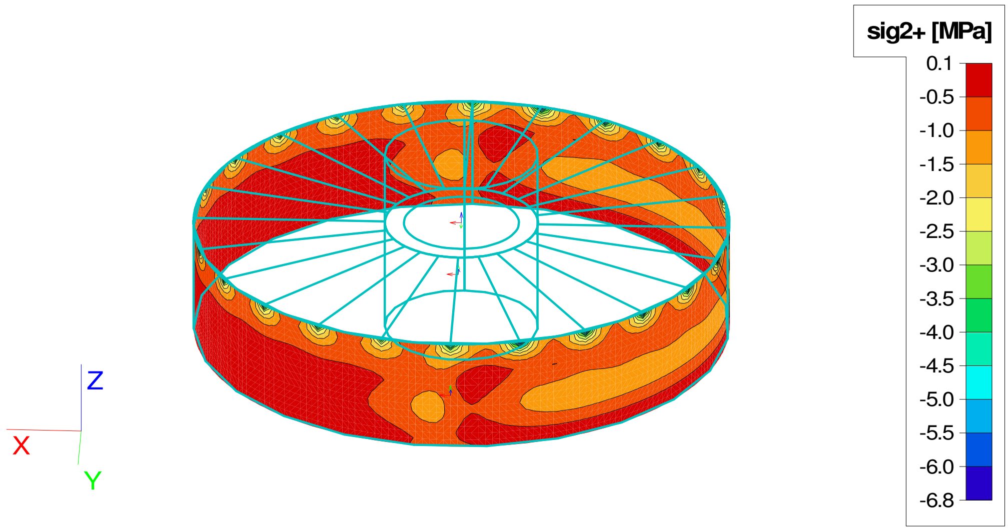
Lineaire berekening, Extreem : Globaal
Selectie : Alle
Combinaties : UGT-Short term
Hoofd grootheden. In knopen, gem. op elem..

BG	Staaf	elem	sig1+ [MPa]	sig2+ [MPa]	alfa+ [deg]	sigE+ [MPa]	sig1- [MPa]	sig2- [MPa]	alfa- [deg]	sigE- [MPa]	taumaxb [MPa]
UGT-Short term	E1	3370	**-3,0**	-6,7	0,06	5,8	5,3	2,1	89,37	4,6	0,7
UGT-Short term	E3	6986	**5,9**	1,8	-45,77	5,2	-0,1	-1,0	69,30	0,9	0,7
UGT-Short term	E1	3470	-3,0	**-6,7**	-0,06	**5,8**	**5,3**	**2,1**	-89,37	**4,6**	0,7
UGT-Short term	E3	8089	4,0	**1,9**	56,28	3,5	-0,6	-1,8	-32,20	1,6	0,3
UGT-Short term	E1	1140	0,5	-0,4	**-90,00**	0,8	-0,8	-0,9	-90,00	0,9	0,0
UGT-Short term	E1	780	1,3	-0,9	**90,00**	2,0	-1,6	-2,1	90,00	1,9	0,0
UGT-Short term	E1	59	0,0	0,0	-28,23	**0,0**	-0,1	-0,2	-0,48	0,2	0,2
UGT-Short term	E3	7773	2,6	0,5	-81,36	2,4	**-2,0**	-3,2	31,56	2,8	0,3
UGT-Short term	E2	5036	3,7	1,5	-89,14	3,2	-1,8	**-4,6**	-0,63	4,0	0,8
UGT-Short term	E1	3540	-0,8	-3,1	0,00	2,8	1,6	-0,5	**-90,00**	1,9	0,6
UGT-Short term	E2	5928	-0,7	-2,6	0,00	2,4	2,9	1,1	**90,00**	2,5	0,3
UGT-Short term	E2	5112	0,0	0,0	-90,00	0,0	0,0	0,0	89,98	**0,0**	0,0
UGT-Short term	E1	1020	1,2	-1,1	90,00	2,0	-1,4	-2,1	90,00	1,9	**0,0**
UGT-Short term	E1	3361	-1,9	-3,2	-0,55	2,8	3,0	1,3	80,23	2,6	**1,0**

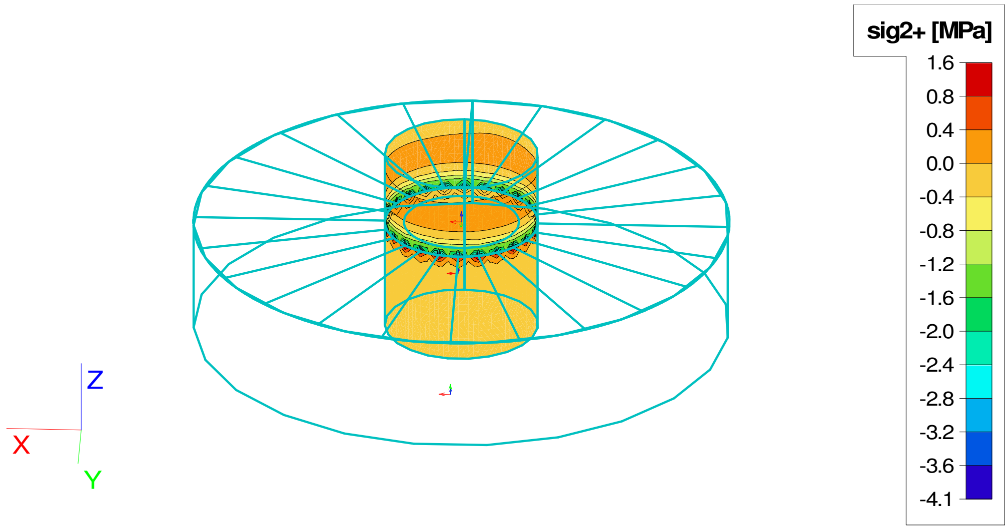
11. 2D element - Spanningen



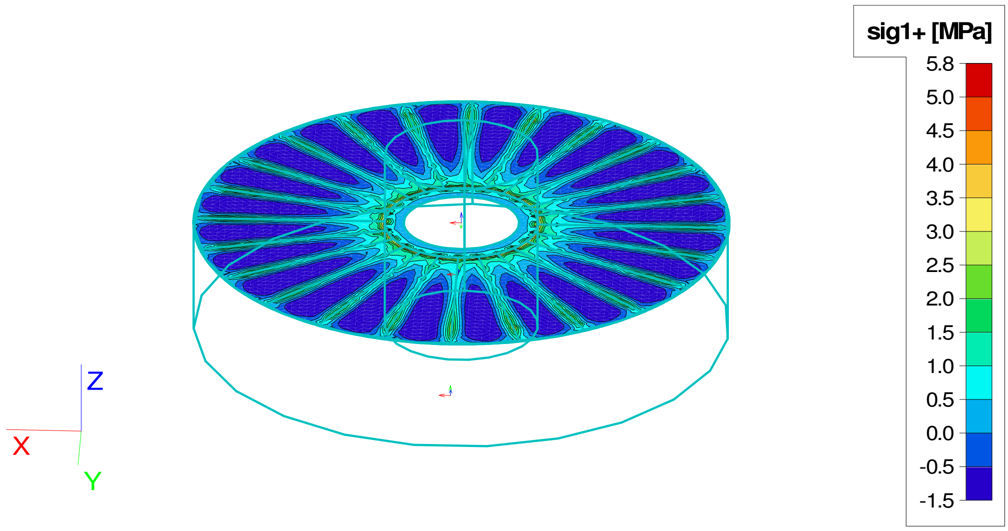
12. 2D element - Spanningen



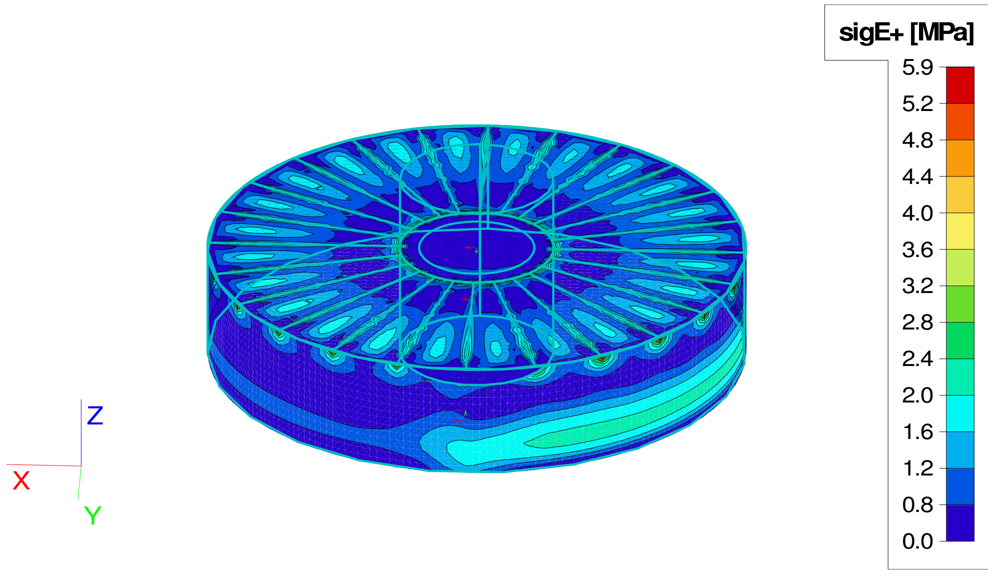
13. 2D element - Spanningen



14. 2D element - Spanningen



15. 2D element - Spanningen



16. 2D element - Spanningen

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Combinaties : UGT2-Long term
Hoofd grootheden. In knopen, gem. op elem..

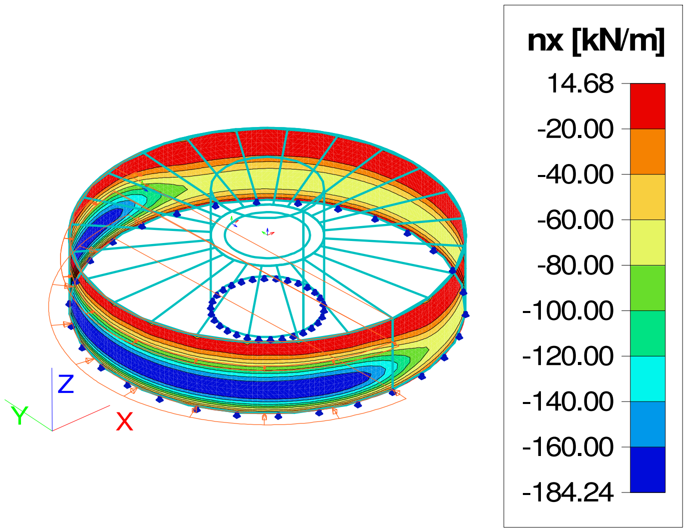
BG	Staaf	elem	sig1+ [MPa]	sig2+ [MPa]	alfa+ [deg]	sigE+ [MPa]	sig1- [MPa]	sig2- [MPa]	alfa- [deg]	sigE- [MPa]	taumaxb [MPa]
UGT2-Long term	E1	3470	**-1,7**	**-4,0**	-0,10	**3,5**	**3,4**	**1,6**	-88,94	**2,9**	0,4
UGT2-Long term	E3	6986	**2,4**	0,8	-45,14	2,1	0,0	-0,4	67,09	0,4	0,3
UGT2-Long term	E3	8089	1,6	**0,8**	55,39	1,4	-0,2	-0,7	-30,14	0,6	0,1
UGT2-Long term	E1	1140	0,6	-0,4	**-90,00**	0,8	-0,7	-0,9	-90,00	0,8	0,0
UGT2-Long term	E2	4680	0,0	-0,1	**90,00**	0,1	-0,2	-0,2	0,03	0,2	0,0
UGT2-Long term	E2	5096	0,0	0,0	88,76	**0,0**	0,0	0,0	-88,91	0,0	0,0
UGT2-Long term	E1	833	1,5	-0,6	84,28	1,9	**-1,7**	-2,3	73,66	2,1	0,0
UGT2-Long term	E1	1074	1,3	-0,6	84,15	1,7	-1,6	**-2,3**	78,72	2,1	0,0
UGT2-Long term	E2	5928	-0,3	-1,1	0,00	1,0	1,2	0,5	**-90,00**	1,0	0,1
UGT2-Long term	E1	3420	-0,6	-2,0	0,00	1,7	1,4	0,1	**90,00**	1,3	0,3
UGT2-Long term	E2	5112	0,0	0,0	-89,98	0,0	0,0	0,0	89,96	**0,0**	0,0
UGT2-Long term	E1	780	1,4	-0,9	90,00	2,0	-1,5	-2,1	90,00	1,9	**0,0**
UGT2-Long term	E1	3361	-1,0	-1,6	0,94	1,4	1,6	0,7	72,88	1,4	**0,6**

17. 2D element - Interne krachten

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Combinaties : UGT-Short term
Basis grootheden. In knopen, gem. op elem..

BG	Staaf	elem	mx [kNm/m]	my [kNm/m]	mxy [kNm/m]	vx [kN/m]	vy [kN/m]	nx [kN/m]	ny [kN/m]	nxy [kN/m]
UGT-Short term	E2	5040	**-7,61**	-14,94	**-2,99**	35,67	94,05	-13,50	-54,90	-20,04
UGT-Short term	E2	6000	**7,15**	15,54	2,76	43,96	87,18	28,83	13,78	14,16
UGT-Short term	E2	5036	-6,74	**-16,52**	0,00	1,17	87,15	-20,80	-70,08	-4,84
UGT-Short term	E2	5908	2,54	**17,20**	0,05	1,06	76,76	13,01	21,82	-0,60
UGT-Short term	E2	4945	-7,49	-14,88	**3,01**	-34,28	93,88	-12,74	-54,44	10,57
UGT-Short term	E1	3361	1,84	3,41	0,16	**-56,09**	-4,10	-24,08	-12,31	10,79
UGT-Short term	E1	3369	1,87	4,39	-0,06	**50,20**	-4,81	-9,77	-11,76	0,89
UGT-Short term	E2	4976	-4,81	-15,49	0,02	-0,11	**-101,19**	-16,70	-58,04	1,59
UGT-Short term	E2	4960	-4,81	-15,49	-0,02	-0,12	**101,17**	-16,71	-58,05	-1,60
UGT-Short term	E1	1063	-1,05	-2,80	0,06	-0,19	3,02	**-184,24**	-14,17	5,46
UGT-Short term	E3	7707	-0,88	-0,28	-0,18	16,47	-8,75	**107,20**	34,92	7,78
UGT-Short term	E2	5028	-6,57	-16,19	-0,03	-0,97	85,50	-19,29	**-70,13**	-1,35
UGT-Short term	E3	6635	-0,31	-1,01	0,20	-2,95	-20,31	42,43	**108,20**	-16,31
UGT-Short term	E1	1	-0,67	-0,64	0,72	-17,07	11,08	-6,07	-13,45	**-51,14**
UGT-Short term	E1	120	-0,01	-0,02	-0,73	-16,15	-11,41	-6,08	-13,47	**50,04**

18. 2D element - Interne krachten

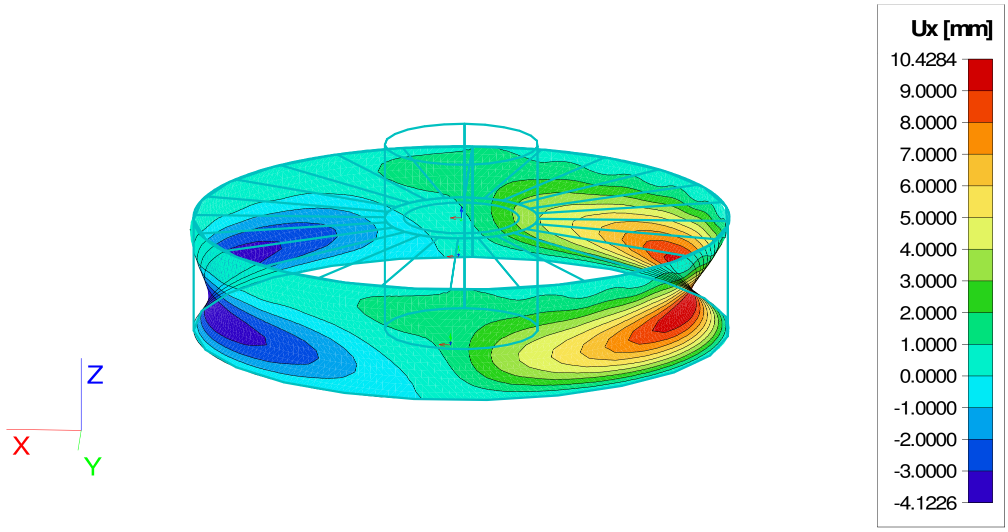


19. Verplaatsing van knopen

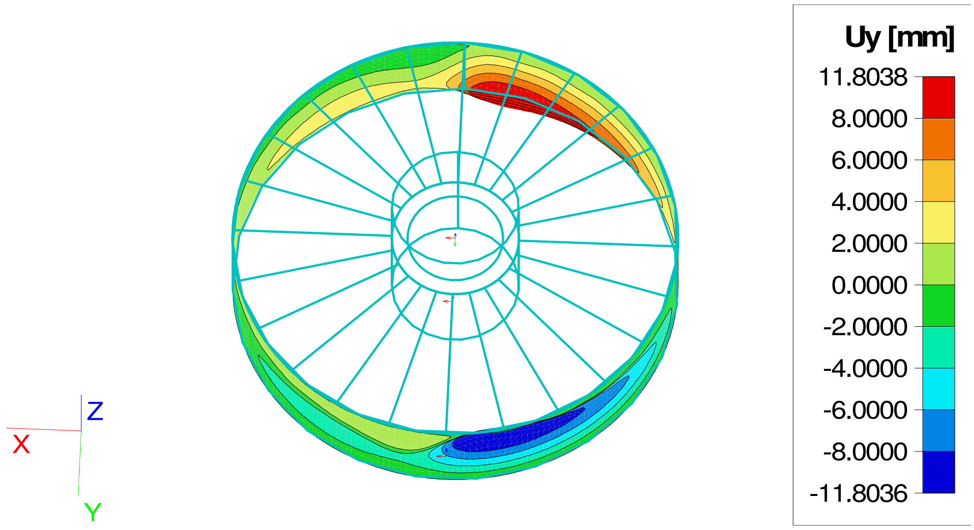
Lineaire berekening, Extreem : Globaal
Selectie : E1..E3
Combinaties : BGT1-Long term

BG	Staaf	Knoop	Ux [mm]	Uy [mm]	Uz [mm]	Fix [mrad]	Fiy [mrad]	Fiz [mrad]
BGT1-Long term	E1	1381	**-3,9716**	0,0000	0,0882	0,0	0,6	0,0
BGT1-Long term	E1	1261	**10,0843**	0,0000	0,3061	0,0	1,2	0,0
BGT1-Long term	E1	1553	3,0880	**-11,8036**	0,3710	-0,9	0,4	0,1
BGT1-Long term	E1	1449	3,0875	**11,8038**	0,3710	0,9	0,4	-0,1
BGT1-Long term	E3	6806	0,4261	0,1453	**-18,3806**	0,3	-0,9	0,0
BGT1-Long term	E1	3386	0,7555	0,5746	**0,8434**	1,8	-1,4	0,1
BGT1-Long term	E3	6544	0,7896	0,3938	-2,8040	**-18,7**	-1,5	0,0
BGT1-Long term	E3	8347	0,7895	-0,3933	-2,8035	**18,7**	-1,5	0,0
BGT1-Long term	E3	7600	-0,0497	-0,0335	-3,4013	1,7	**-18,6**	0,1
BGT1-Long term	E3	9246	0,7502	-0,0673	-2,3165	1,6	**18,1**	-0,1
BGT1-Long term	E1	1682	1,1322	6,2114	0,3262	3,9	0,7	**-6,8**
BGT1-Long term	E1	1801	1,1322	-6,2044	0,3261	-3,9	0,7	**6,8**

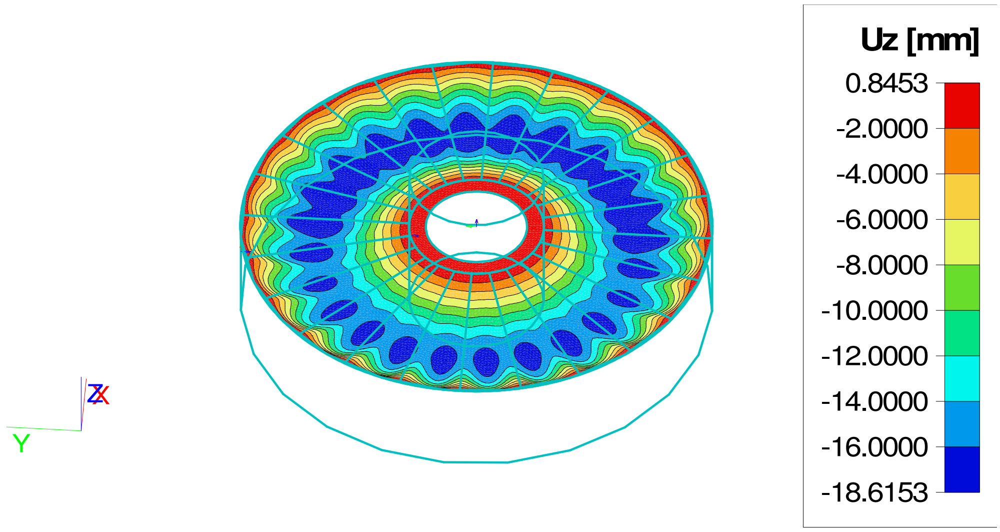
20. Verplaatsing van knopen



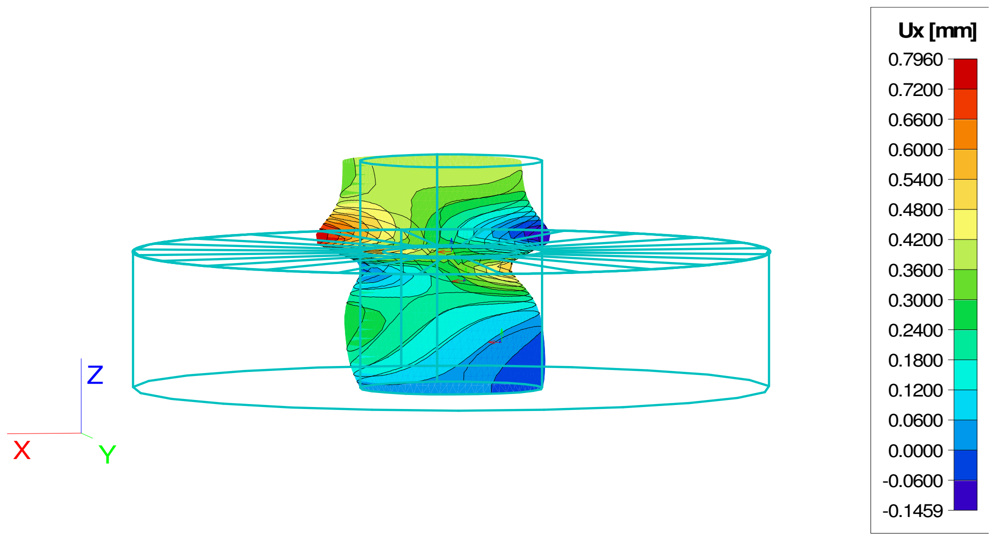
21. Verplaatsing van knopen



22. Uz vloer



23. Verplaatsing van knopen

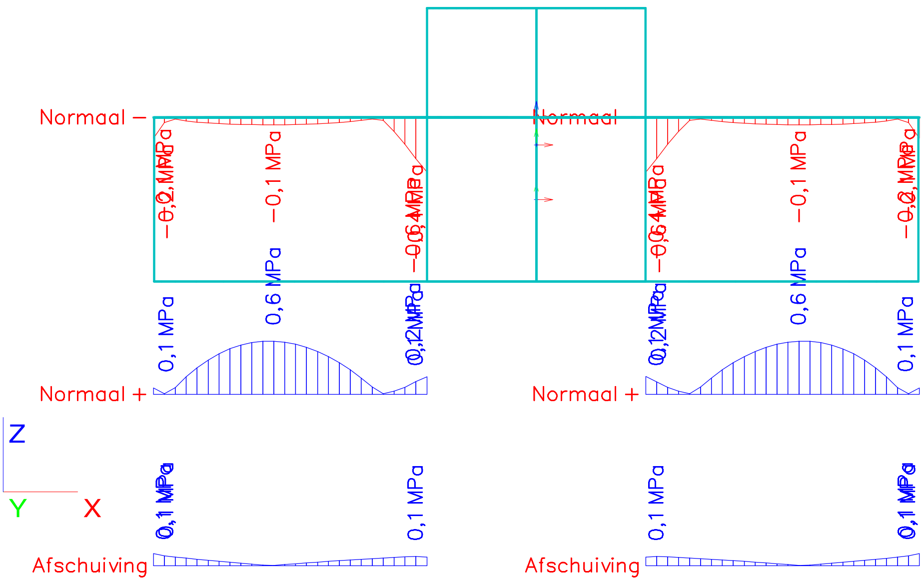


24. Spanning

Lineaire berekening, Extreem : Globaal
Selectie : S5,S14,S21,S27,S35,S36
Combinaties : UGT-Short term

Staaf	BG	dx [m]	Normaal - [MPa]	Normaal + [MPa]	Afschuiving [MPa]	Von Mises [MPa]	Vermoeiïng [MPa]	Kappa [-]
S21	UGT-Short term	0,000	**-4,2**	1,4	0,6	**4,2**	0,0	0,00
S21	UGT-Short term	1,000	**-0,1**	0,4	0,5	0,9	0,0	0,00
S27	UGT-Short term	4,800	-0,7	**0,0**	0,8	1,4	0,0	0,00
S14	UGT-Short term	3,000	-0,6	**4,1**	0,0	4,1	0,0	0,00
S36	UGT-Short term	2,749	-0,2	0,4	**0,0**	0,4	0,0	0,00
S35	UGT-Short term	12,828	-1,9	2,5	**1,3**	2,7	0,0	0,00
S36	UGT-Short term	11,912	-0,2	0,4	0,0	**0,4**	0,0	0,00
S5	UGT-Short term	0,000	-4,0	1,3	0,6	4,0	**0,0**	**0,00**

25. Spanning

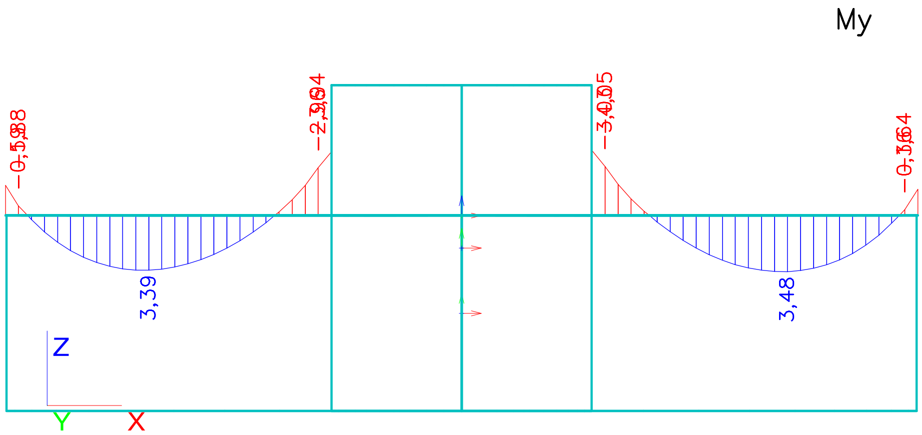


26. Interne krachten in staaf

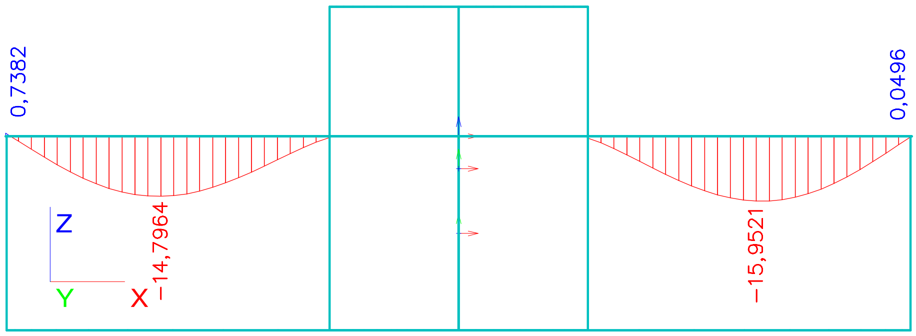
Lineaire berekening, Extreem : Globaal, Systeem : Hoofd
Selectie : S5,S14,S21,S27,S35,S36
Combinaties : UGT-Short term

Staaf	BG	dx [m]	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
S21	UGT-Short term/1	0,000	**-36,71**	0,08	11,05	-0,01	**-4,33**	0,00
S21	UGT-Short term/1	3,000	**46,94**	0,02	-0,38	0,00	3,53	-0,01
S36	UGT-Short term/1	9,163	7,49	**-10,56**	-4,61	**-0,49**	0,92	0,54
S35	UGT-Short term/1	12,828	7,48	**10,56**	4,60	**0,49**	0,92	0,54
S27	UGT-Short term/1	5,000	-19,39	-0,03	**-16,60**	0,00	-1,81	0,00
S14	UGT-Short term/1	0,200	-28,80	-0,02	**11,64**	0,00	-3,20	-0,01
S14	UGT-Short term/1	3,000	46,68	-0,01	-0,35	0,00	**3,55**	0,01
S35	UGT-Short term/1	12,461	6,32	3,75	1,33	0,32	0,22	**-0,15**
S36	UGT-Short term/1	9,163	7,35	10,30	4,59	0,47	0,94	**0,54**

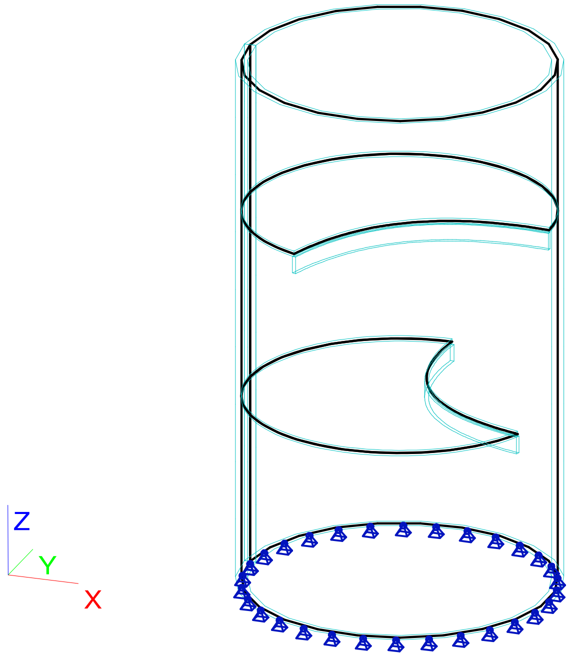
27. Interne krachten in staaf



28. Vervormingen van staaf



1. Overzicht constructie

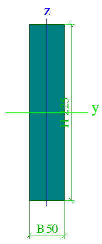


2. Materialen

Naam	Acrylic Short term
Type	Algemeen materiaal
E-mod [MPa]	1,8940e+03
Poisson - nu	0,4
G-mod [MPa]	6,7643e+02
Massa eenheid [kg/m³]	1200,0
Thermisch uitz. [m/mK]	0,00
Log. decrement	0,15
Specifieke hitte [J/gK]	1,4700e+00
Naam	Acrylic Long term
Type	Algemeen materiaal
E-mod [MPa]	7,2700e+02
Poisson - nu	0,4
G-mod [MPa]	2,5964e+02
Massa eenheid [kg/m³]	1200,0
Thermisch uitz. [m/mK]	0,00
Log. decrement	0,15
Specifieke hitte [J/gK]	1,4700e+00

3. Doorsneden

Naam	CS2	
Type	Rechthoek	
Uitgebreid	225; 50	
Onderdeelmateriaal	Acrylic Long term	
Bouwwijze	Algemeen	
Knik y-y, z-z	b	b
EEM berekening	✓	



A [m²]	1,1250e-02	
A y, z [m²]	9,3900e-03	9,3750e-03
I y, z [m⁴]	4,7461e-05	2,3438e-06
I w [m⁶], t [m⁴]	0,0000e+00	7,9731e-06
Wel y, z [m³]	4,2188e-04	9,3750e-05
Wpl y, z [m³]	6,3281e-04	1,4062e-04
d y, z [mm]	0	0
c YLCS, ZLCS [mm]	25	113
alpha [deg]	0,00	
AL [m²/m]	5,5000e-01	

4. Belastingsgevallen

Naam	Omschrijving	Actie type	Lastgroep	Belastingtype	Spec	Richting	Duur	'Master' belastingsgeval
BG1		Permanent	LG1	Eigen gewicht		-Z		
BG2	Vloerlast BG	Variabel	LG2	Statisch	Standaard		Kort	Geen

5. Combinaties

Naam	Type	Belastingsgevallen	Coëff. [-]
UGT-Short term	Lineair - UGT	BG1	1,20
		BG2 - Vloerlast BG	1,50
UGT2-Long term	Lineair - UGT	BG1	1,35
		BG2 - Vloerlast BG	0,38
BGT1-Short term	Lineair - BGT	BG1	1,00
		BG2 - Vloerlast BG	1,00
BGT1-Long term	Lineair - BGT	BG1	1,00
		BG2 - Vloerlast BG	0,60

6. Lasten op oppervlak

Naam	Rich	Type	Waarde [kN/m²]	2D-element	Belastingsgeval	Systeem
SF3	Z	Kracht	-3,00	E6	BG2 - Vloerlast BG	GCS
SF4	Z	Kracht	-3,00	E7	BG2 - Vloerlast BG	GCS

7. 2D-element

Naam	Materiaal	D. [mm]	Dikte type	Type	Laag
E5	Acrylic Long term	155	konstant	schaal (98)	Laag1
E6	Acrylic Long term	75	konstant	vloer (90)	Laag1
E7	Acrylic Long term	75	konstant	vloer (90)	Laag1

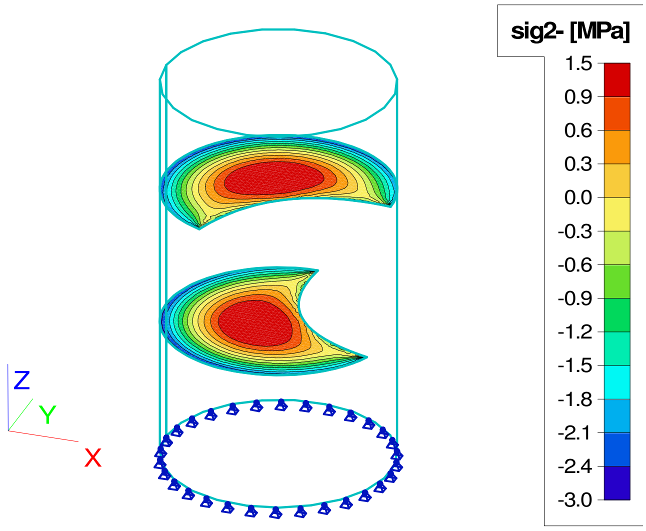
8. 2D element - Spanningen

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Combinaties : UGT-Short term
Hoofd grootheden. In knopen, gem. op elem..

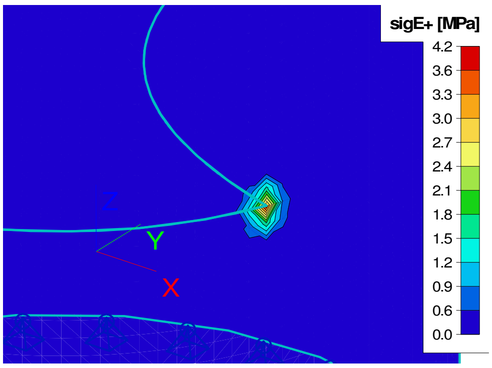
BG	Staaf	elem	sig1+ [MPa]	sig2+ [MPa]	alfa+ [deg]	sigE+ [MPa]	sig1- [MPa]	sig2- [MPa]	alfa- [deg]	sigE- [MPa]	taumaxb [MPa]
UGT-Short term	E6	9247	**-1,6**	-1,8	33,21	1,7	1,7	1,4	-56,15	1,6	0,0
UGT-Short term	E6	9693	**3,5**	0,9	54,55	3,1	1,3	-0,9	-63,21	2,0	0,3
UGT-Short term	E5	8861	-0,9	**-4,5**	-23,64	**4,2**	**4,4**	0,9	62,81	**4,0**	**2,4**
UGT-Short term	E7	10936	2,9	**1,2**	-34,47	2,5	-0,9	-2,3	53,61	2,1	0,1

BG	Staaf	elem	sig1+ [MPa]	sig2+ [MPa]	alfa+ [deg]	sigE+ [MPa]	sig1- [MPa]	sig2- [MPa]	alfa- [deg]	sigE- [MPa]	taumaxb [MPa]
UGT-Short term	E7	10562	-1,1	-1,4	**-89,99**	1,3	1,4	0,9	1,31	1,2	0,0
UGT-Short term	E5	8993	0,2	0,1	**90,00**	0,2	-0,1	-0,3	0,68	0,3	0,0
UGT-Short term	E5	8521	0,0	0,0	42,88	**0,0**	0,0	0,0	-1,42	0,0	0,0
UGT-Short term	E6	9846	2,6	1,1	-56,03	2,2	**-1,0**	-2,6	33,89	2,3	0,1
UGT-Short term	E6	9791	3,5	1,1	10,16	3,1	-0,7	**-3,0**	-72,82	2,7	0,6
UGT-Short term	E7	10413	-1,5	-1,8	-57,64	1,7	1,7	**1,5**	33,47	1,6	0,0
UGT-Short term	E5	7827	0,0	0,0	-2,11	0,0	0,0	0,0	**-89,99**	0,0	0,0
UGT-Short term	E5	7770	0,0	0,0	1,16	0,0	0,0	0,0	**89,99**	0,0	0,0
UGT-Short term	E5	7704	0,0	0,0	-1,24	0,0	0,0	0,0	-39,80	**0,0**	0,0
UGT-Short term	E5	7793	0,0	0,0	80,36	0,0	0,0	0,0	-7,70	0,0	**0,0**

9. 2D element - Spanningen



10. 2D element - Spanningen



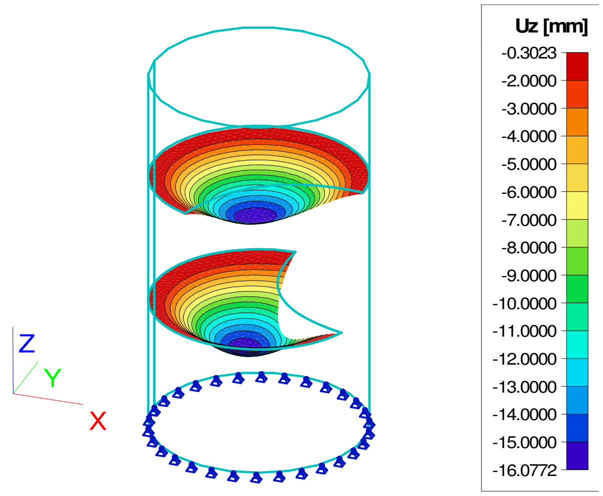
11. Verplaatsing van knopen

Lineaire berekening, Extreem : Globaal
Selectie : Alle
Combinaties : BGT1-Long term

BG	Staaf	Knoop	Ux [mm]	Uy [mm]	Uz [mm]	Fix [mrad]	Fiy [mrad]	Fiz [mrad]
BGT1-Long term	E6	29	**-0,2916**	0,0097	-6,1099	-0,7	-8,2	1,3
BGT1-Long term	E5	2737	**0,2102**	-0,0251	-0,2632	-0,1	-0,1	0,0
BGT1-Long term	E7	118	-0,0269	**-0,2303**	-5,9423	8,2	-0,8	1,3
BGT1-Long term	E6	83	0,0580	**0,2451**	-6,5869	-8,1	2,0	-1,3
BGT1-Long term	E6	9351	-0,1255	0,1445	**-16,0772**	-0,6	0,4	-0,1
BGT1-Long term	E5	K72	0,0000	0,0000	**0,0000**	0,0	-0,3	0,0
BGT1-Long term	E7	10169	-0,1049	-0,0646	-7,7212	**-13,0**	1,6	-0,1
BGT1-Long term	E6	9735	-0,1028	0,1181	-7,0256	**13,3**	0,5	0,0
BGT1-Long term	E6	9479	-0,1519	0,0415	-7,5581	3,0	**-10,7**	0,5

BG	Staaf	Knoop	Ux [mm]	Uy [mm]	Uz [mm]	Fix [mrad]	Fiy [mrad]	Fiz [mrad]
BGT1-Long term	E7	10494	-0,1311	-0,0481	-6,7166	-0,8	**13,3**	0,0
BGT1-Long term	E6	10	0,0300	0,2316	-8,6786	-9,1	-0,4	**-1,5**
BGT1-Long term	E7	103	-0,0518	-0,2107	-8,4870	8,3	-4,0	**1,5**

12. Verplaatsing van knopen

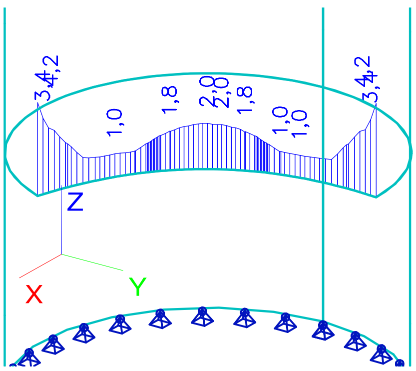


13. Spanning

Lineaire berekening, Extreem : Staaf
Selectie : Alle
Combinaties : UGT-Short term

Staaf	BG	dx [m]	Normaal - [MPa]	Normaal + [MPa]	Afschuiving [MPa]	Von Mises [MPa]	Vermoeiïng [MPa]	Kappa [-]
S2	UGT-Short term	0,000	**-4,2**	2,0	0,3	**4,2**	**0,0**	**0,00**
S2	UGT-Short term	2,562	**0,0**	1,0	0,5	1,0	0,0	0,00
S2	UGT-Short term	0,791	-0,1	**0,0**	0,6	1,0	0,0	0,00
S2	UGT-Short term	1,840	-0,2	**2,0**	**0,0**	2,0	0,0	0,00
S2	UGT-Short term	2,780	-0,1	0,3	**0,6**	1,0	0,0	0,00
S2	UGT-Short term	2,617	-0,1	0,8	0,5	**1,0**	0,0	0,00
S3	UGT-Short term	0,000	**-4,2**	2,0	0,3	**4,2**	**0,0**	**0,00**
S3	UGT-Short term	1,118	**0,0**	1,0	0,5	1,0	0,0	0,00
S3	UGT-Short term	0,791	-0,1	**0,0**	0,6	1,0	0,0	0,00
S3	UGT-Short term	1,793	-0,2	**2,1**	0,0	2,1	0,0	0,00
S3	UGT-Short term	1,840	-0,2	2,1	**0,0**	2,1	0,0	0,00
S3	UGT-Short term	2,944	-0,3	0,1	**0,6**	1,1	0,0	0,00
S3	UGT-Short term	1,009	-0,1	0,7	0,5	**1,0**	0,0	0,00

14. Spanning

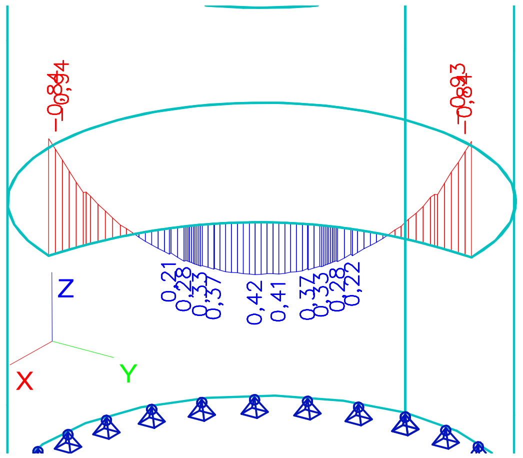


15. Interne krachten in staaf

Lineaire berekening, Extreem : Globaal, Systeem : Hoofd
Selectie : Alle
Combinaties : UGT-Short term

Staaf	BG	dx [m]	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
S3	UGT-Short term/1	0,068	**-12,71**	0,96	1,67	0,03	-0,83	-0,03
S2	UGT-Short term/1	1,793	**10,48**	0,00	0,12	0,00	0,41	-0,01
S3	UGT-Short term/1	3,680	-12,60	**-1,53**	-0,64	-0,02	-0,91	-0,08
S2	UGT-Short term/1	0,000	-12,32	**1,51**	0,66	0,02	-0,93	-0,08
S3	UGT-Short term/1	3,312	-8,76	0,05	**-3,30**	0,00	-0,42	0,02
S3	UGT-Short term/1	0,368	-8,72	-0,04	**3,35**	0,00	-0,42	0,02
S2	UGT-Short term/1	1,104	4,78	-0,12	1,96	**-0,05**	0,22	0,00
S3	UGT-Short term/1	2,576	4,71	0,12	-1,98	**0,04**	0,22	0,00
S2	UGT-Short term/1	3,680	-12,21	-1,52	-0,65	-0,02	**-0,94**	-0,08
S3	UGT-Short term/1	1,793	10,30	0,00	0,12	0,00	**0,43**	-0,01
S3	UGT-Short term/1	0,000	-12,59	1,45	0,71	0,02	-0,91	**-0,09**
S3	UGT-Short term/1	0,273	-10,48	0,05	3,24	0,01	-0,53	**0,02**

16. Interne krachten in staaf

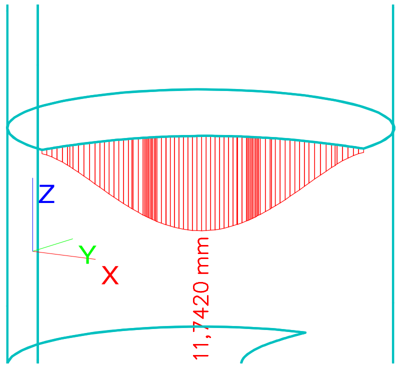


17. Vervormingen van staaf

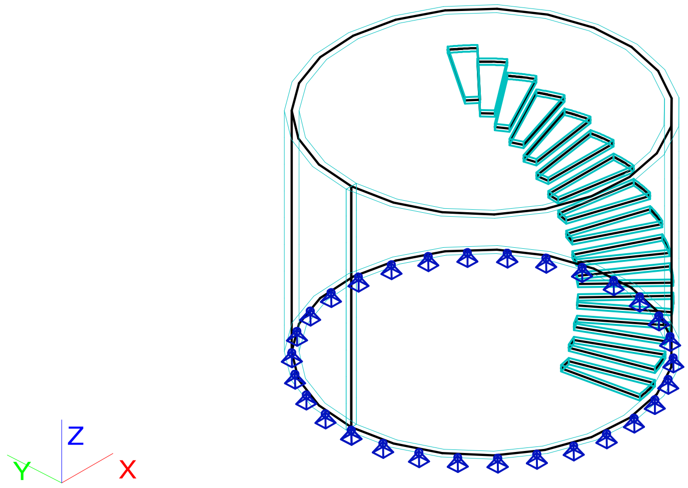
Lineaire berekening, Extreem : Globaal
Selectie : Alle
Combinaties : BGT1-Long term

BG	Staaf	dx [m]	ux [mm]	uy [mm]	uz [mm]	fix [mrad]	fiy [mrad]	fiz [mrad]
BGT1-Long term/2	S2	0,791	**-0,9785**	0,2030	-5,9423	1,7	8,0	1,3
BGT1-Long term/2	S3	2,889	**0,9657**	0,1837	-6,1211	1,7	**-8,1**	-1,3
BGT1-Long term/2	S3	3,339	0,8228	**-0,2579**	-2,4111	-1,8	-6,6	0,2
BGT1-Long term/2	S2	1,840	0,0001	**1,6277**	-11,5373	11,8	-0,1	0,0
BGT1-Long term/2	S3	1,840	0,0055	1,6043	**-11,7420**	11,8	0,1	0,0
BGT1-Long term/2	S2	3,680	0,5725	0,0174	**-0,3023**	-0,1	-3,2	-0,4
BGT1-Long term/2	S3	0,341	-0,7826	-0,2445	-2,3875	**-1,8**	6,7	-0,2
BGT1-Long term/2	S2	1,840	-0,0382	1,6272	-11,5373	**11,8**	0,1	0,0
BGT1-Long term/2	S3	0,736	-0,9224	0,1162	-5,6362	1,0	**8,1**	1,2
BGT1-Long term/2	S3	2,576	0,8583	0,7544	-8,6786	5,8	-7,1	**-1,5**
BGT1-Long term/2	S2	1,104	-0,8751	0,7643	-8,4870	5,8	7,1	**1,5**

18. Vervormingen van staaf



1. Overzicht constructie



2. Materialen

Naam	Acrylic Short term
Type	Algemeen materiaal
E-mod [MPa]	1,8940e+03
Poisson - nu	0,4
G-mod [MPa]	6,7643e+02
Massa eenheid [kg/m³]	1200,0
Thermisch uitz. [m/mK]	0,00
Log. decrement	0,15
Specifieke hitte [J/gK]	1,4700e+00

Naam	Acrylic Long term
Type	Algemeen materiaal
E-mod [MPa]	9,0900e+02
Poisson - nu	0,4
G-mod [MPa]	3,2464e+02
Massa eenheid [kg/m³]	1200,0
Thermisch uitz. [m/mK]	0,00
Log. decrement	0,15
Specifieke hitte [J/gK]	1,4700e+00

3. Belastingsgevallen

Naam	Omschrijving	Actie type	Lastgroep	Belastingtype	Spec	Richting	Duur	'Master' belastingsgeval
BG1		Permanent	LG1	Eigen gewicht		-Z		
BG2	Vloerlast BG	Variabel	LG2	Statisch	Standaard		Kort	Geen

4. Combinaties

Naam	Type	Belastingsgevallen	Coëff. [-]
UGT-Short term	Lineair - UGT	BG1	1,20
		BG2 - Vloerlast BG	1,50
UGT2-Long term	Lineair - UGT	BG1	1,35
		BG2 - Vloerlast BG	0,38
BGT1-Short term	Lineair - BGT	BG1	1,00
		BG2 - Vloerlast BG	1,00
BGT1-Long	Lineair - BGT	BG1	1,00

Naam	Type	Belastingsgevallen	Coëff. [-]
BGT1-Long	Lineair - BGT	BG2 - Vloerlast BG	0,60

5. 2D-element

Naam	Materiaal	D. [mm]	Dikte type	Type	Laag
E5	Acrylic Long term	80	konstant	vloer (90)	Laag1
E6	Acrylic Long term	80	konstant	vloer (90)	Laag1
E7	Acrylic Long term	80	konstant	vloer (90)	Laag1
E8	Acrylic Long term	80	konstant	vloer (90)	Laag1
E9	Acrylic Long term	80	konstant	vloer (90)	Laag1
E10	Acrylic Long term	80	konstant	vloer (90)	Laag1
E11	Acrylic Long term	80	konstant	vloer (90)	Laag1
E12	Acrylic Long term	80	konstant	vloer (90)	Laag1
E13	Acrylic Long term	80	konstant	vloer (90)	Laag1
E14	Acrylic Long term	80	konstant	vloer (90)	Laag1
E15	Acrylic Long term	80	konstant	vloer (90)	Laag1
E16	Acrylic Long term	80	konstant	vloer (90)	Laag1
E17	Acrylic Long term	80	konstant	vloer (90)	Laag1
E18	Acrylic Long term	80	konstant	vloer (90)	Laag1
E19	Acrylic Long term	80	konstant	vloer (90)	Laag1
E20	Acrylic Long term	155	konstant	schaal (98)	Laag1

6. Vrije oppervlakte last

Naam	Belastingsgeval
FF1	BG2 - Vloerlast BG

7. Genereer vrije lasten

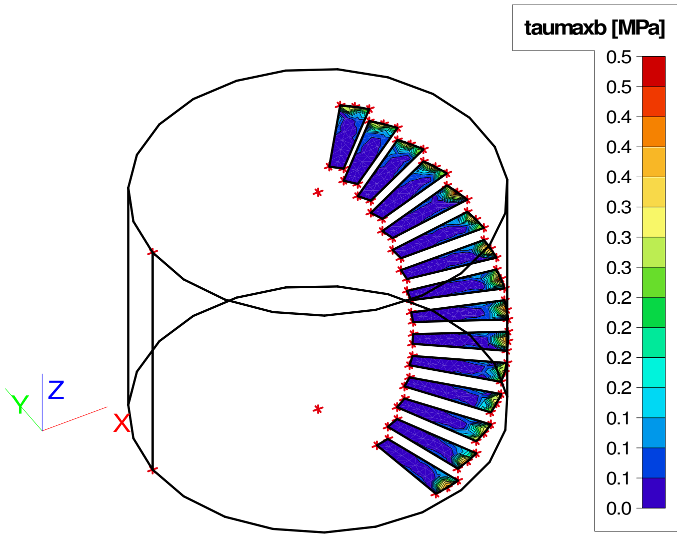
Naam	Belastingsgeval	2D-element	Rich Verdeling	Belastingstype Type	Oorspronkelijke belasting	q [kN/m²]	Systeem Locatie
GFF1	BG2 - Vloerlast BG	E10	Z Gelijkmatig	Oppervlak Kracht	FF1	-3,00	Element LCS Lengte

8. 2D element - Spanningen

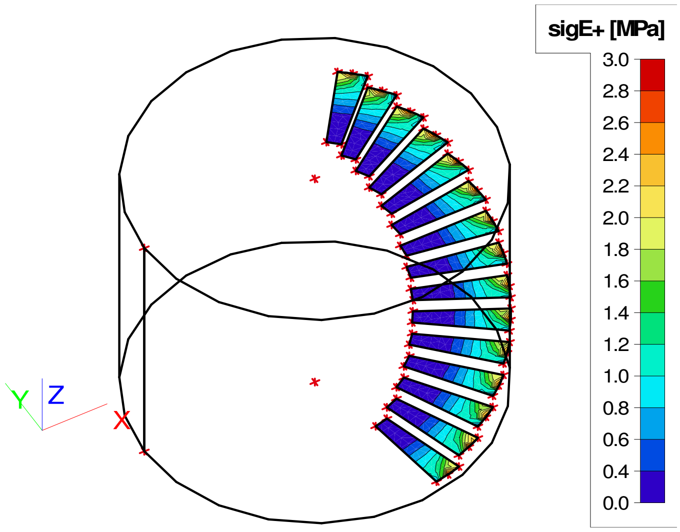
Lineaire berekening, Extreem : Globaal
Selectie : E19,E20
Combinaties : UGT-Short term
Hoofd grootheden. In knopen, gem. op elem..

BG	Staaf	elem	sig1+ [MPa]	sig2+ [MPa]	alfa+ [deg]	sigE+ [MPa]	sig1- [MPa]	sig2- [MPa]	alfa- [deg]	sigE- [MPa]	taumaxb [MPa]
UGT-Short term	E20	4205	**-0,1**	-0,5	-10,93	0,5	0,3	0,1	77,93	0,2	0,1
UGT-Short term	E19	454	**2,8**	0,2	66,37	**2,7**	-0,2	**-2,8**	-23,62	**2,7**	**0,3**
UGT-Short term	E20	4265	-0,1	**-0,6**	-9,60	0,5	0,3	0,0	77,74	0,3	0,1
UGT-Short term	E19	453	2,7	**0,8**	56,42	2,4	**-0,9**	-2,7	-33,53	2,4	0,3
UGT-Short term	E20	4024	0,0	0,0	**-89,75**	0,0	0,0	0,0	0,30	0,0	0,0
UGT-Short term	E20	4077	0,0	0,0	**89,92**	0,0	0,0	0,0	1,27	0,0	0,0
UGT-Short term	E20	4014	0,0	0,0	-48,82	**0,0**	0,0	0,0	60,78	0,0	0,0
UGT-Short term	E19	455	0,9	-0,4	87,25	1,1	**0,4**	-0,9	-2,77	1,1	0,3
UGT-Short term	E20	4207	0,0	-0,3	0,12	0,3	0,2	**0,1**	77,71	0,2	0,1
UGT-Short term	E20	3650	0,0	0,0	-87,58	0,0	0,0	-0,1	**-89,90**	0,1	0,0
UGT-Short term	E20	4093	0,0	0,0	-85,12	0,0	0,0	-0,1	**89,47**	0,1	0,0
UGT-Short term	E20	4043	0,0	0,0	12,21	0,0	0,0	0,0	-45,75	**0,0**	0,0
UGT-Short term	E20	2648	0,0	0,0	-2,09	0,0	0,0	0,0	3,20	0,0	**0,0**

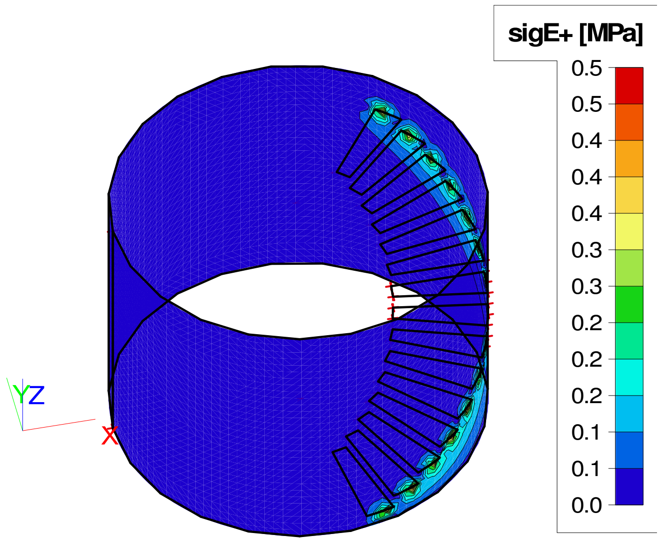
9. 2D element - Spanningen



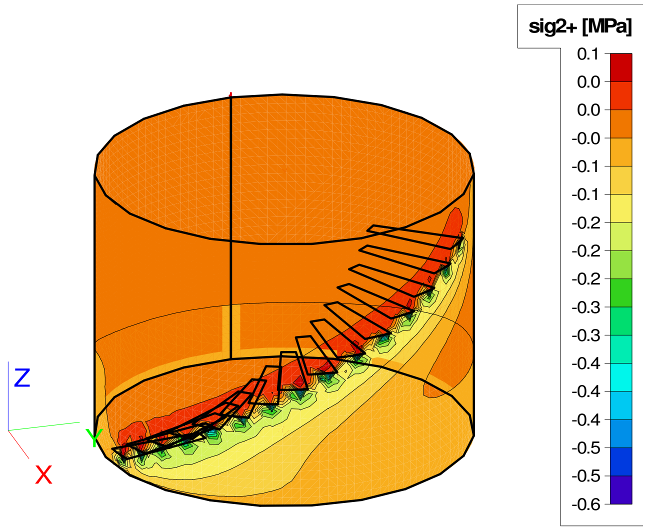
10. 2D element - Spanningen



11. 2D element - Spanningen



12. 2D element - Spanningen



13. Verplaatsing van knopen

Lineaire berekening, Extreem : Globaal
Selectie : E19,E20
Combinaties : BGT1-Long term

BG	Staaf	Knoop	Ux [mm]	Uy [mm]	Uz [mm]	Fix [mrad]	Fiy [mrad]	Fiz [mrad]
BGT1-Long term	E19	K107	**-0,0614**	0,0369	**-7,6465**	7,8	-5,9	-0,1
BGT1-Long term	E20	1790	**0,0779**	0,0073	-0,0437	0,1	0,0	0,0
BGT1-Long term	E20	4450	-0,0559	**-0,0436**	-0,0709	0,1	0,0	0,0
BGT1-Long term	E20	2764	0,0484	**0,0451**	-0,0634	0,1	0,0	0,0
BGT1-Long term	E19	K105	-0,0181	-0,0063	**0,0387**	2,3	-2,6	-0,1
BGT1-Long term	E20	K40	0,0032	0,0101	-0,0310	**-0,3**	-0,2	-0,1
BGT1-Long term	E19	K108	-0,0552	0,0442	-7,5461	**7,8**	-5,8	-0,1
BGT1-Long term	E19	598	-0,0571	0,0325	-6,6787	7,8	**-5,9**	-0,1
BGT1-Long term	E20	4276	0,0000	0,0000	0,0000	0,1	**0,1**	0,0
BGT1-Long term	E20	1798	-0,0042	0,0197	-0,0390	-0,1	-0,2	**-0,1**
BGT1-Long term	E20	1317	-0,0127	0,0073	-0,0209	0,0	-0,1	**0,1**

14. Verplaatsing van knopen