

**TOPOLOGICAL DESIGN OF
COMPRESSION STRUCTURES
WITH PRESTRESSING
TENDONS**

Developed at the Department of Structural Mechanics of University of Granada

by

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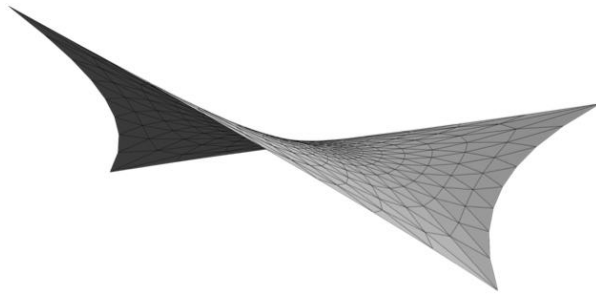
СИБИРСКИЙ ФЕДЕРАЛЬНЫЙ УНИВЕРСИТЕТ
SIBERIAN FEDERAL UNIVERSITY

Form-finding

The Force Density Method (FDM) is used to solve the form-finding problem of pin-jointed networks. The use of FDM together with Topological Mapping (TM) allows the designer to compute the equilibrium configuration of a network regardless the geometry of the structure.

A new type of structures: compression structures with prestressing tendons

Compression structures with prestressing tendons are a new type of structures which combines a compression structure with a discrete number of tension members treated as ties. They are an intermediate case between tension-only structures and compression-only structures. As tension and compression members exist, the force density matrix can be singular or ill-conditioned. Consequently, the solution of the equilibrium equation is not as simple as in the case of tension-only and compression-only structures. In this catalogue, nine compression structures with prestressing tendons are presented to show the potential of this new type of structures.

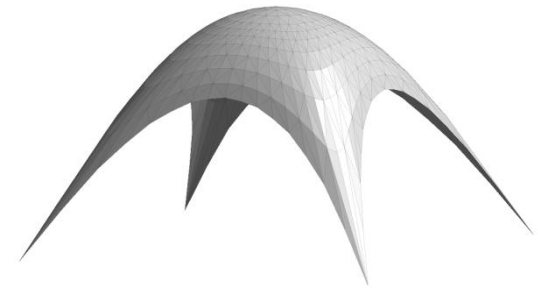
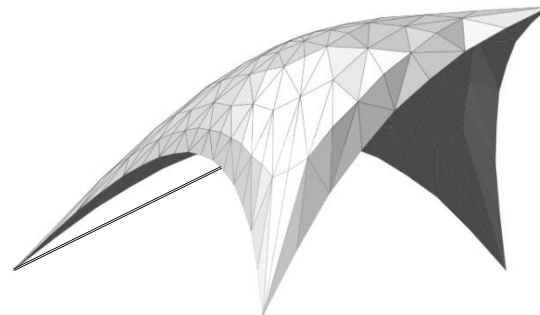


Tension structures

Positive force:length ratio
No self-weight; Supports

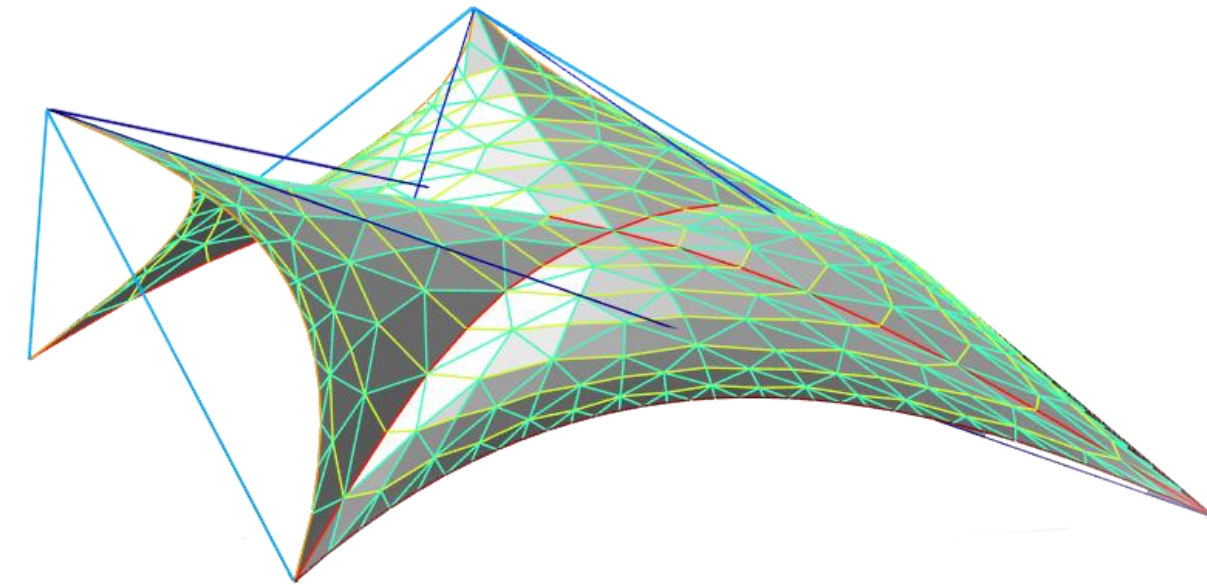
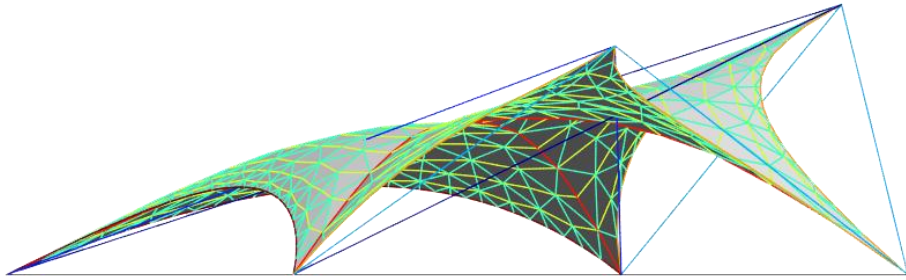
Compression structures with prestressing tendons

Positive and negative force:length ratio
Self-weight; Supports



Compression structures

Negative force:length ratio
Self-weight; Supports



Input data

Number of rings	8
Number of nodes in initial ring	8
Number of contour anchor points	4
Weight of ribs (kN/m)	0,5
Self-weight (kN/m ²)	0,7
Number of ties	8

INSPIRED BY BEETLE

Maximum height: 15,860 m

Material: steel and glass

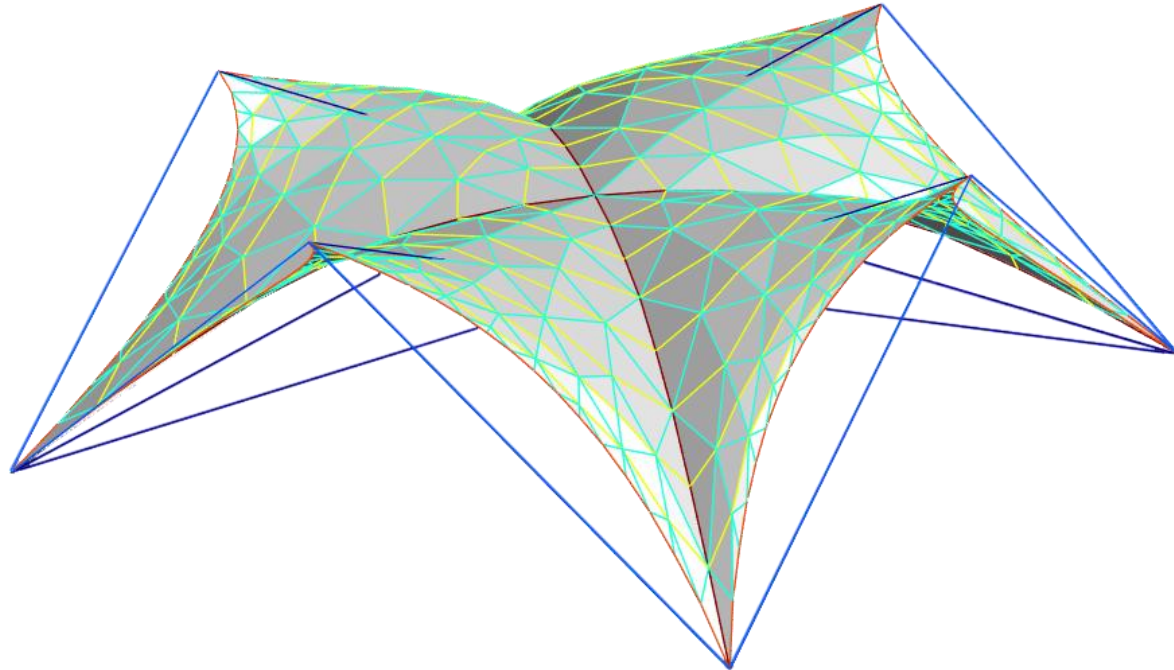
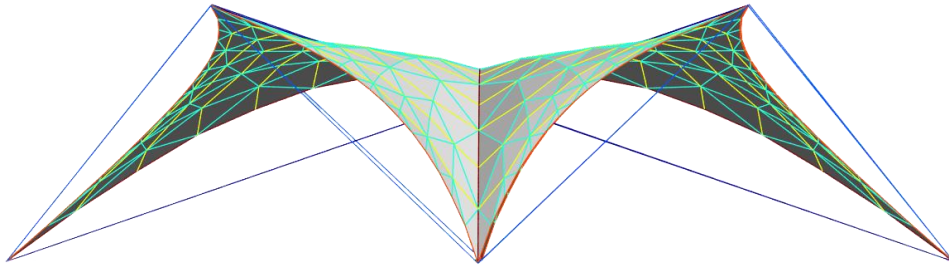
Force:length coefficient	Coordinates of anchor points		
	X _i (m)	Y _i (m)	Z _i (m)
— 1,260	0,0	0,0	0,0
— 1,037	40,0	0,0	0,0
— 0,408	40,0	40,0	0,0
— -4	0,0	40,0	0,0
— -7			
— -18			
— -50			
— -80			

k_{lim} 1247,9

Force:length coefficient of ties

0,408 1,037 1,260

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8
Type of topology	A	C	A	C	A	C	A	C
Force:length coefficient of ring branches	-7	-7	-7	-7	-7	-7	-7	-18
Force:length coefficient of radial branches	-4	-4	-4	-4	-4	-4	-4	-4



Input data

Number of rings	8
Number of nodes in initial ring	8
Number of contour anchor points	4
Weight of ribs (kN/m)	1,41
Self-weight (kN/m ²)	4,7
Number of ties	12

INSPIRED BY M-LETTER

Maximum height: 15,250 m

Material: concrete

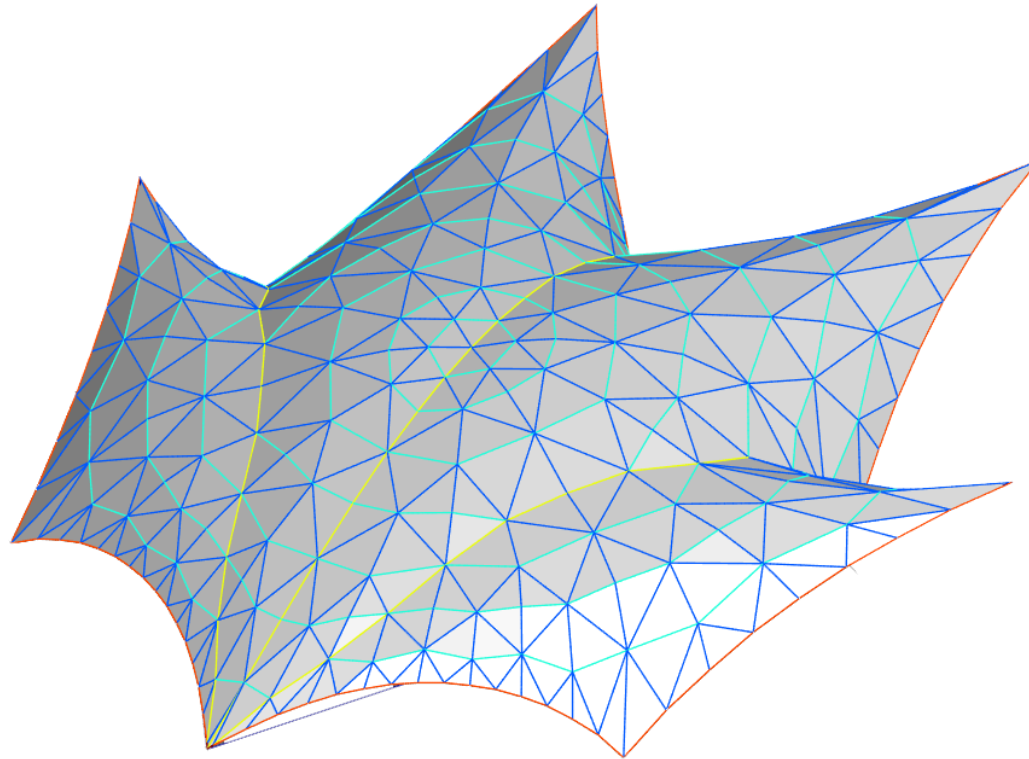
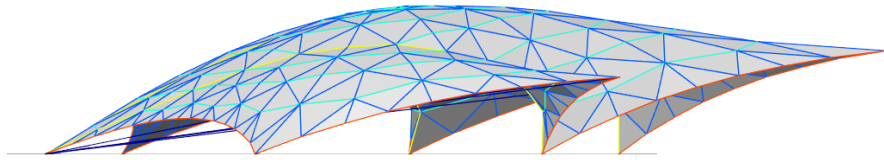
Force:length coefficient	Coordinates of anchor points		
	X _i (m)	Y _i (m)	Z _i (m)
8,1	0,00	0,00	0,00
4,05	40,00	0,00	0,00
-20	40,00	40,00	0,00
-25	0,00	40,00	0,00
-150			
-340			

K_{ijm} 1474,1

Force:length coefficient of ties

4,05 8,1

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8
Type of topology	A	C	A	C	A	C	A	C
Force:length coefficient of ring branches	-25	-25	-25	-25	-25	-25	-25	-150
Force:length coefficient of radial branches	-20	-20	-20	-20	-20	-20	-20	-20



Input data

Number of rings	8
Number of nodes in initial ring	6
Number of contour anchor points	6
Weight of ribs (kN/m)	1,41
Self-weight (kN/m ²)	4,7
Number of ties	4

INSPIRED BY SEASHELL

Maximum height : 0,940 m

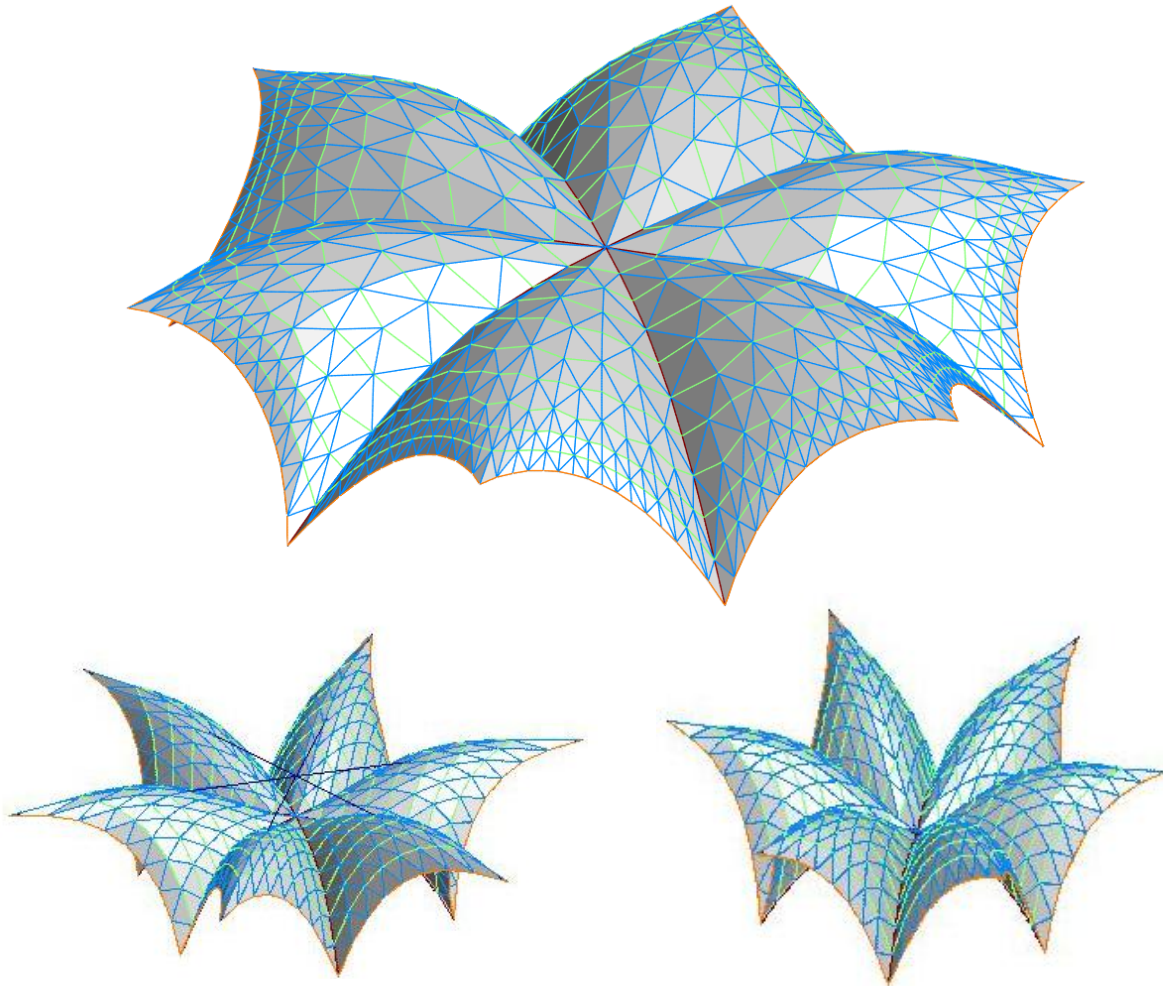
Material: concrete

Force:length coefficient	Coordinates of anchor points		
	X _i (m)	Y _i (m)	Z _i (m)
6,42	1,0	0,0	0,0
-2,5	3,0	0,0	0,0
-3,5	4,0	1,73	0,0
-20	3,0	3,46	0,0
-55	1,0	3,46	0,0
-500	0,0	1,73	0,0
k_{lim}	1060,5		

Force:length coefficient of ties

6,42

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8
Type of topology	A	C	A	C	A	C	A	C
Force:length coefficient of ring branches	-3,5	-3,5	-3,5	-3,5	-3,5	-3,5	-3,5	-55
Force:length coefficient of radial branches	-2,5	-2,5	-2,5	-2,5	-2,5	-2,5	-2,5	-2,5



Different configurations of the ties (connected above and under the structure)

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8	Ring 9	Ring 10
Type of topology	A	C	A	C	A	C	A	C	C	C
Force:length coefficient of ring branches	-3	-3	-3	-3	-3	-3	-3	-3	-3	-50
Force:length coefficient of radial branches	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2

Input data

Number of rings	10
Number of nodes in initial ring	6
Number of contour anchor points	12
Weight of ribs (kN/m)	1,41
Self-weight (kN/m ²)	4,7
Number of ties	6

INSPIRED BY FLOWER

Maximum height : 1,890 m

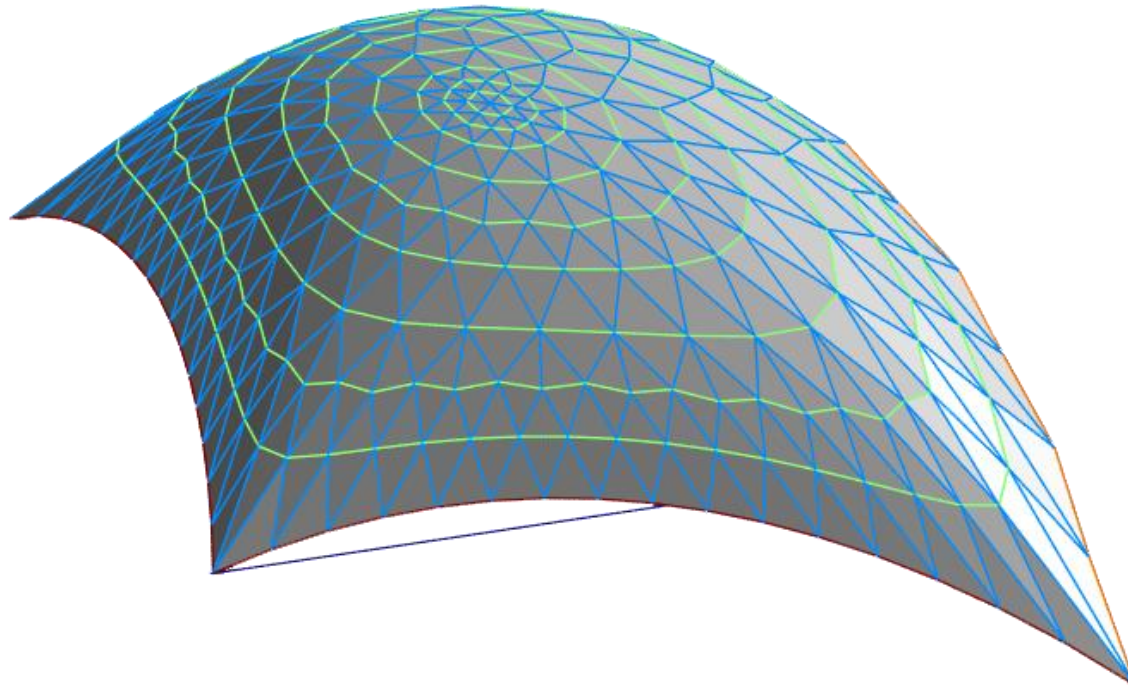
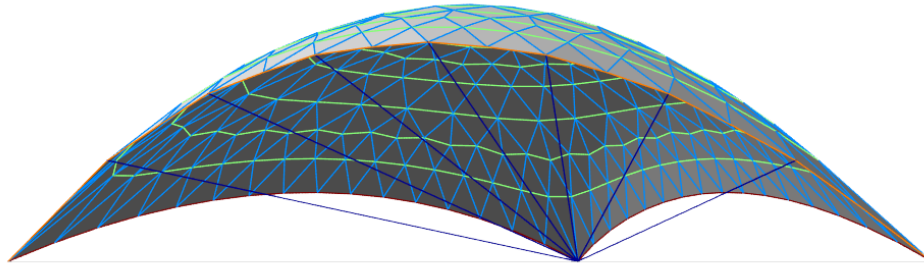
Material: concrete

Force:length coefficient	Coordinates of anchor points		
	X _i (m)	Y _i (m)	Z _i (m)
— 4,03	3,50	9,00	0,00
— -2	3,50	5,00	0,00
— -3	7,00	3,00	0,00
— -50	10,50	5,00	0,00
— -100	10,50	9,00	0,00
	7,00	11,00	0,00

k_{lim} 3511,8

Force:length coefficient of ties

4,03



Input data

Number of rings	10
Number of nodes in initial ring	6
Number of contour anchor points	3
Weight of ribs (kN/m)	1,41
Self-weight (kN/m ²)	4,7
Number of ties	7

INSPIRED BY SEASHELL

Maximum height: 4,470 m

Material: concrete

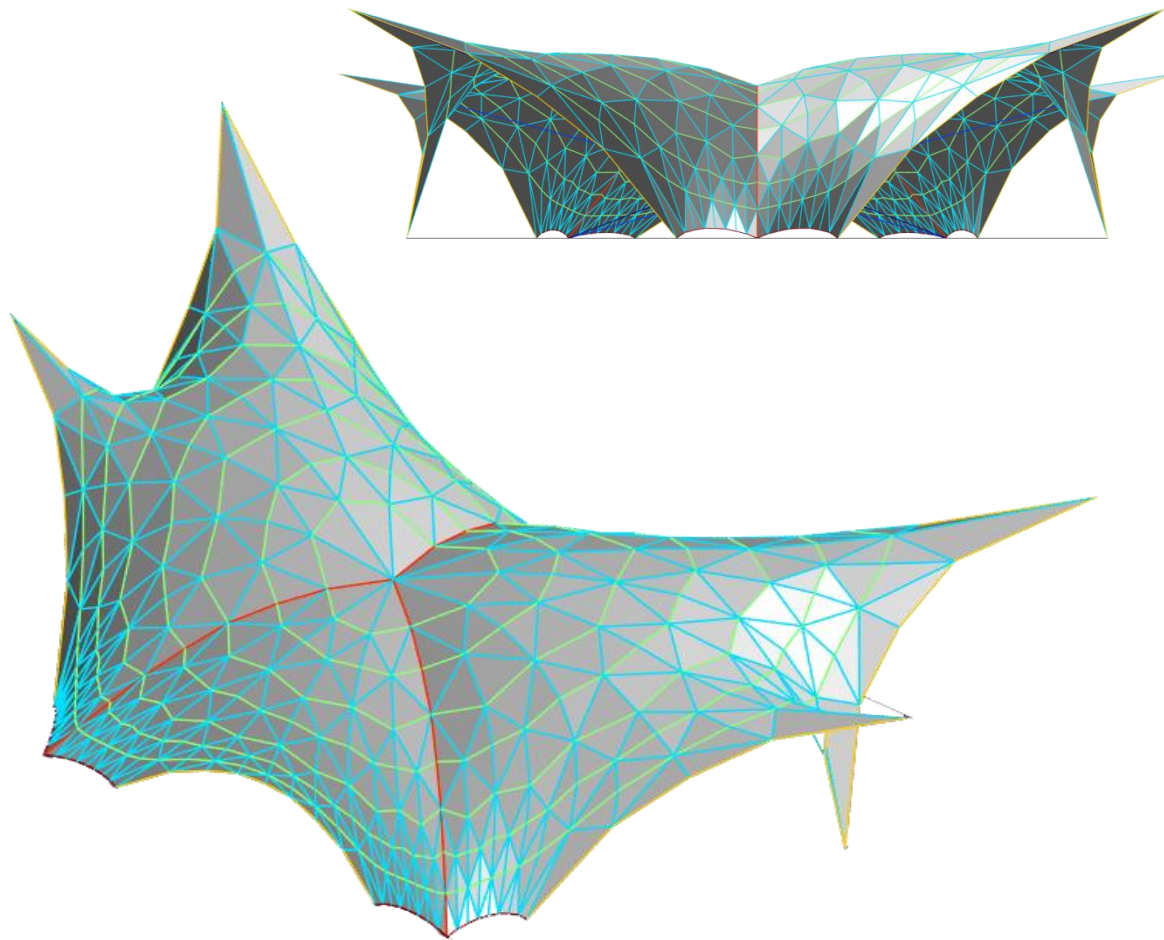
Force:length coefficient	Coordinates of anchor points		
	X _i (m)	Y _i (m)	Z _i (m)
— 2,515	0,0	8,7	0,0
— -5	5,0	0,0	0,0
— -7	15,0	0,0	0,0
— -80			
— -200			

k_{lim} 1920,9

Force:length coefficient of ties

2,515

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8	Ring 9	Ring 10
Type of topology	A	B	B	A	B	B	A	B	B	B
Force:length coefficient of ring branches	-7	-7	-7	-7	-7	-7	-7	-7	-7	-80
Force:length coefficient of radial branches	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5



Input data	
Number of rings	8
Number of nodes in initial ring	11
Number of contour anchor points	11
Weight of ribs (kN/m)	1,41
Self-weight (kN/m ²)	4,7
Number of ties	4

INSPIRED BY BAT

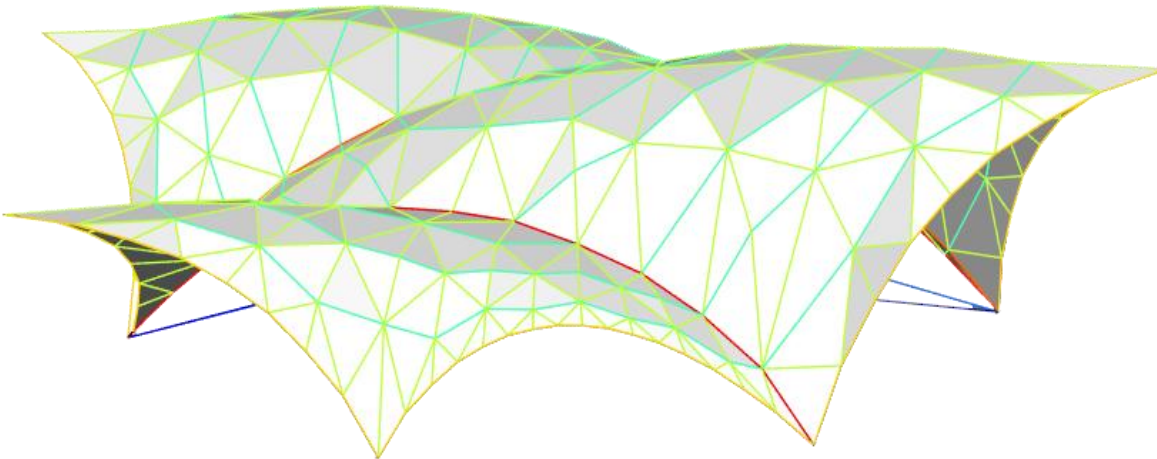
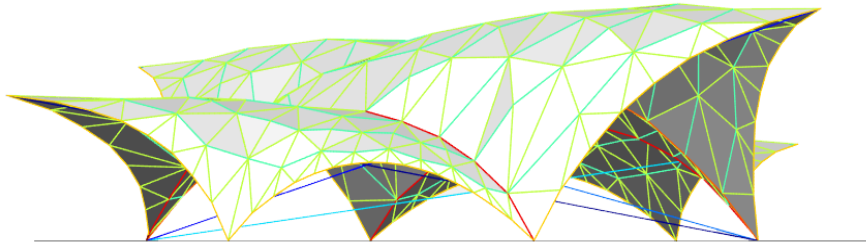
Maximum height : 26,810 m

Material: concrete

Force:length coefficient	Coordinates of anchor points		
	X _i (m)	Y _i (m)	Z _i (m)
— 38	-20,00	40,00	0,00
— 29,56	-0,80	8,00	0,00
— -45	4,00	0,00	0,00
— -50	14,00	0,00	0,00
— -120	50,00	0,00	0,00
— -350	60,00	0,00	0,00
— -2500	64,80	8,00	0,00
	84,00	40,00	0,00
	44,00	58,00	0,00
	32,00	64,00	0,00
	20,00	58,00	0,00
k _{lim}	1603,3		

Force:length coefficient of ties	
29,56	38

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8
Type of topology	A	C	A	C	A	C	C	C
Force:length coefficient of ring branches	-50	-50	-50	-50	-50	-50	-50	-120
Force:length coefficient of radial branches	-45	-45	-45	-45	-45	-45	-45	-45



Input data

Number of rings	8
Number of nodes in initial ring	6
Number of contour anchor points	6
Weight of ribs (kN/m)	1,41
Self-weight (kN/m ²)	4,7
Number of ties	4

INSPIRED BY SYDNEY OPERA

Maximum height: 5,700 m

Material: concrete

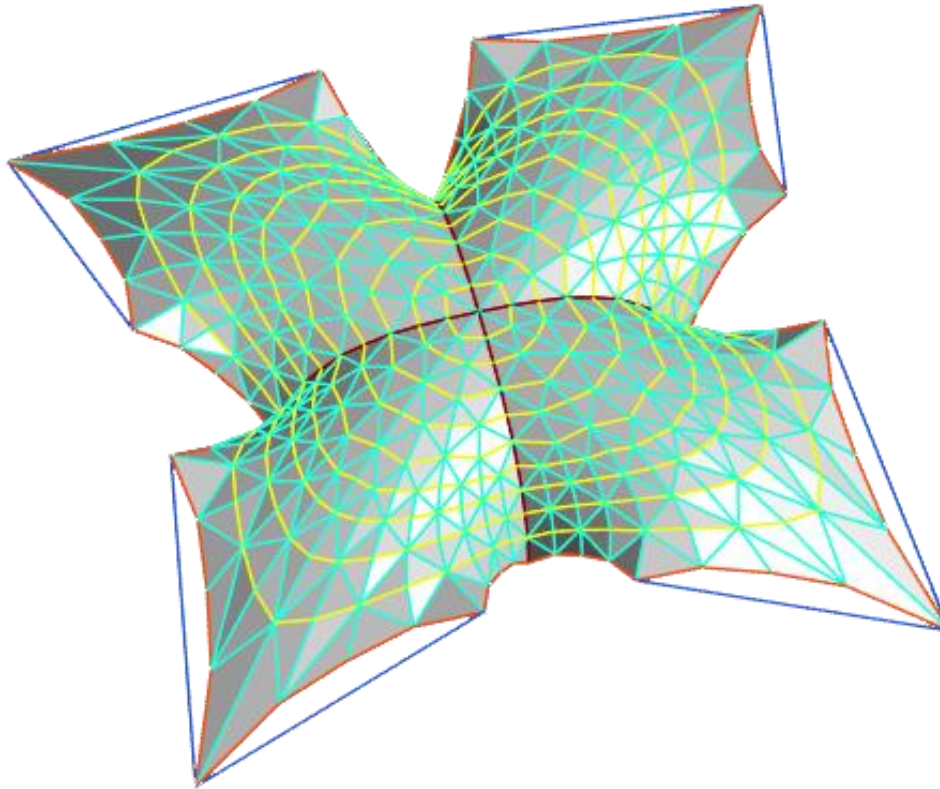
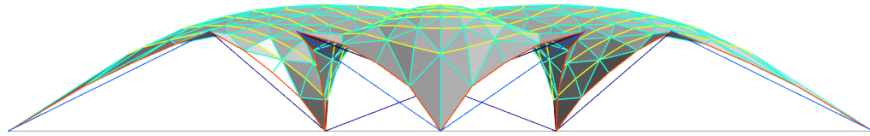
Force:length coefficient	Coordinates of anchor points		
	X _i (m)	Y _i (m)	Z _i (m)
7,95	4,00	0,00	0,00
7,23	12,00	0,00	0,00
5,78	16,00	6,92	0,00
5,06	12,00	13,84	0,00
-5	4,00	13,84	0,00
-5,5	0,00	6,92	0,00
-60			
-120			
-130			
-1000			

k_{lim} 855,55

Force:length coefficient of ties

5,06 5,78 7,23 7,95

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8
Type of topology	C	A	C	A	C	C	A	C
Force:length coefficient of ring branches	-5	-5	-5	-5	-5	-5	-5	-60
Force:length coefficient of radial branches	-5,5	-5,5	-5,5	-5,5	-5,5	-5,5	-5,5	-5,5



Input data

Number of rings	10
Number of nodes in initial ring	8
Number of contour anchor points	8
Weight of ribs (kN/m)	1,41
Self-weight (kN/m ²)	4,7
Number of ties	16

INSPIRED BY FLOWER

Maximum height: 4,400 m

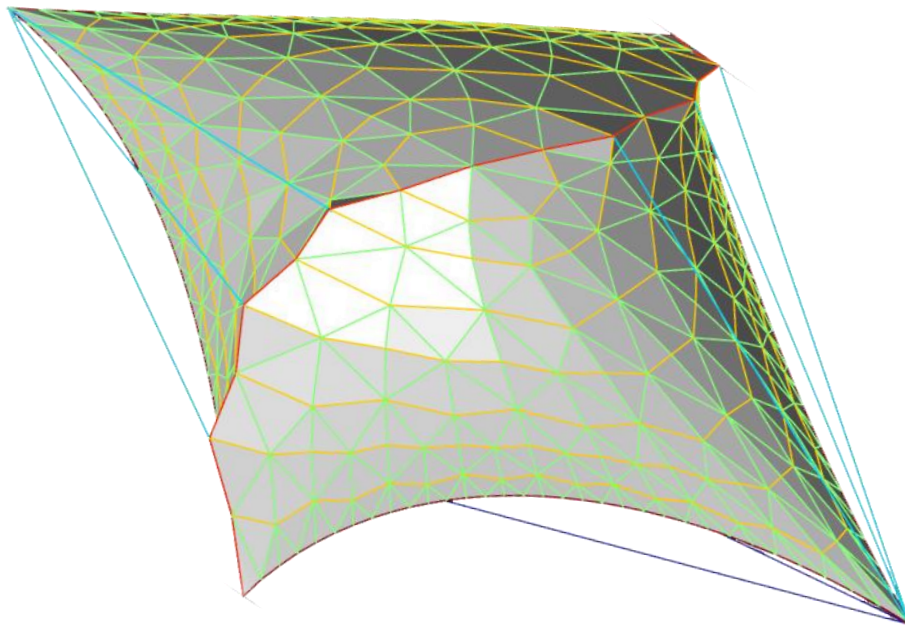
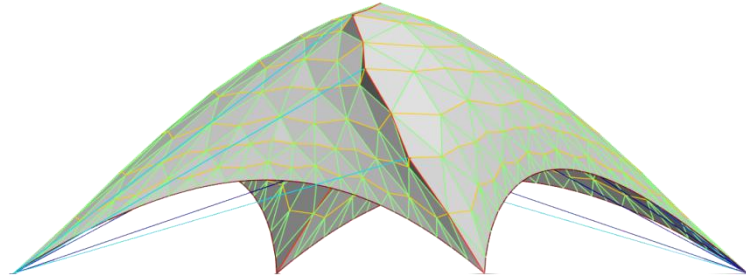
Material: concrete

Force:length coefficient	Coordinates of anchor points		
	X _i (m)	Y _i (m)	Z _i (m)
— 13,97	0,0	15,0	0,0
— 6,99	11,0	11,0	0,0
— -10	15,0	0,0	0,0
— -12	19,0	11,0	0,0
— -70	30,0	15,0	0,0
— -150	19,0	19,0	0,0
	15,0	30,0	0,0
	11,0	19,0	0,0
k _{lim}	774,14		

Force:length coefficient of ties

6,99	13,97
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	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8	Ring 9	Ring 10
Type of topology	A	C	A	C	A	C	C	C	C	C
Force:length coefficient of ring branches	-12	-12	-12	-12	-12	-12	-12	-12	-12	-70
Force:length coefficient of radial branches	-10	-10	-10	-10	-10	-10	-10	-10	-10	-10



Input data

Number of rings	8
Number of nodes in initial ring	8
Number of contour anchor points	4
Weight of ribs (kN/m)	1,41
Self-weight (kN/m ²)	4,7
Number of ties	14

INSPIRED BY ROMB

Maximum height: 9,290 m

Material: concrete

Force:length coefficient	Coordinates of anchor points		
	X _i (m)	Y _i (m)	Z _i (m)
8,48	10,0	30,0	0,0
3,38	0,0	15,0	0,0
0,845	10,0	0,0	0,0
-10	20,0	15,0	0,0
-12			
-120			
-400			

k_{lim} 1385,4

Force:length coefficient of ties

0,845 3,38 8,48

	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Ring 6	Ring 7	Ring 8
Type of topology	A	C	A	C	A	C	A	C
Force:length coefficient of ring branches	-12	-12	-12	-12	-12	-12	-12	-400
Force:length coefficient of radial branches	-10	-10	-10	-10	-10	-10	-10	-10

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