Cubiertas de grandes luces para estadios deportivos

Evolución y Tendencias actuales

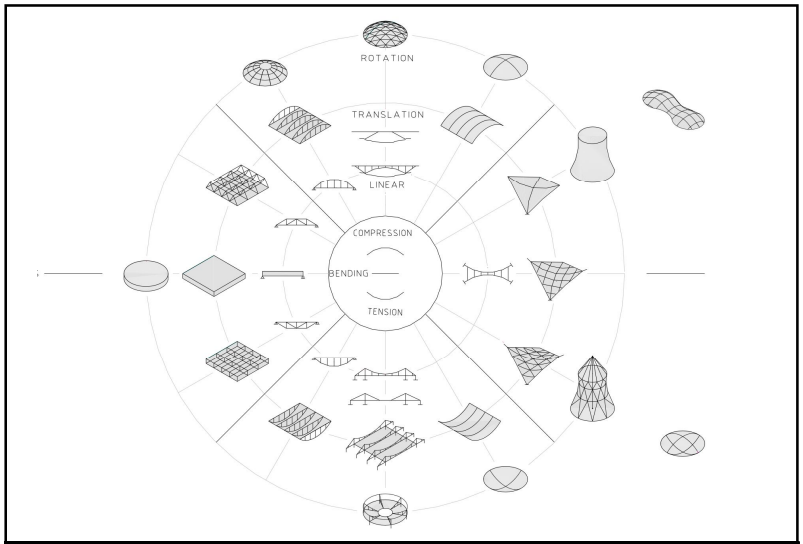
Dr. Ing. Fernando Sima
19.12.2018

Introducción

Berlin 1936 y la TV

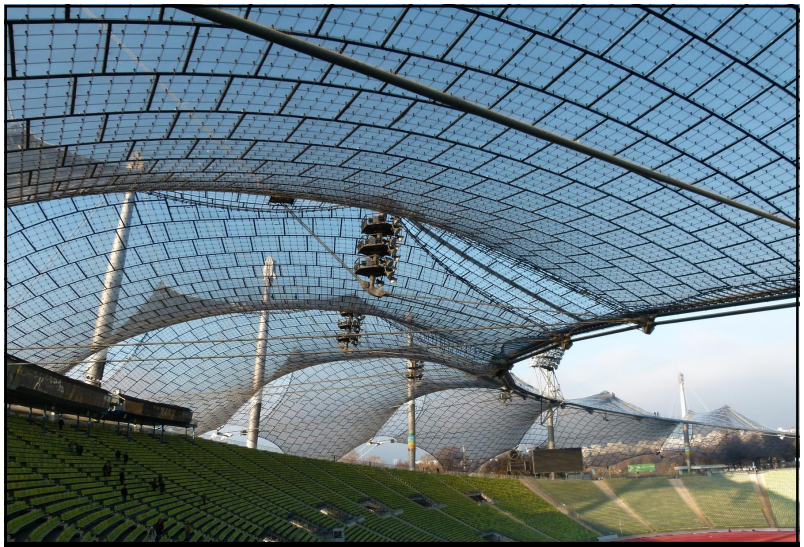
Más que un estadio...

Más que un estadio ...

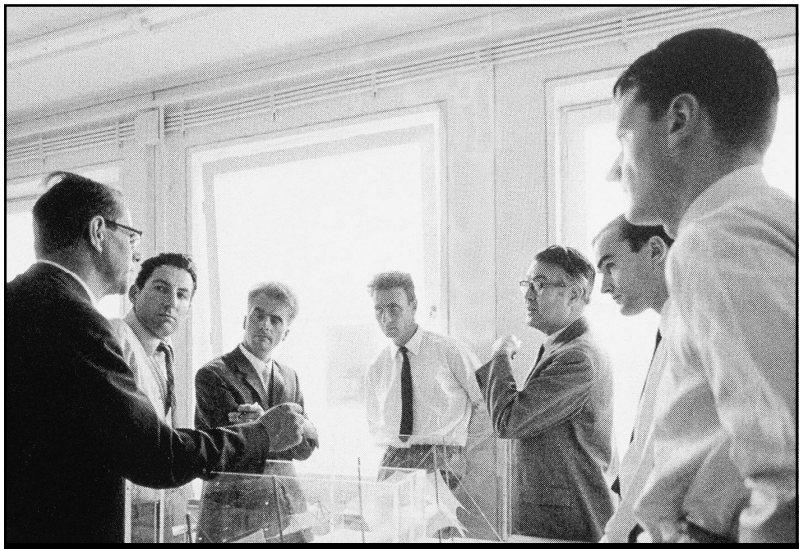


“Orden de las estructuras”

München 1972 – “El origen”

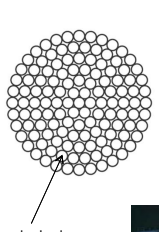


München 1972 – “El origen”

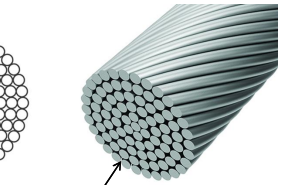


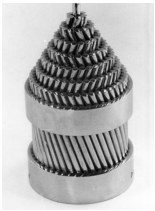
München 1972 – “El origen”

Cordón en espiral abierto (Open Spiral strand – OSS)



Varias capas de alambres helicoidales con dirección alternada y paso menor

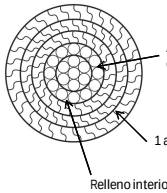




E=170 Gpa
Resistencia 0.9 fctb

Materiales – Cables de acero de alta resistencia

Cable cerrado (Full locked cable – FLC)



Alambres 1370-1570 MPa
E=160 +/- 10 GPa

Menor relación de vacíos que cualquier otro tipo de cable

Cables Pfeifer

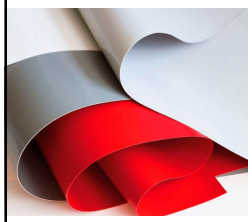
Größe size	Charakt. Bruchkraft charact. breaking load $Z_{B,k}$ DIN 18800* kN	Grenzzugkraft limit tension $Z_{R,d}$ DIN 18800 kN	Metall. Querschnitt metallic cross section ca./approx. mm²	Gewicht weight ca./approx. kg/m	Konstruktion construction **	Seil-Nenndurchmesser nomin. strand dia. d_S mm
PV 40	405	245	281	2,4	WS-1	21
PV 60	621	376	430	3,6	WS-1	26
PV 90	916	555	634	5,3	WS-2	31
PV 115	1170	709	808	6,8	WS-2	35
PV 150	1520	921	1060	8,9	WS-2	40
PV 195	1930	1170	1340	11,2	WS-2	45
PV 240	2380	1442	1650	13,8	WS-2	50
PV 300	3020	1830	2090	17,2	WS-3	55
PV 360	3590	2176	2490	20,5	WS-3	60
PV 420	4220	2558	2920	24,1	WS-3	65
PV 490	4890	2964	3390	27,9	WS-3	70
PV 560	5620	3406	3890	32,1	WS-3	75
PV 640	6390	3873	4420	36,4	WS-3	80
PV 720	7210	4370	4990	41,1	WS-3	85
PV 810	8090	4903	5600	46,2	WS-3	90
PV 910	9110	5521	6310	52,0	WS-3	95
PV 1010	10100	6121	6990	57,6	WS-3	100
PV 1110	11100	6727	7710	63,5	WS-3	105
PV 1220	12200	7394	8460	69,7	WS-3	110
PV 1340	13400	8121	9240	76,2	WS-3	115
PV 1450	14500	8788	10100	83,2	WS-3	120
PV 1580	15800	9576	10900	89,8	WS-3	125
PV 1730	17300	10485	11900	96,7	WS-3	130
PV 1860	18600	11273	12900	104,8	WS-3	135
PV 2000	20000	12121	13900	112,9	WS-3	140

$1 - 13900/(p \cdot 70^2) = 10\ \%$

Protección contra corrosión: galvanizado (GALFAN) y pintado
Densidad eq. 8.8 KN/m³

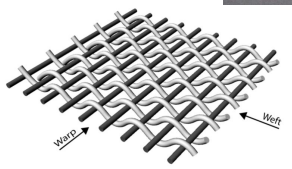
Materiales – Cables de acero de alta resistencia

PES / PVC



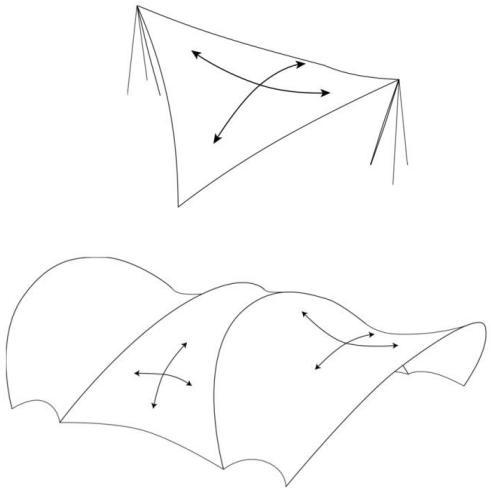
Glass / PTFE

ETFE



Materiales – Membrana

Superficie
Anticlástica



Materiales – Membrana

Formfinding ⇨ Proceso de obtención de la forma que permite el óptimo flujo de esfuerzos dentro de una estructura, para un estado determinado de cargas y condiciones de contorno.

"Form follows force"

Especialmente relevante en estructuras que transfieren los esfuerzos puramente a través de esfuerzo axil o fuerzas en su plano (membrana).

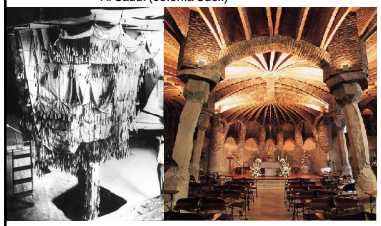
Tracción	Compresión
Cables	Arcos
Redes de cables	Bóvedas
Membranas	Cáscaras
....	....

↓ Estructuras híbridas

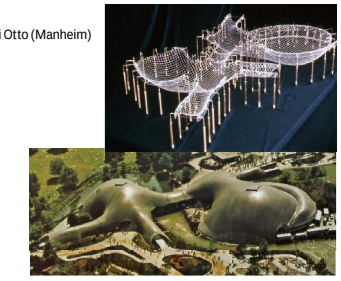
Form-finding

Formfinding "Analógico"

A. Gaudí (Colonia Guell)



Frei Otto (Manheim)

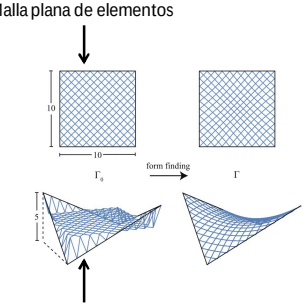


Frei Otto (Pabellón Alemán 1967)

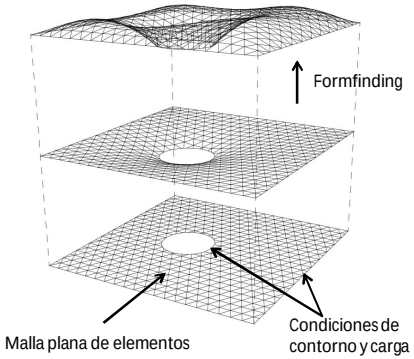
Form-finding

Formfinding "digital"

Malla plana de elementos

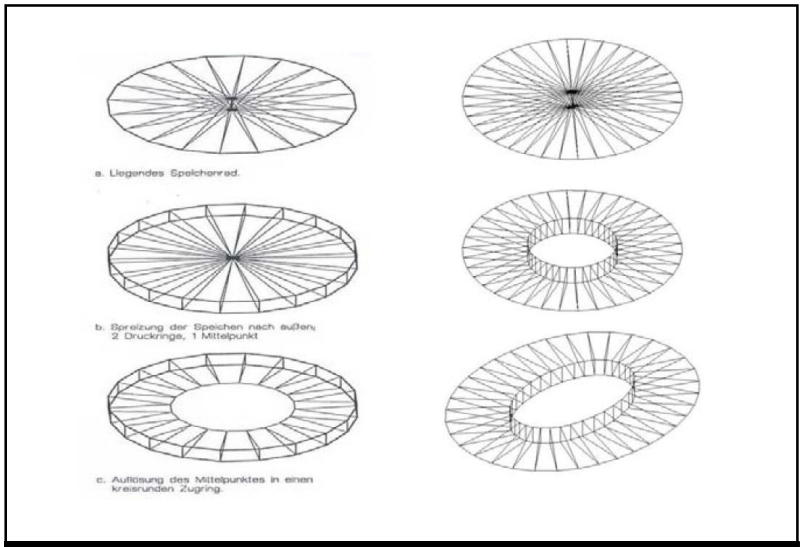


Condiciones de contorno y carga

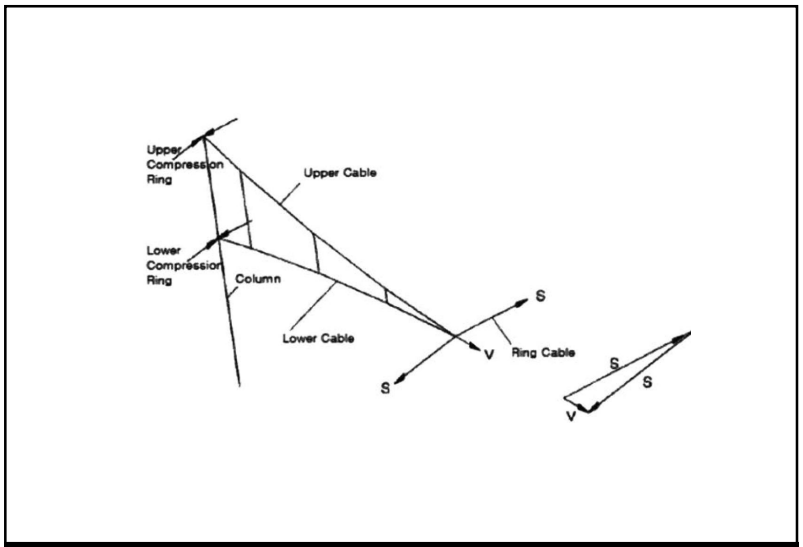


Form-finding

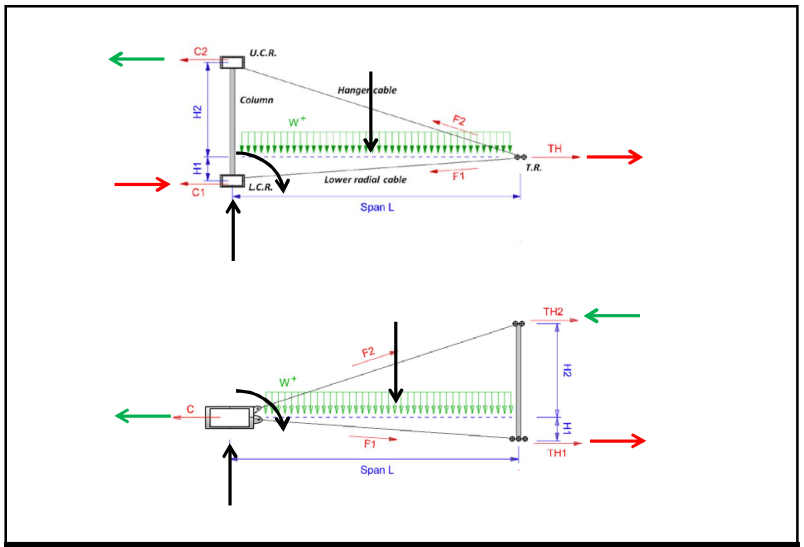
Sistemas estructurales - Spokes Wheel



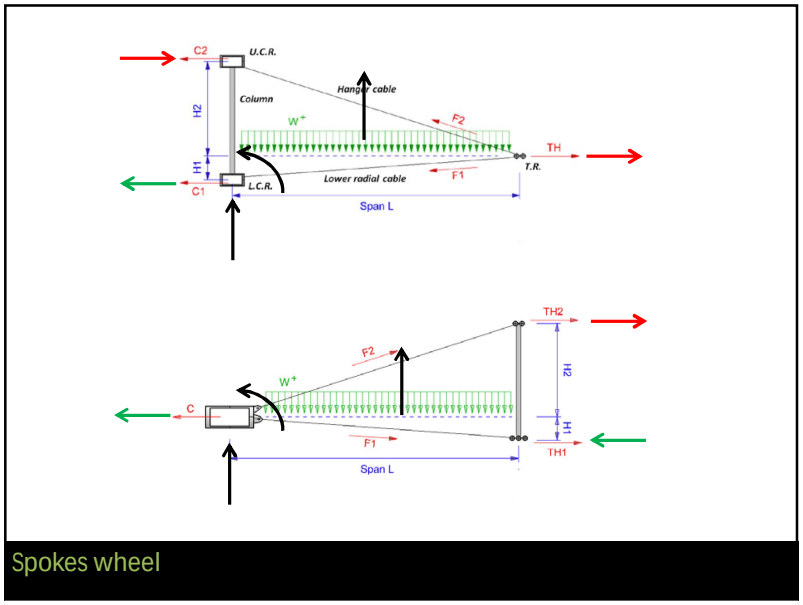
Spokes wheel



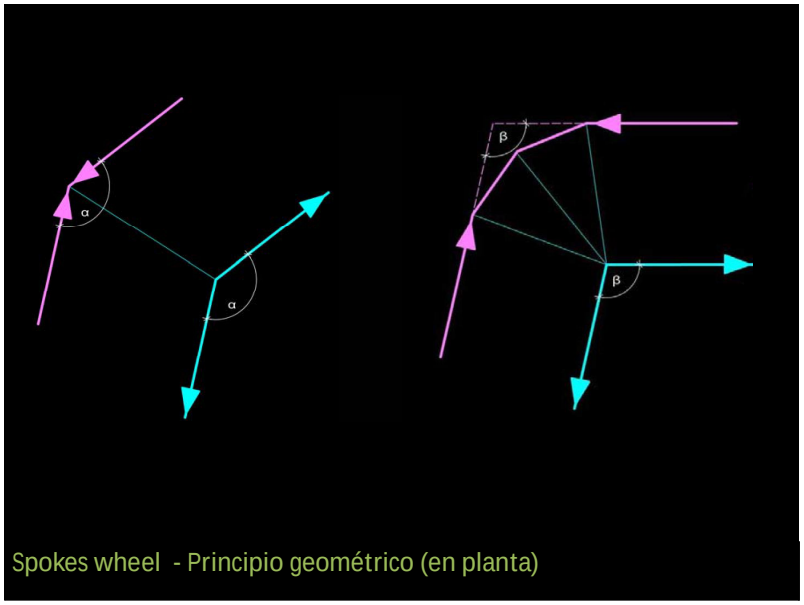
Spokes wheel



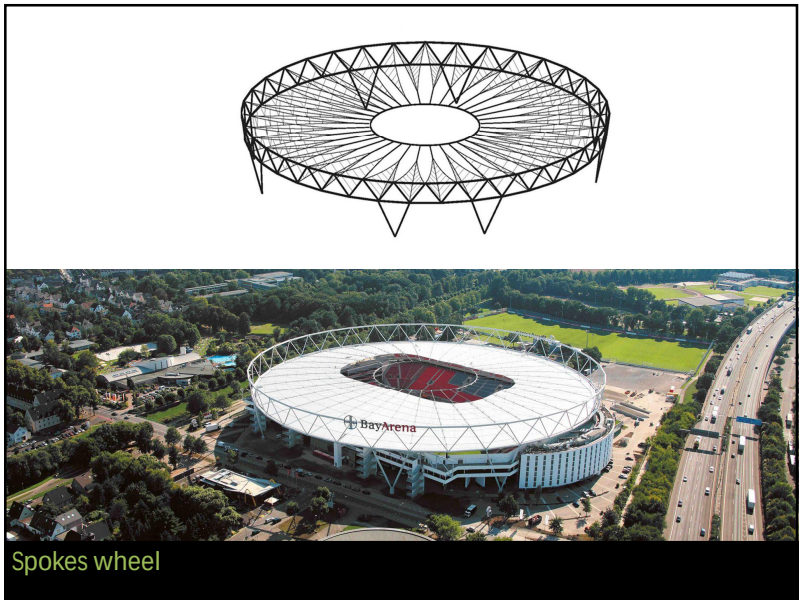
Spokes wheel



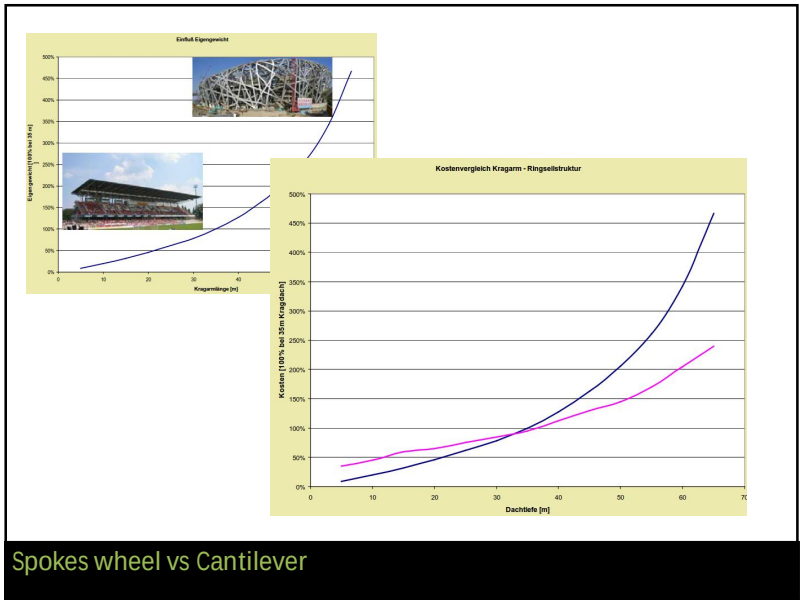
Spokes wheel



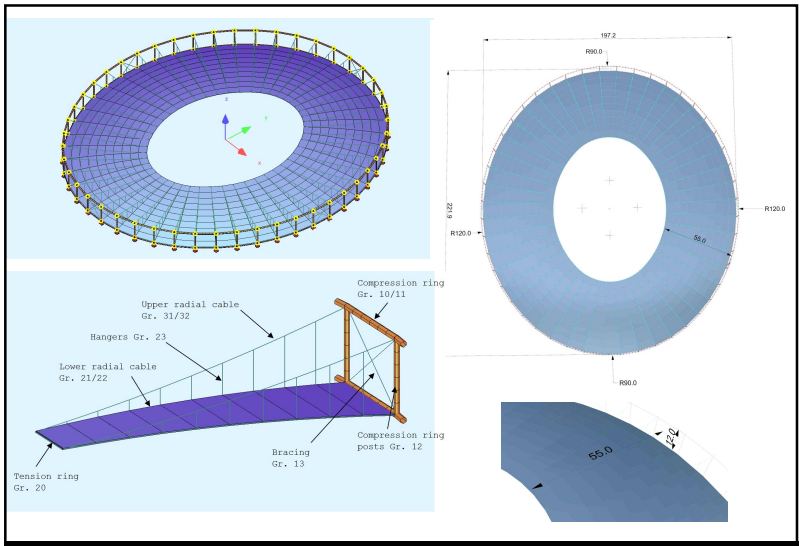
Spokes wheel - Principio geométrico (en planta)



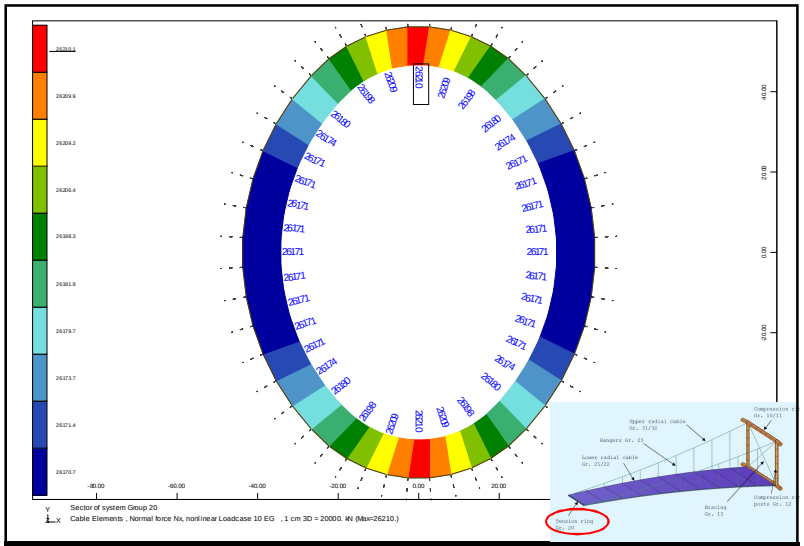
Spokes wheel



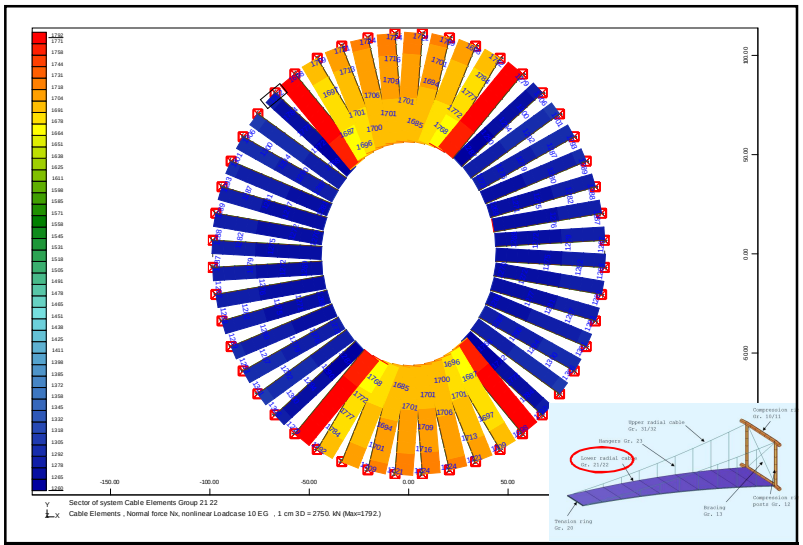
Spokes wheel vs Cantilever



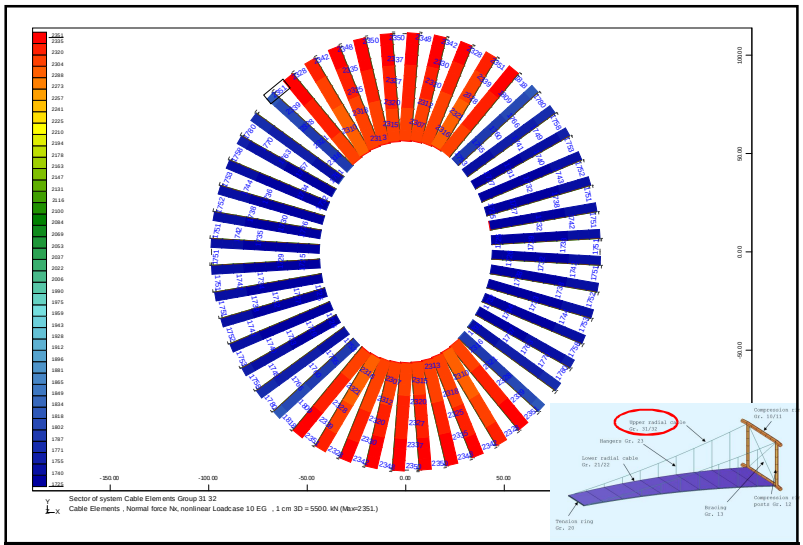
Spokes wheel – Orden de magnitud



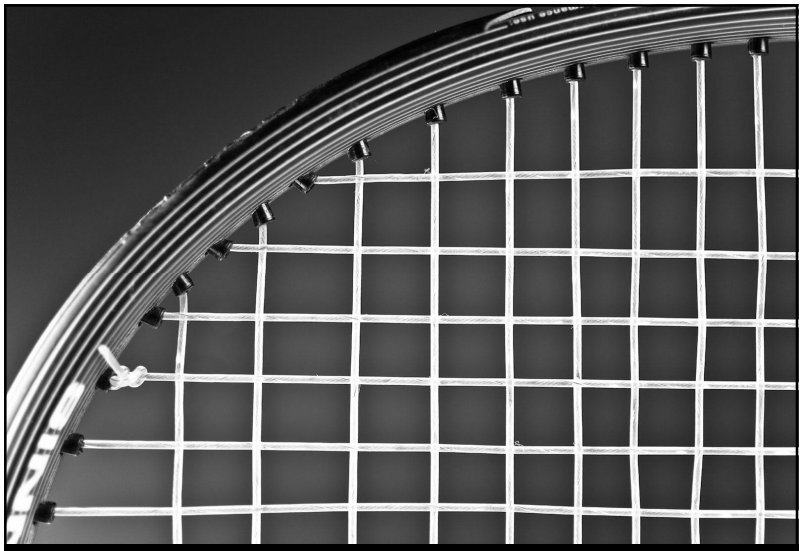
Spokes wheel – Orden de magnitud



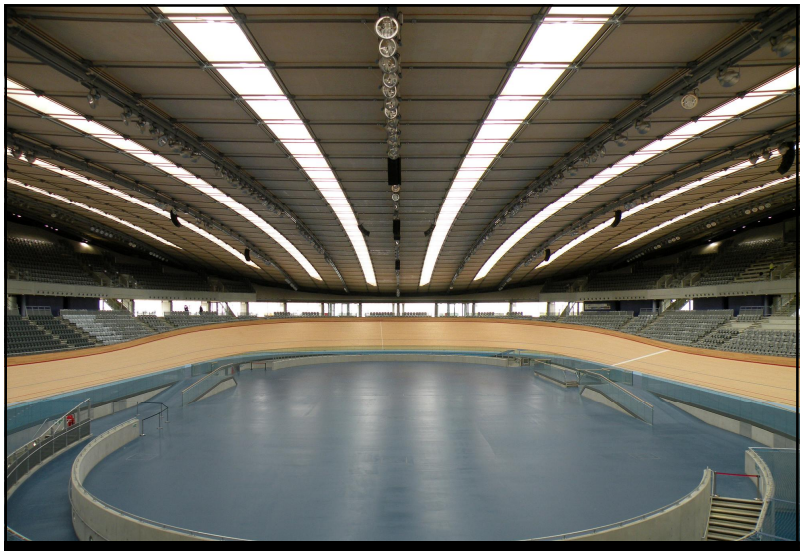
Spokes wheel – Orden de magnitud



Spokes wheel – Orden de magnitud



Sistemas estructurales – Red de cables



Velódromo olímpico Londres 2012

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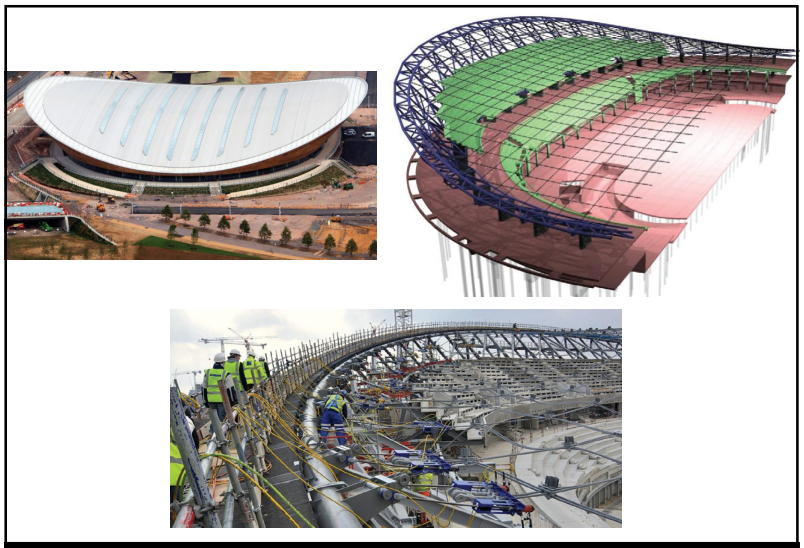
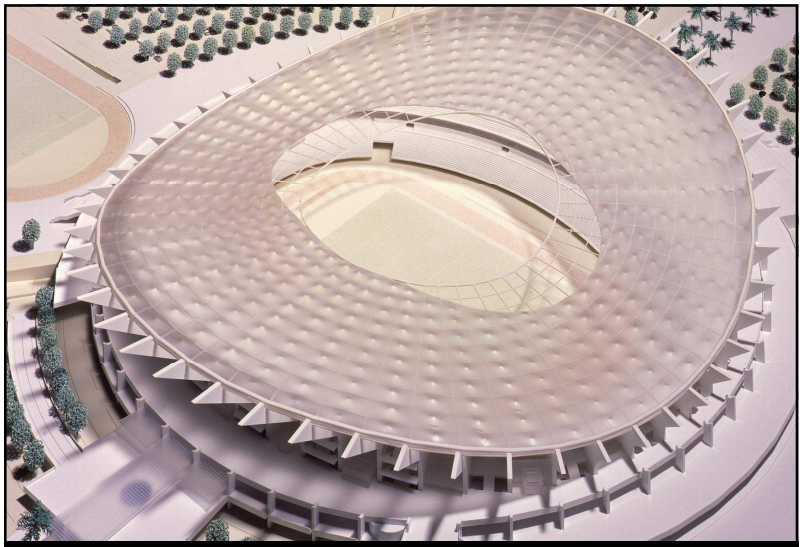
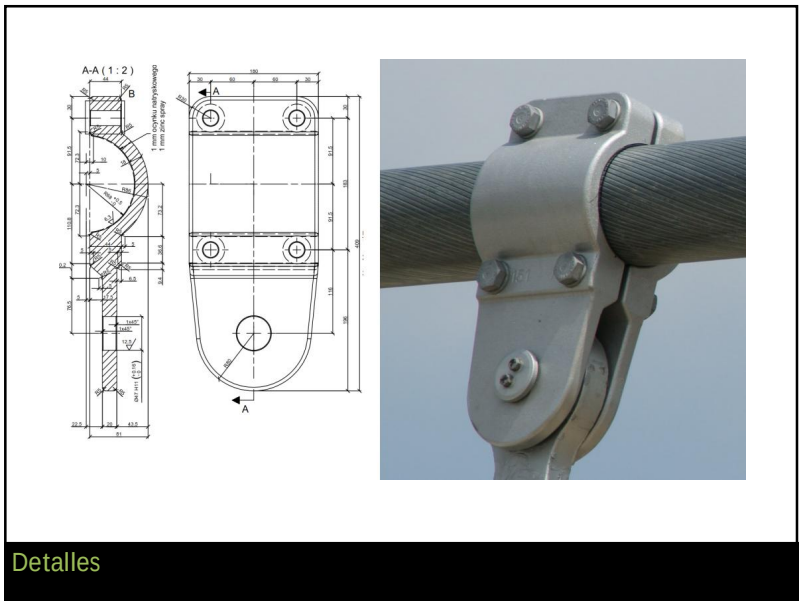


Velódromo olímpico Londres 2012

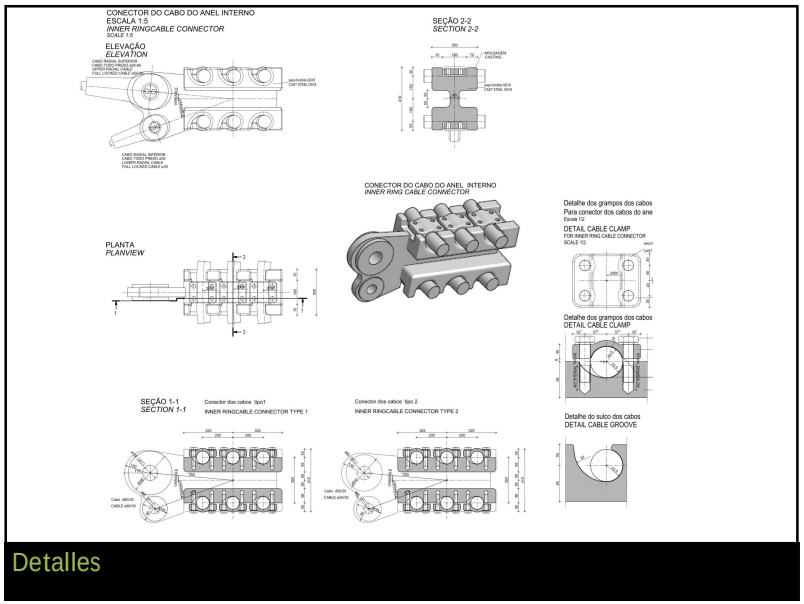


Jaber Al-ahmed Stadium, Kuwait

Jaber Al-ahmed Stadium, Kuwait



Detalles



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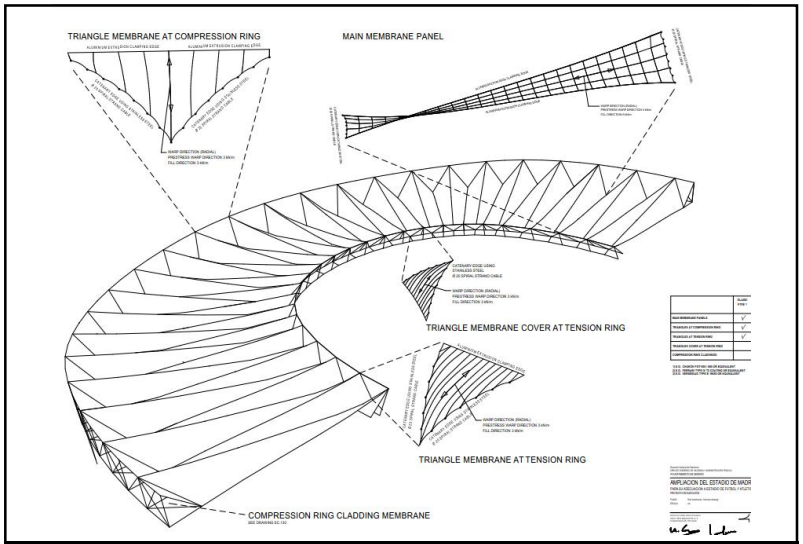

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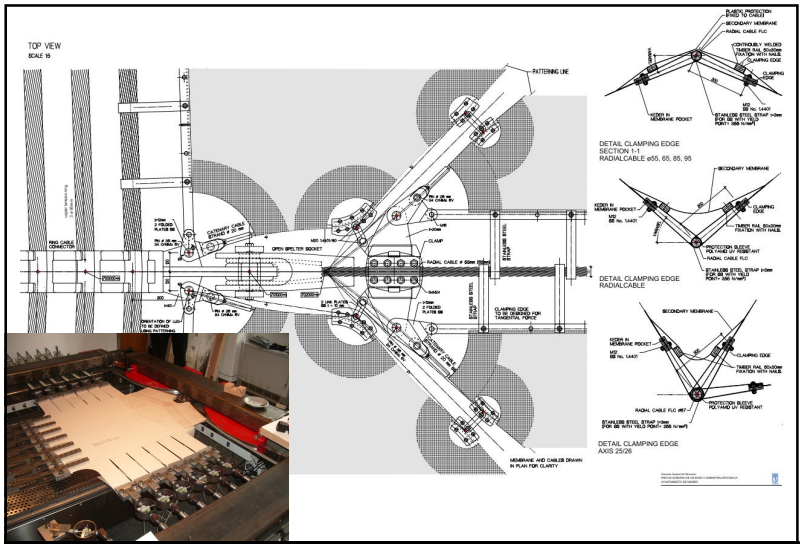

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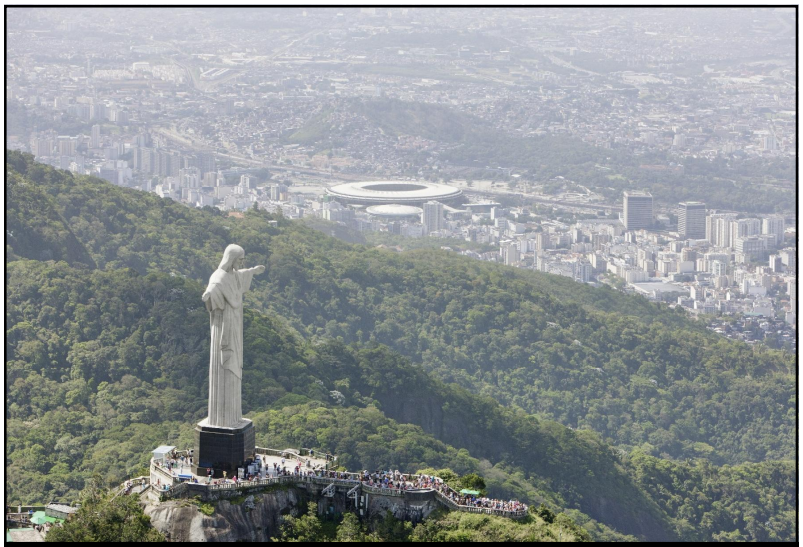
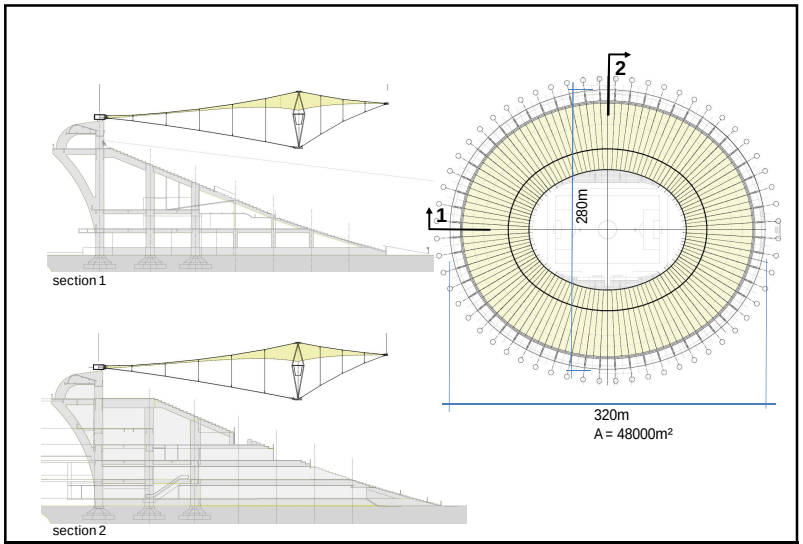


Maracanã

Maracanã



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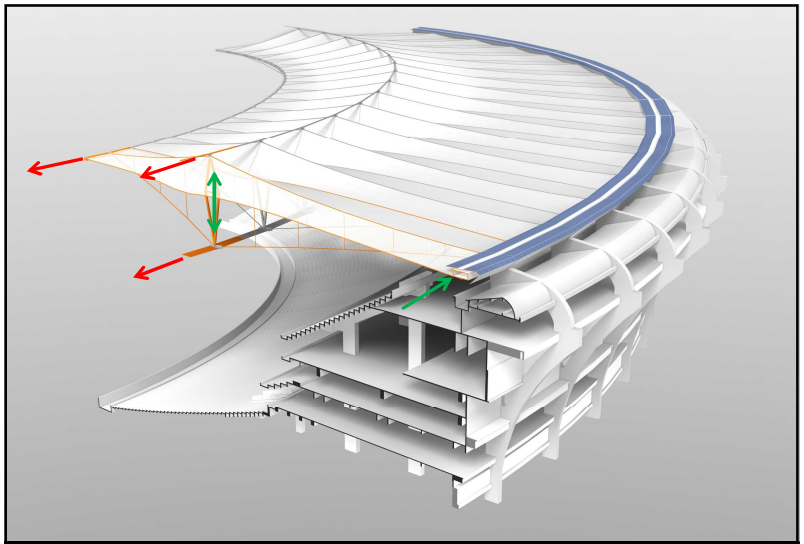
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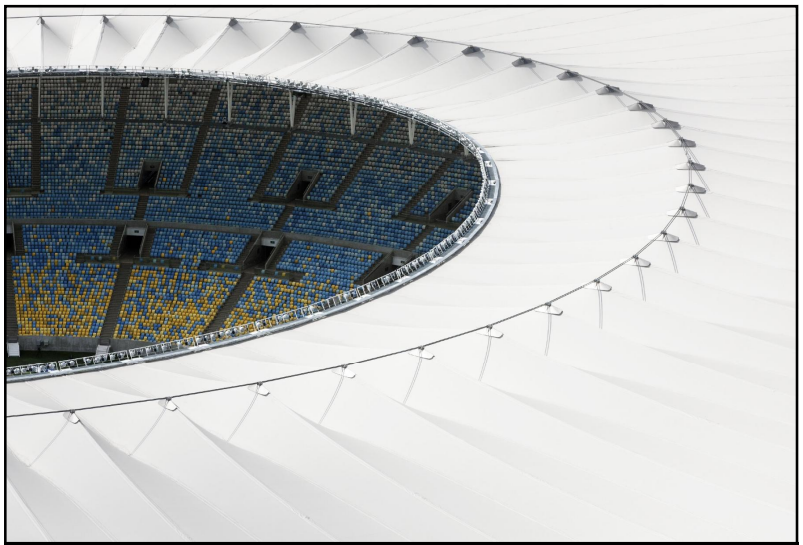
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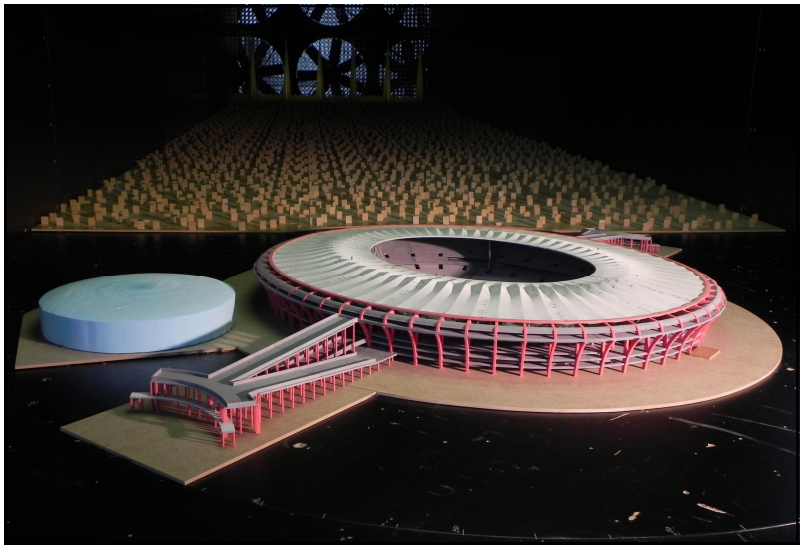
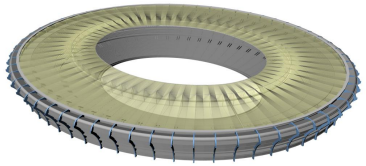
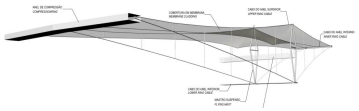
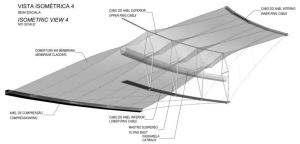

Maracanã

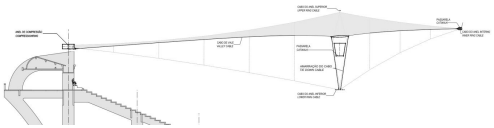
Formfinding “digital”

Cubierta Estadio
Maracanã (sbp 2013)





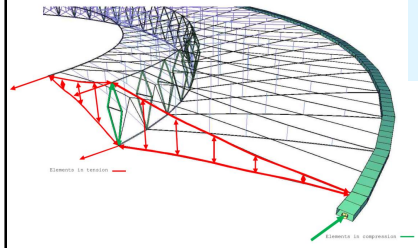




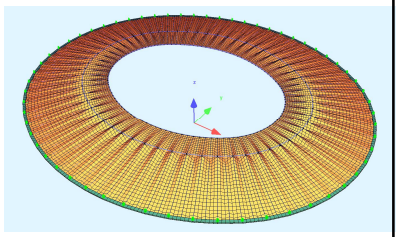
Maracanã

Formfinding “digital”

Cubierta Estadio
Maracanã (sbp 2013)

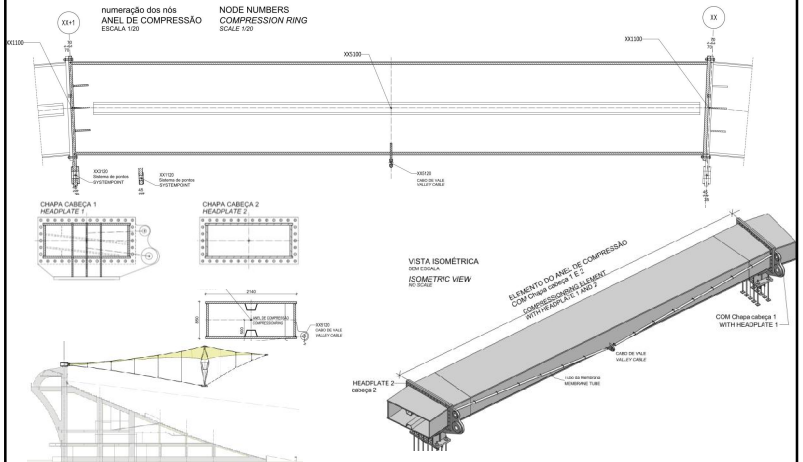


Geometría “formfound” (sbp 2013)



Maracanã

Druckringsegment 2,10m x 0,85m x 14.50m



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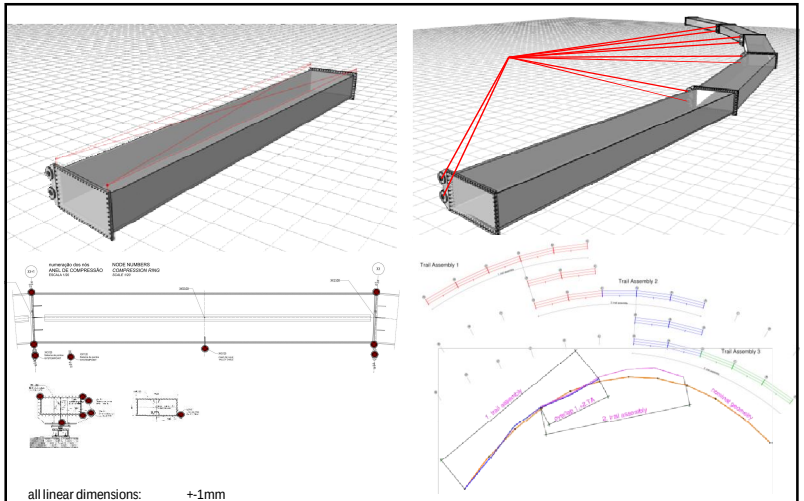
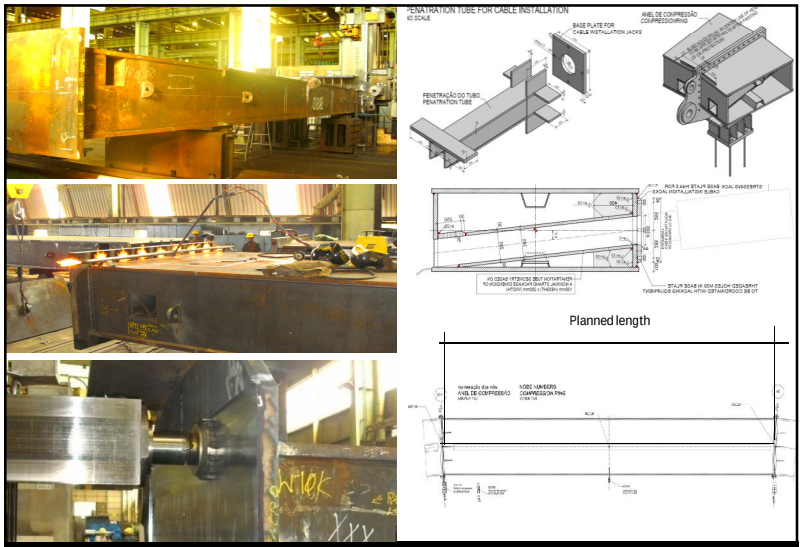


all linear dimensions: +-1mm
end plate angle f: 0,5mm/m
end plate eveness: 0,5mm/m

horizontal deviation (vector): +-10mm
vertical deviation: +-2mm

Maracanã



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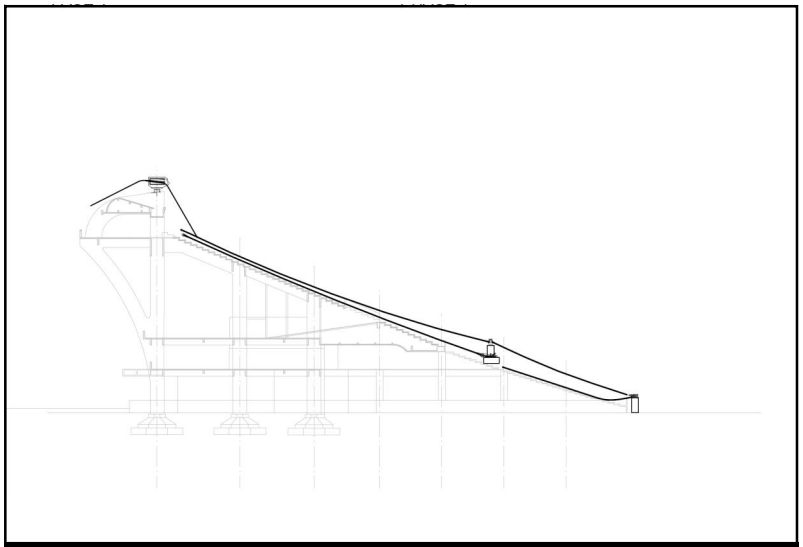

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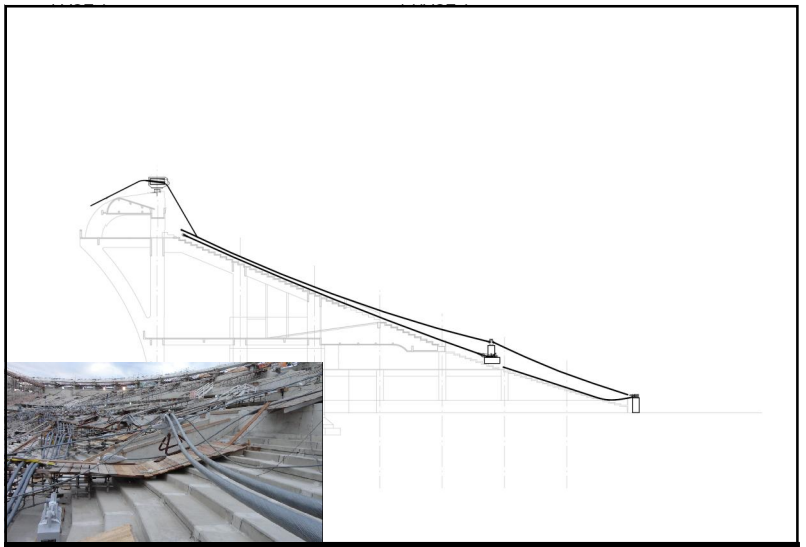

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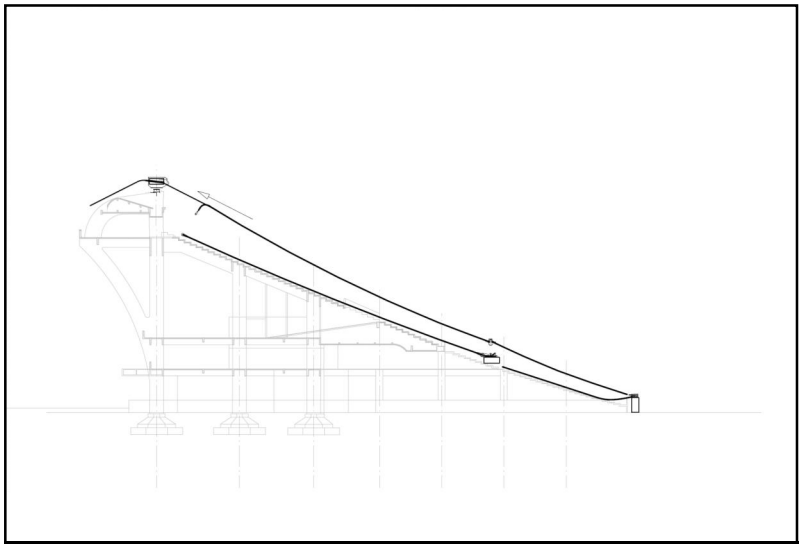
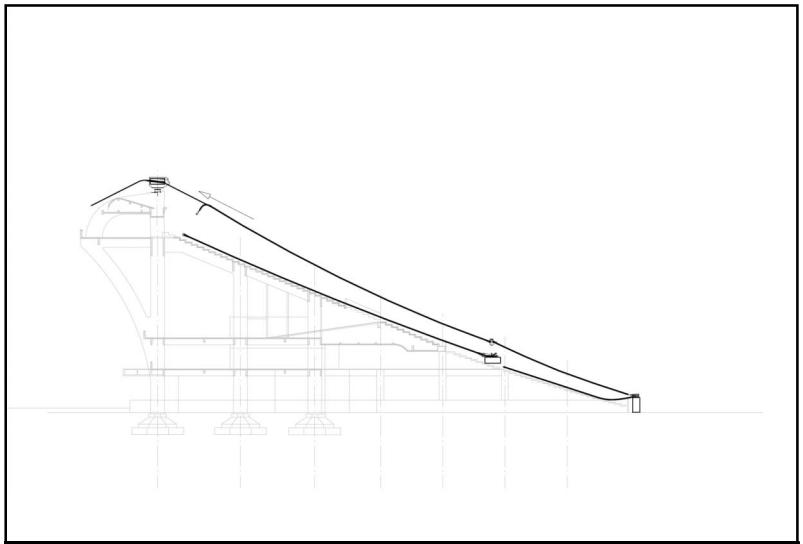


Maracanã



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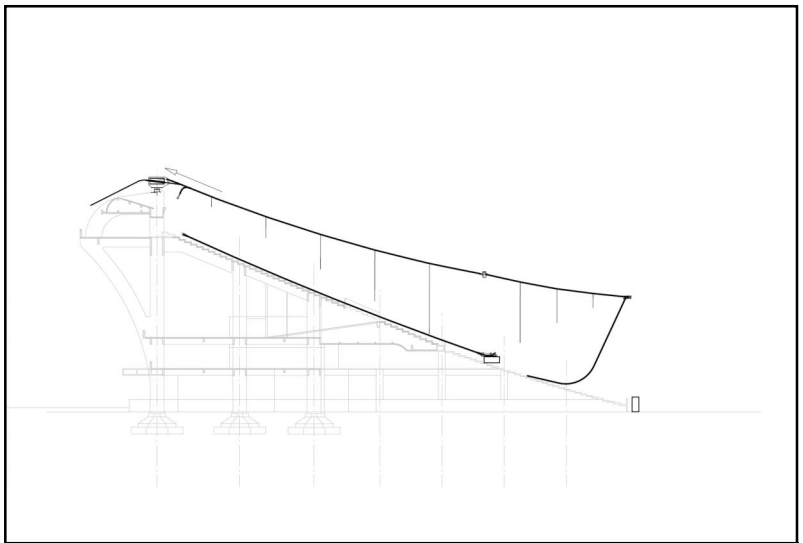

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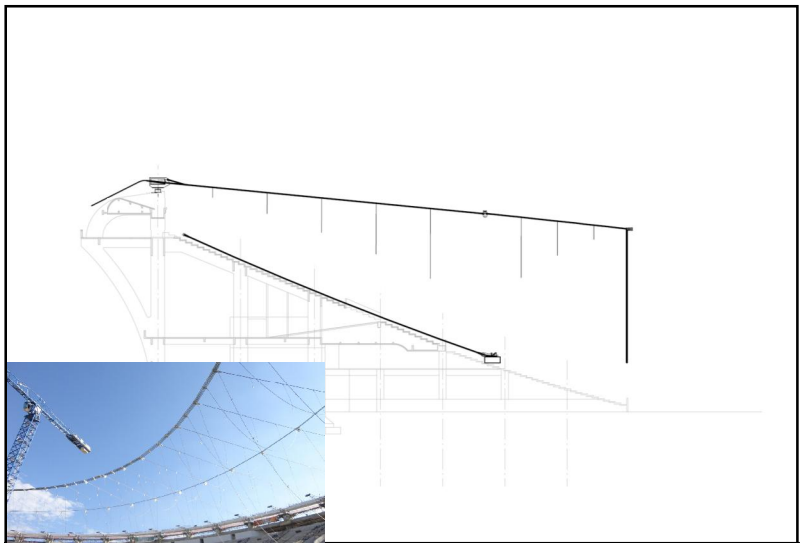

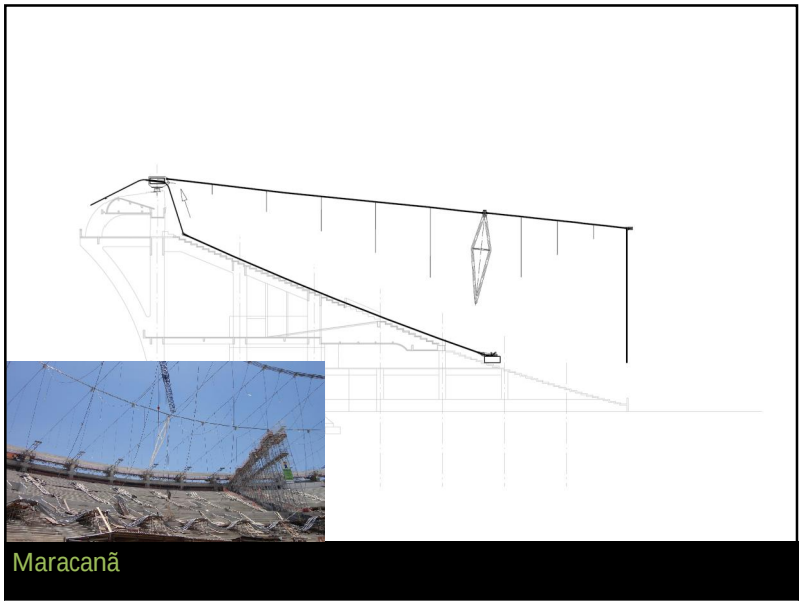
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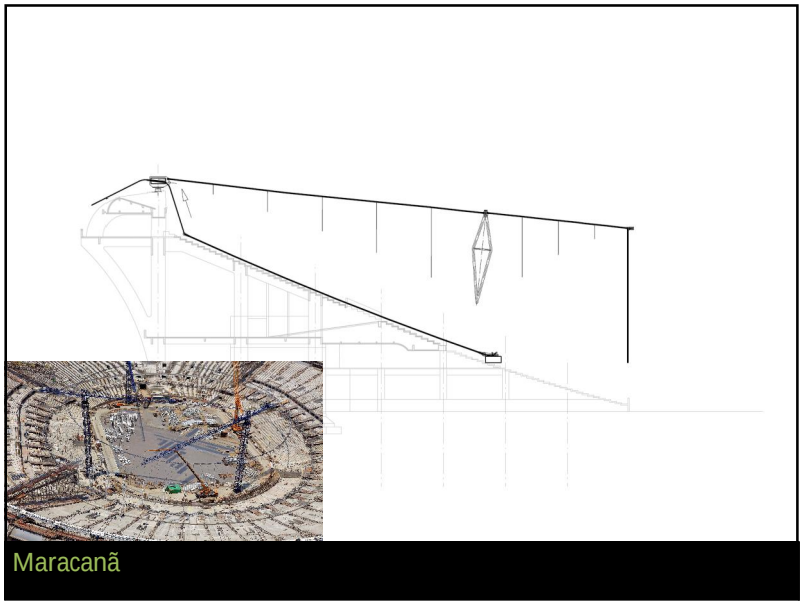
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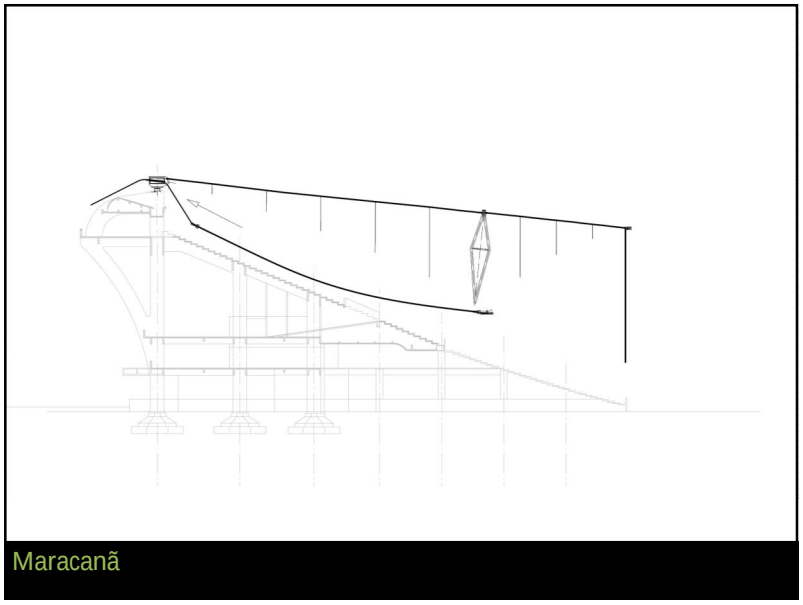
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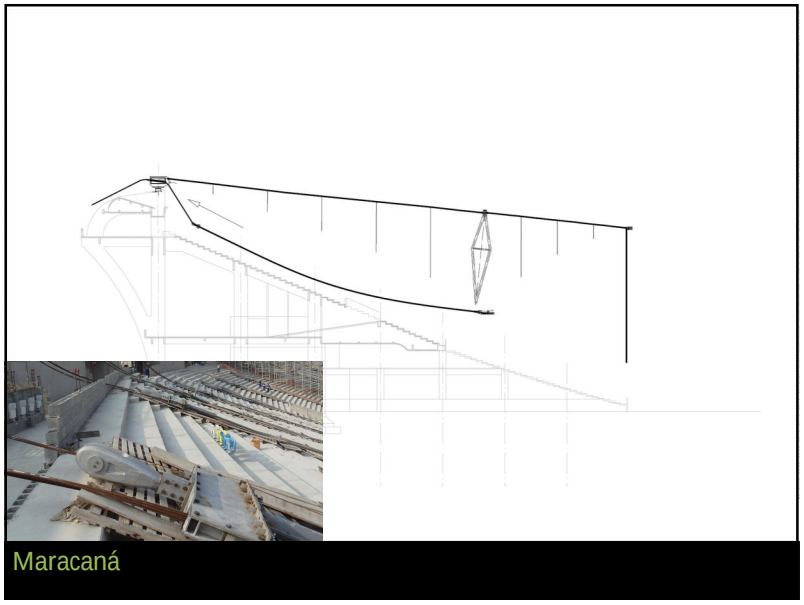
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