FORM FINDING FOR SHELLS

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DEPARTMENT OF MECHANICS, MATERIALS
AND STRUCTURES
BME BUDAPEST

OVERVIEW

WHAT IS A SHELL?

- Structural introduction
- Advantages and disadvantages

BRIEF HISTORY OF SHELLS

FORM FINDING OF SHELLS

- Methods of past and present
- Physical testing/experiments
- Heinz Isler
- Frei Otto

CONTEMOPORARY INSPIRATIONAL RESULTS

CHALLENGES OF FORM FINDING

- Techniques

WHAT IS A SHELL?

BASICS

t/R=
0.3/55 mm
~1/200

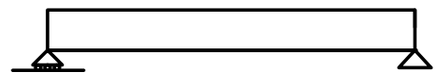
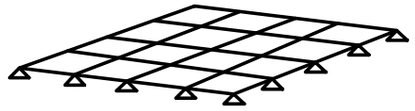
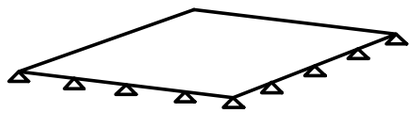
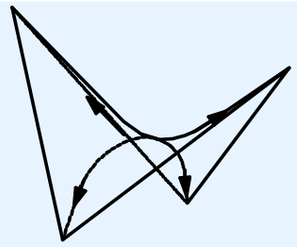
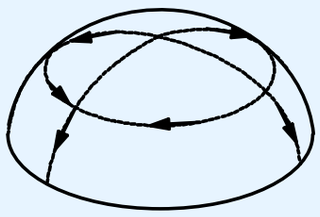
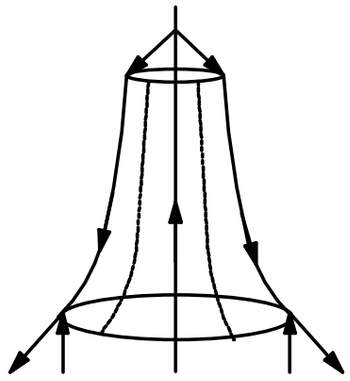
t/R=
3/600 mm
~1/200

t/R=
0.06/90 m
~1/1500!

Bus garage, Kelenföld (I. Menyhárd, J. Padányi Gulyás 1941)

MIEA

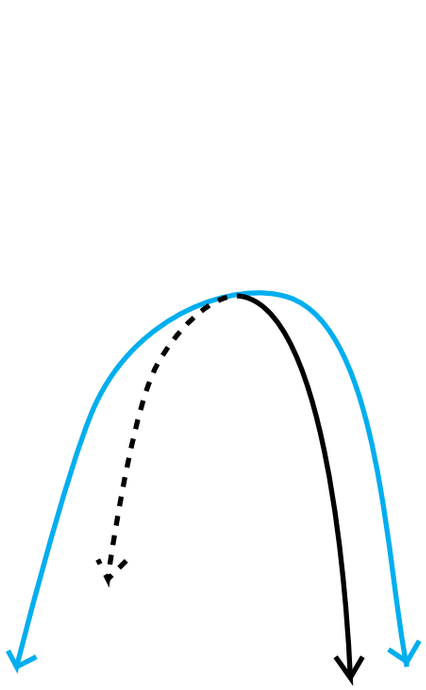
THE PAPER
AND THE BEAM

	BENDING	‘BENDING-FREE’	
		COMPRESSION	TENSION
2D ‘LINE’			
3D ‘SURFACE’	 	 	

TYPE OF SHELLS

CURVATURE

ELLIPTIC



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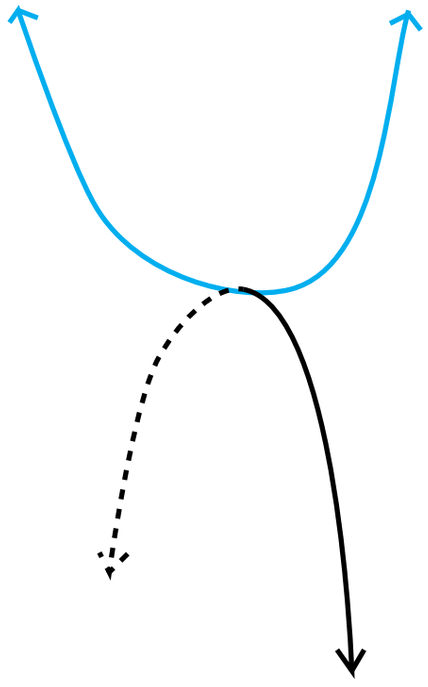
HYPERBOLIC



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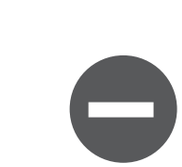
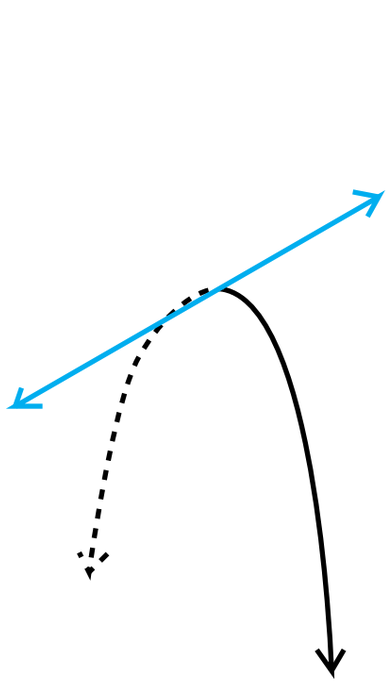


PARABOLIC



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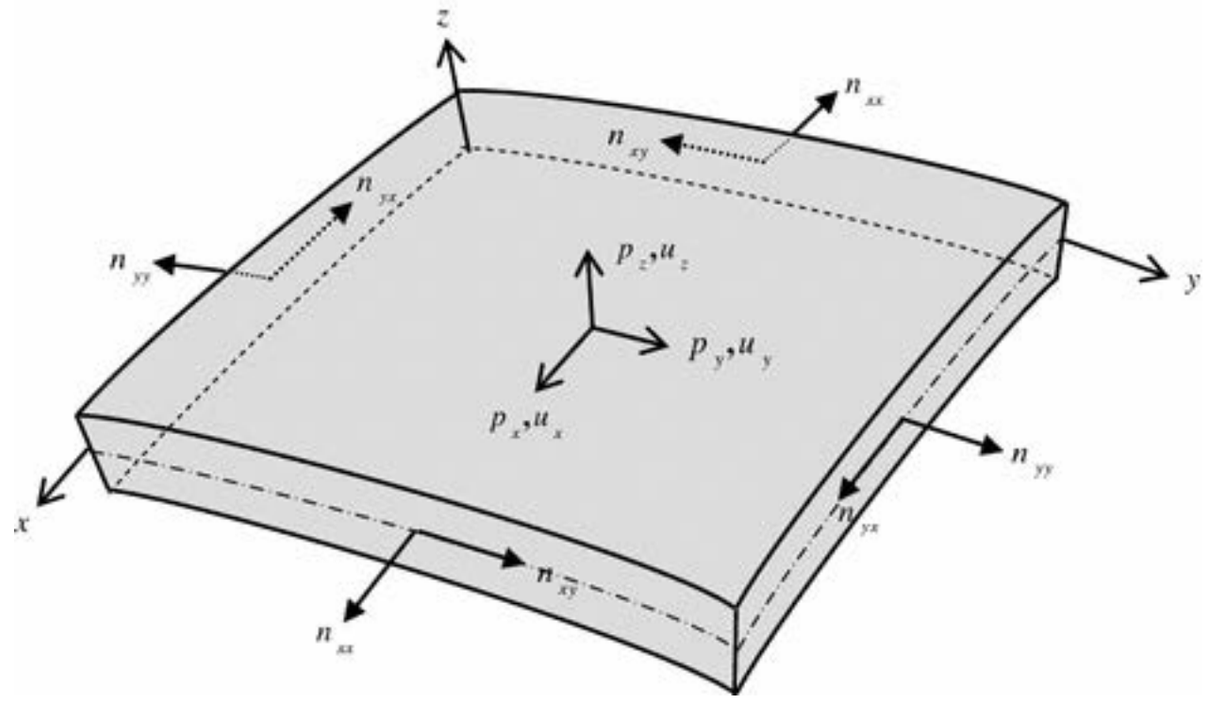
FREE-FORM

VARIES

THEORY
OF SHELLS

FILMS - **MEMBRANE SHELLS** - SHELLS

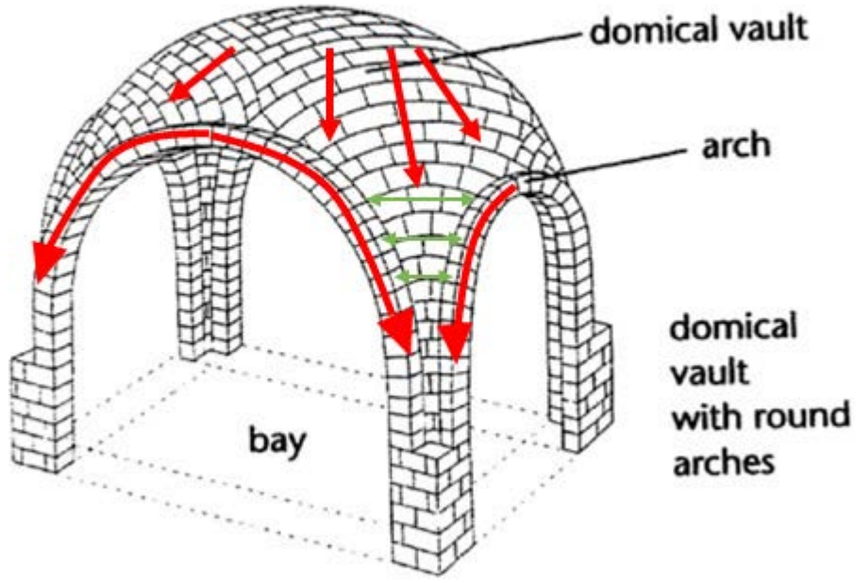


FAILURE OF MEMBARNE SHELLS
BUCKLING - ROLE OF BENDING STIFFNESS
‘HONESTY OF HANGING CLOTH MODELS’

AREAS MOST AFFECTED BY BUCKILNG: EDGES, HOLES

THEORY
OF SHELLS

SUPPORTS



EQUILIBRIUM IS SEARCHED FOR

(LIMITED) RANGE OF SHELL GEOMETRIES + MEMBRANE STRESS STATE=>
SUPPORTING CONDITION

ENGINEERING ANALYSIS

VS

(SUPPORTING) CONDITION + MEMBRANE STRESS STATE =>
SHELL GEOMETRY
FUNICULAR SHELLS,

FORM-FINDING, FREE-FORM SHELLS

HANGING MODELS
OR COMPUTER-AIDED
(EG. TNA, FORCE DENSITY METHOD)

BRIEF HISTORY OF SHELLS

GENERAL TRENDS

KEEP
CALM
AND
LOVE
MATH

Bahnfhof Stuttgart (F. Otto 1997)

ENGINEERING ANALYSIS

mathematical models

FORMFINDING, INTUITION

model building

GERMAN SCHOOL

HUNGARIAN SCHOOL

E. TORROJA

P.L. NERVI

F. CANDELA

SANTIAGO CALATRAVA

CECIL BALMOND

JÜRG CONZETT

ANTONI GAUDI

ROBERT MAILLART

HEINZ ISLER

FREI OTTO

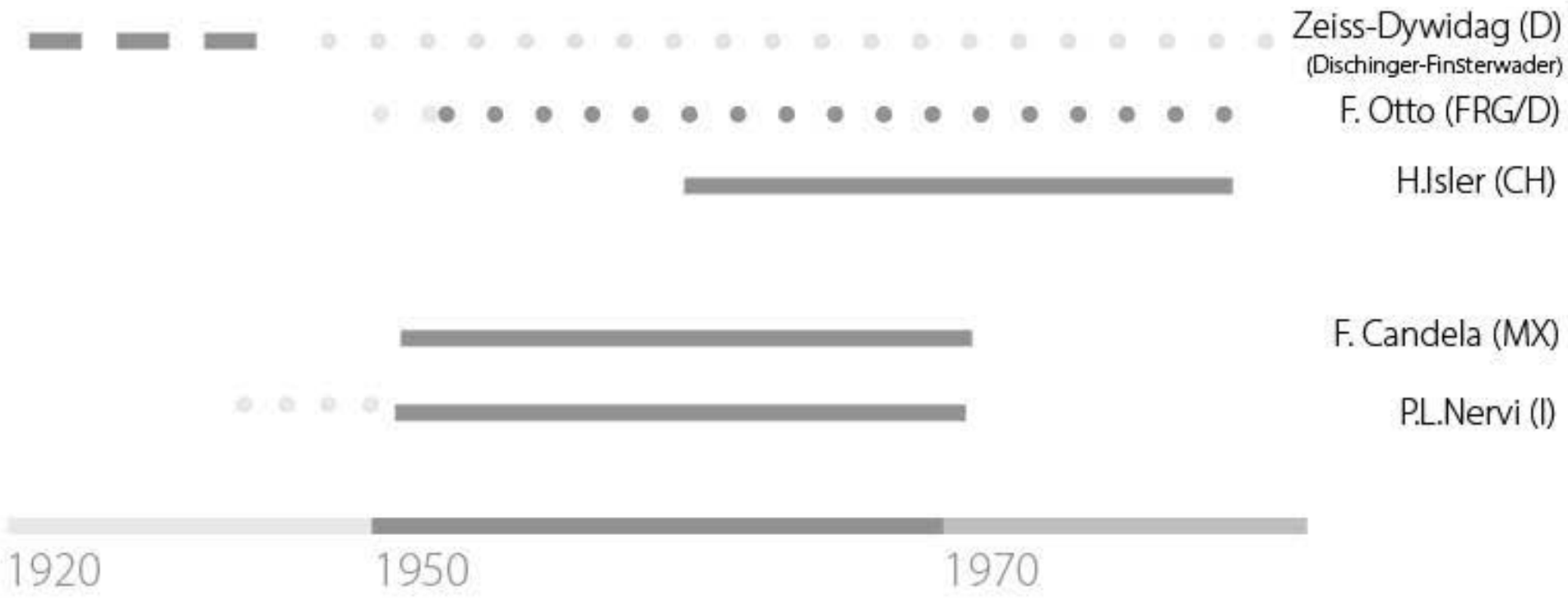
Hangar, Oriveto, Model (P. L. Nervi 1939)

PERIODIZATION
WHY TO BUILD SHELLS?

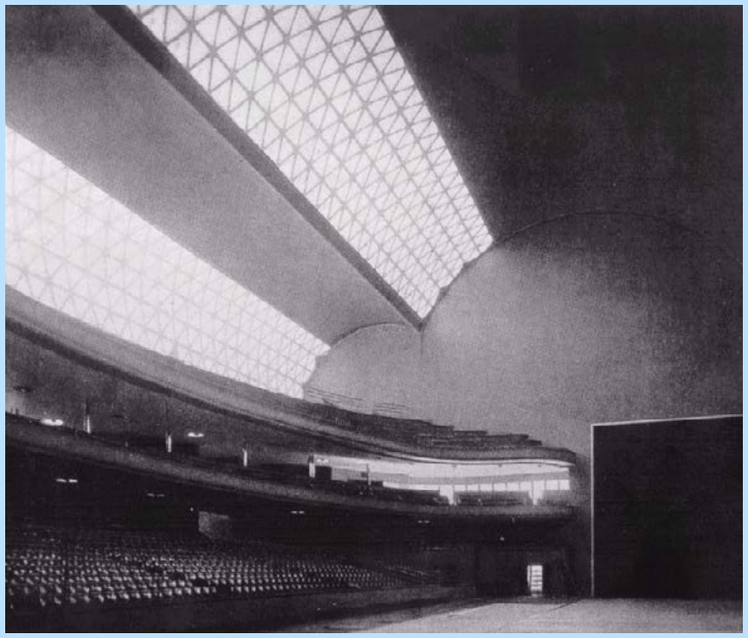
Pantehon, Rome (II. century AC)

PERIODIZATION

WHY TO BUILD SHELLS?

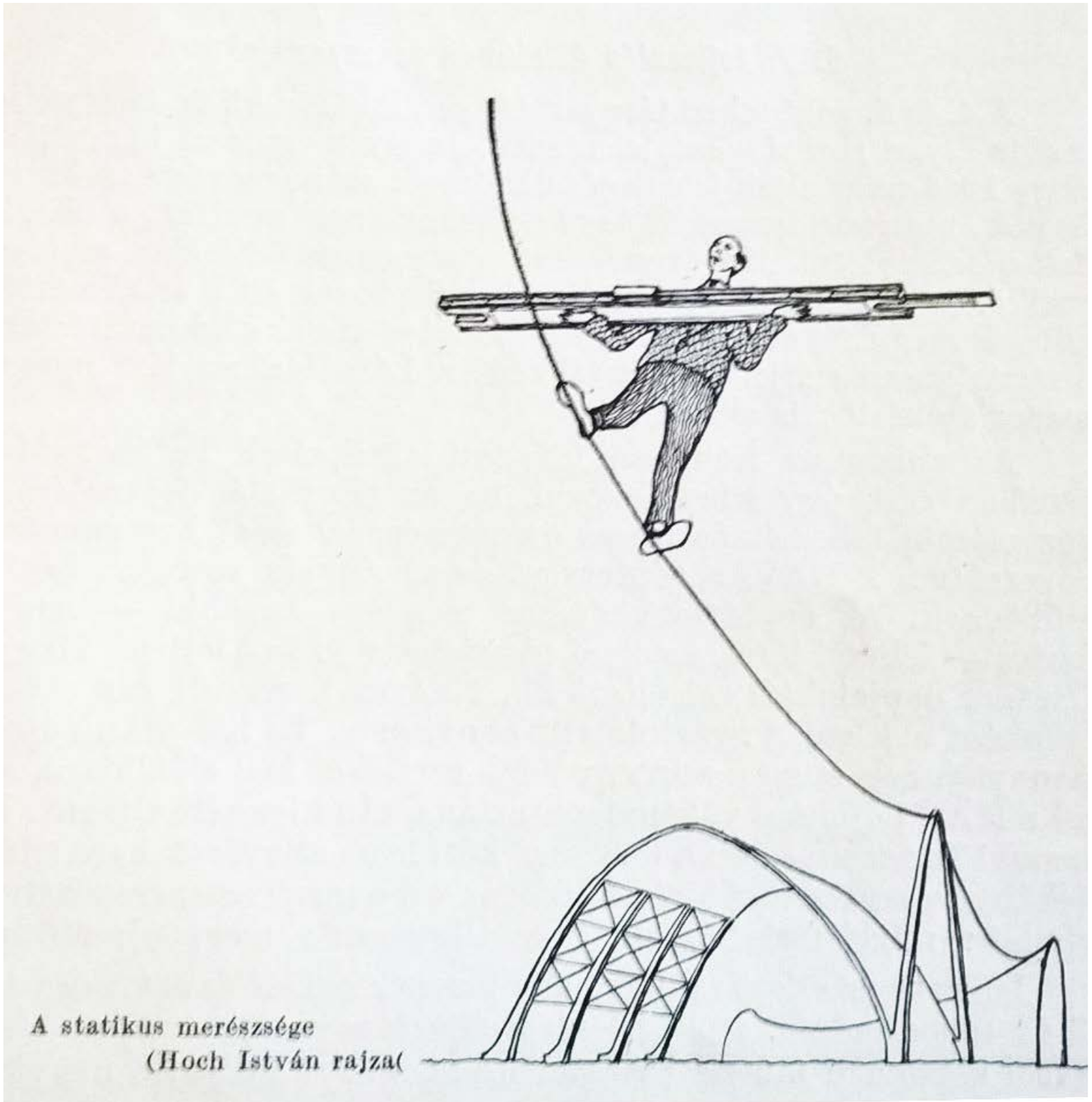


BEGINNING



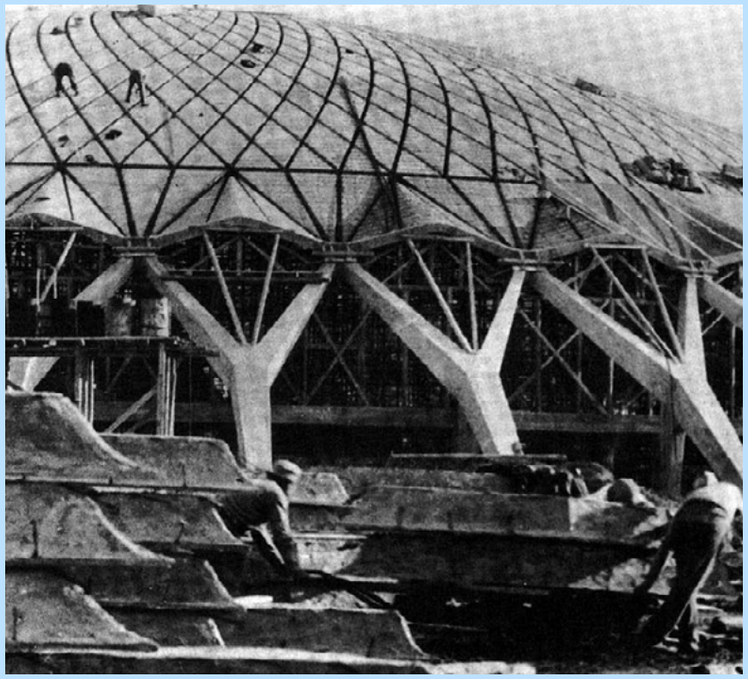
Tallin, Chrsitiani&Nielsen 1917 | Csepel, Dywidag 1930

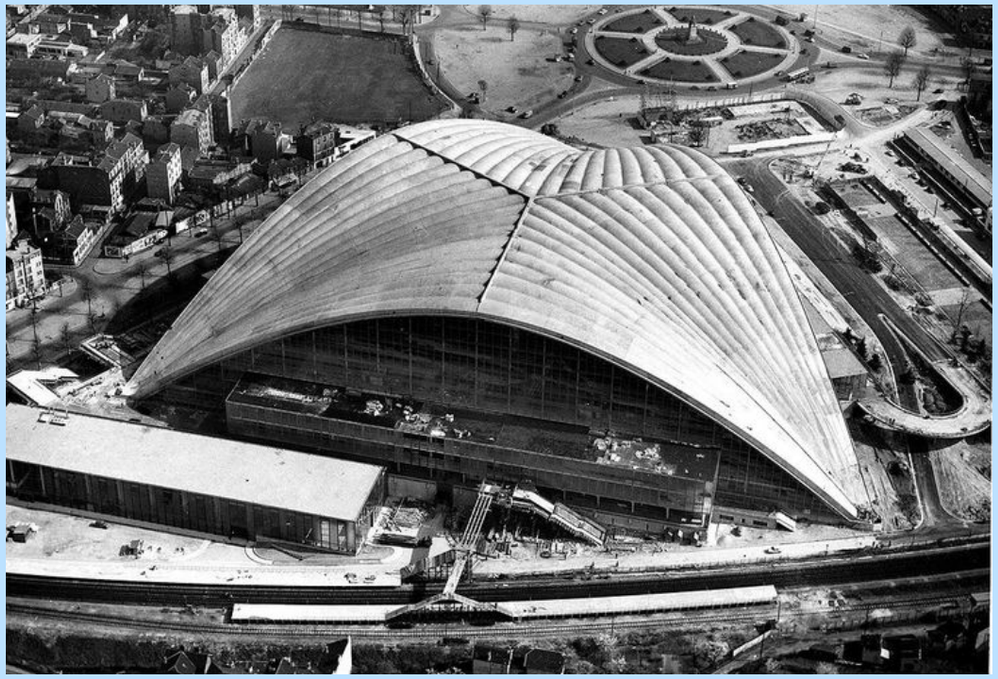
Frontón, Torroja 1935 | Orvieto, Nervi 1939



A statikus merészsége
(Hoch István rajza(

HEYDAY



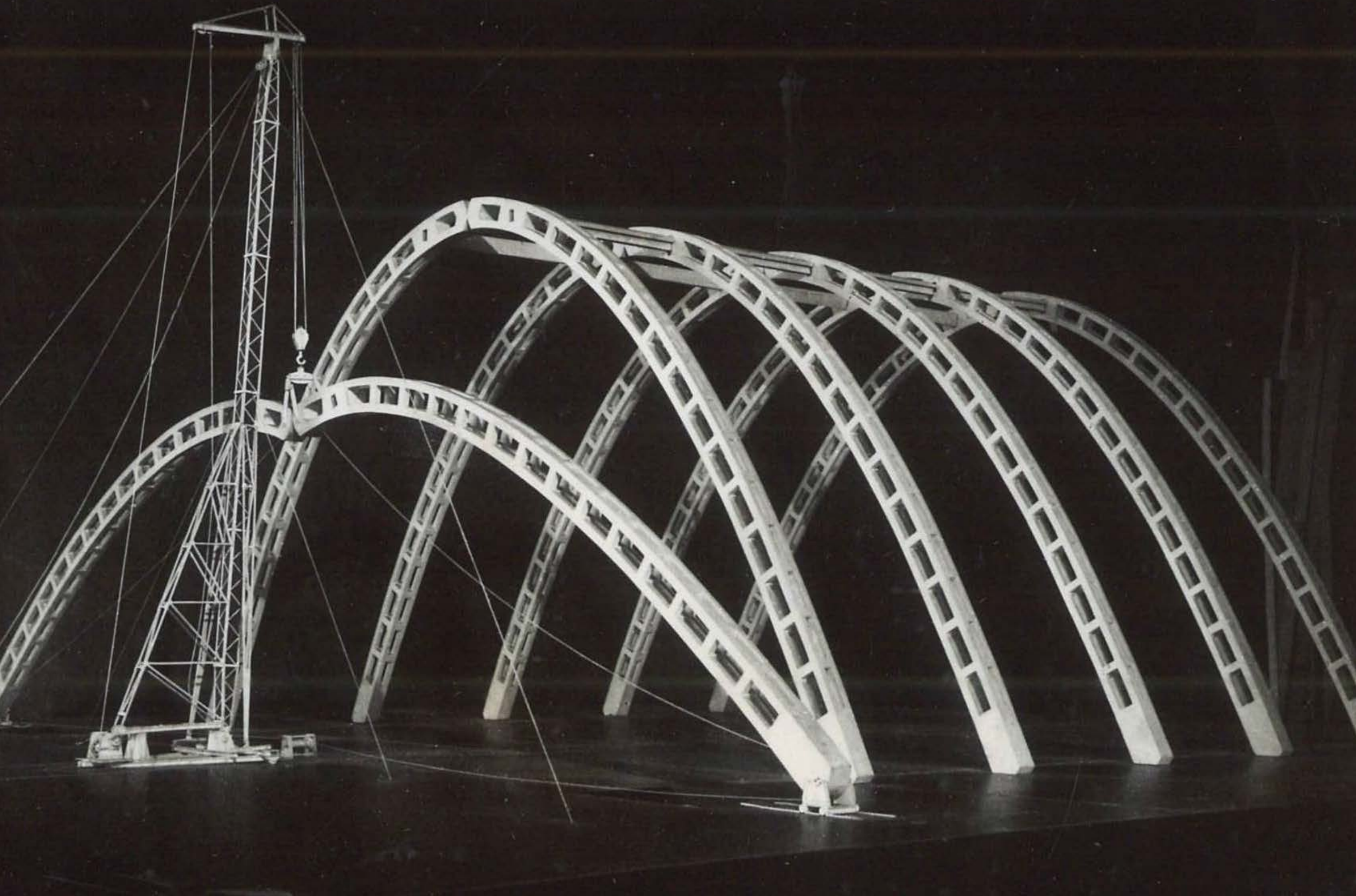


Nervi, Rome 1960

Esquillan,Paris1958

Candela, Mexico 1955

Isler,Lommiswill,1969



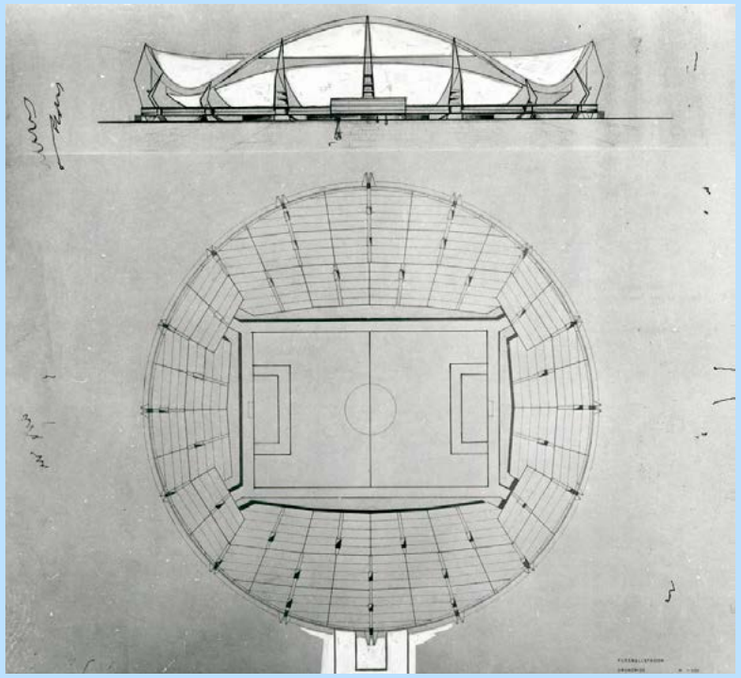
Salt warehouse, Kazincbarcika (M. Gnädig 1952)

MIEA

Salt warehouse, Kazincbarcika (M. Gnädig 1952)

MIEA

LATE PERIOD



Isler, Brügi, 1973

Otto, Mannheim 1972

Nervi, San Francisco, 1971

Polónyi, Müngersdorf

Slettebakken kirke, Bergen (Tore Sveram, Flach-Tonnensen 1971)

St. Hallvard kirke, Oslo (Lund+Slaatto,Borring+Rognerud1966)

FORM FINDING OF SHELLS

FUNICULAR SHELLS

EFFECTIVE FORMS

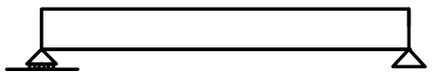
‘BENDING-FREE’

BENDING

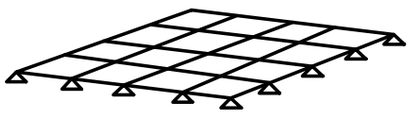
COMPRESSION

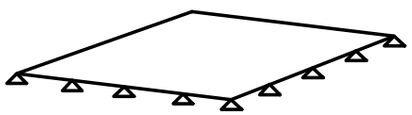
TENSION

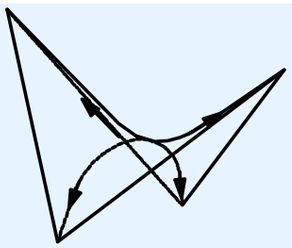
2D ‘LINE’

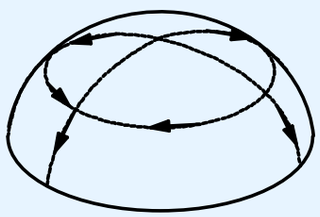


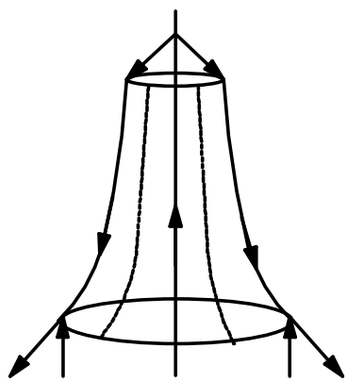
3D ‘SURFACE’





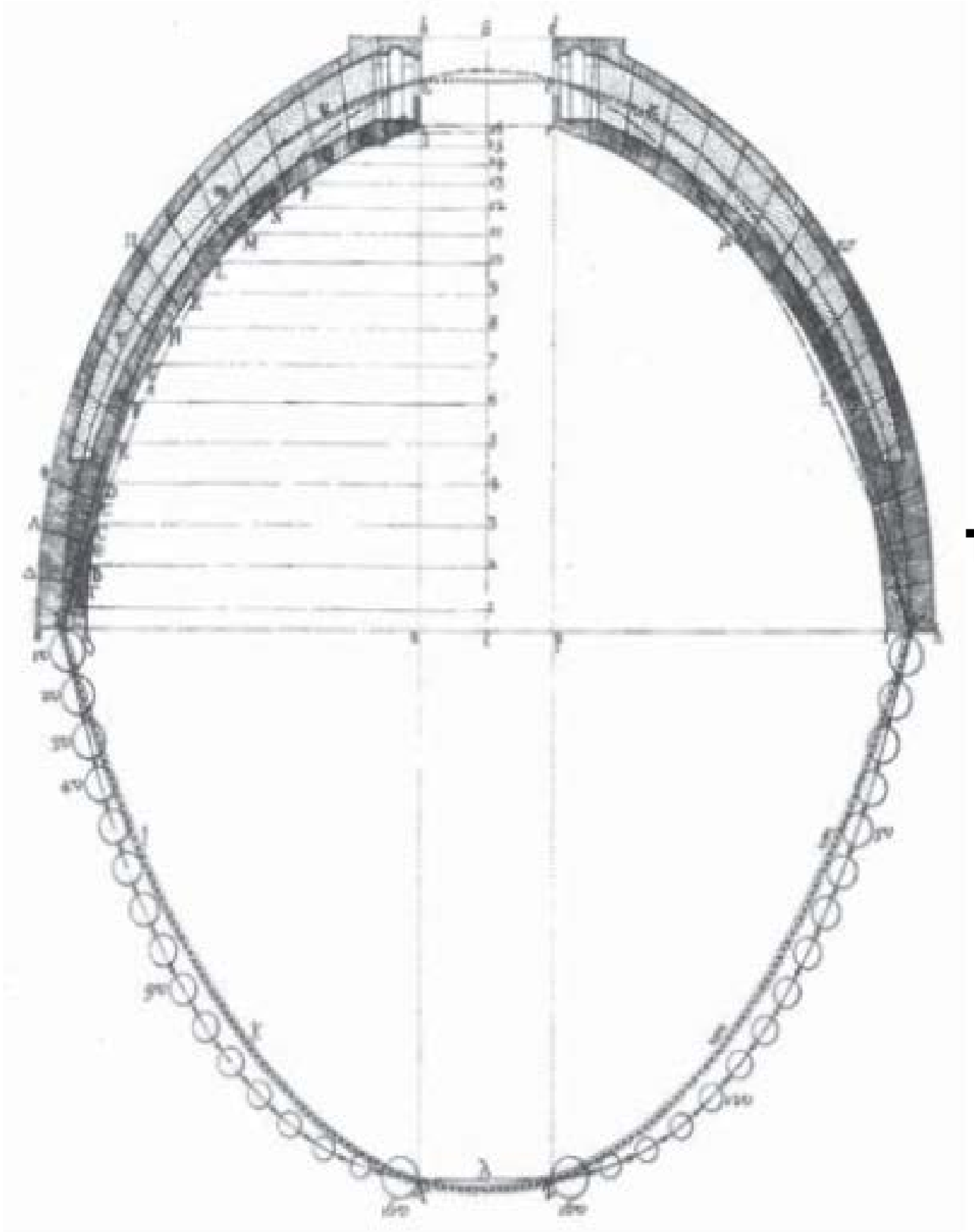




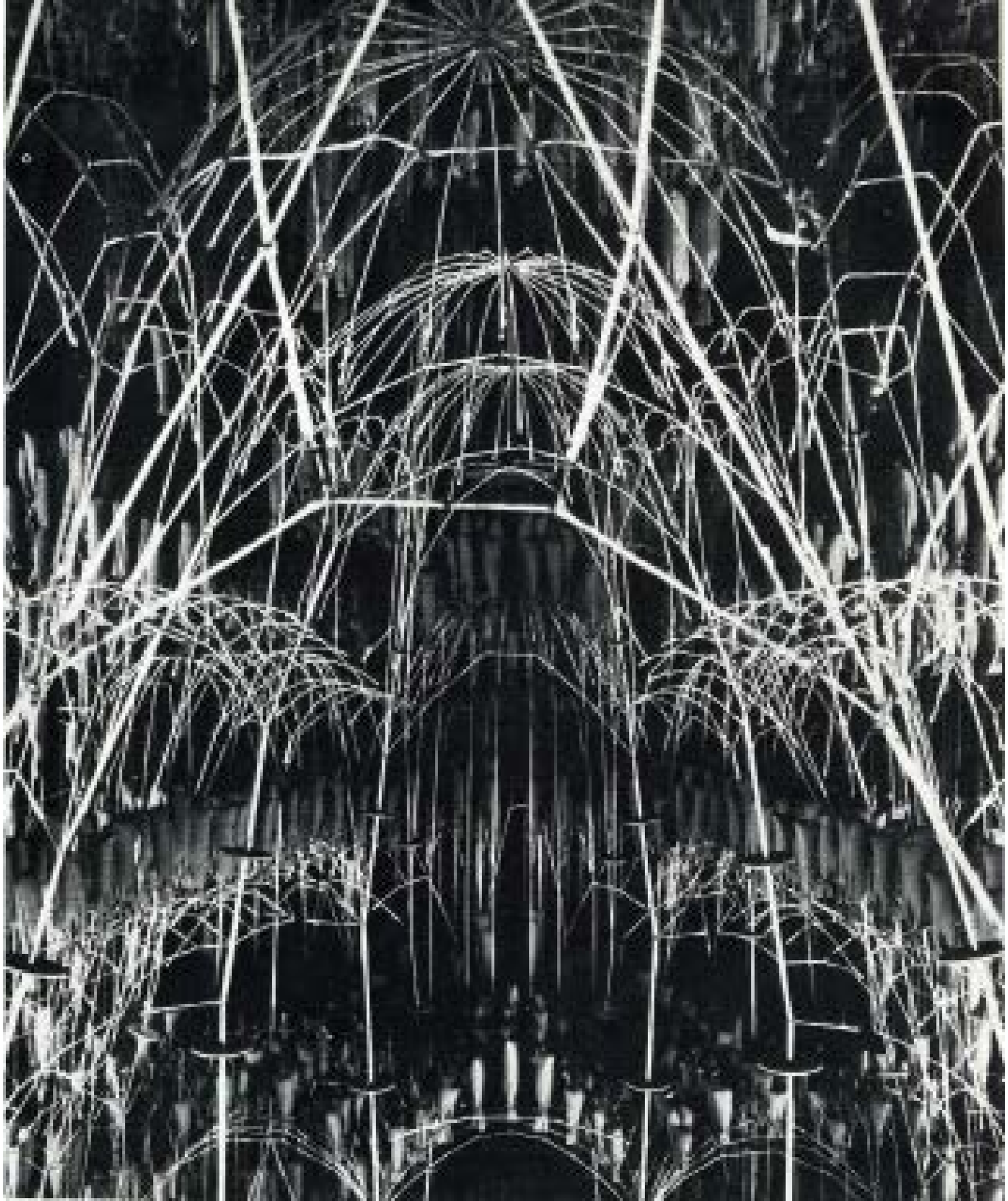



ROBERT HOOKE
1635-1703
Scientist
Architect
Engineer

AS HANGS
SO, BUT
WILL STAND



THE FLEXIBLE LINE
INVERTED
THE RIGID ARCH

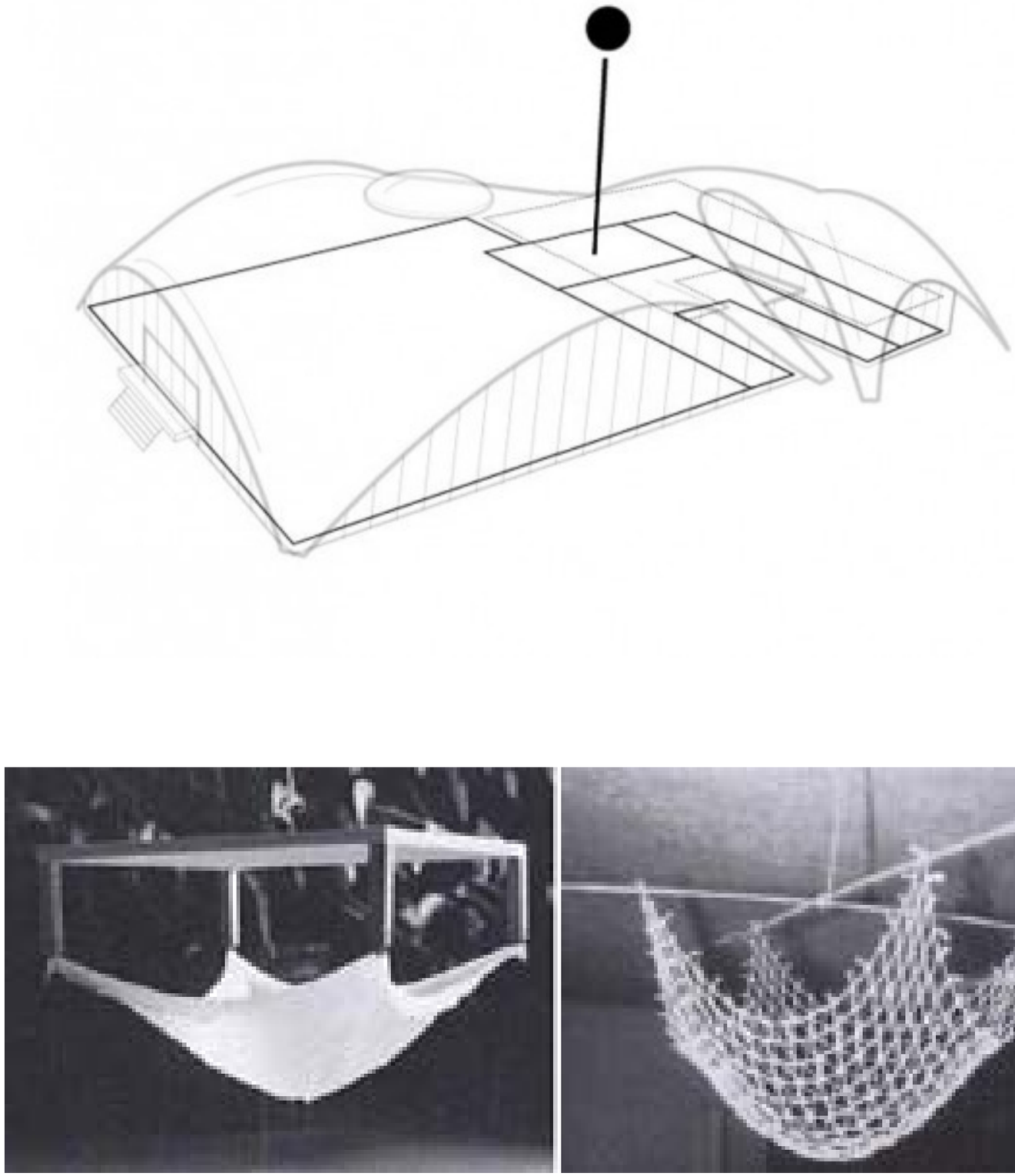


Colonia Güell crypt (Antoni Gaudi) 1898-1915

RESTIRCTIONS
ON FORM

Pavillon Sicli, Geneve (H. Isler, C. Hilberer 1969)

Pavillon Sicli, Geneve (H. Isler, C. Hilberer 1969)



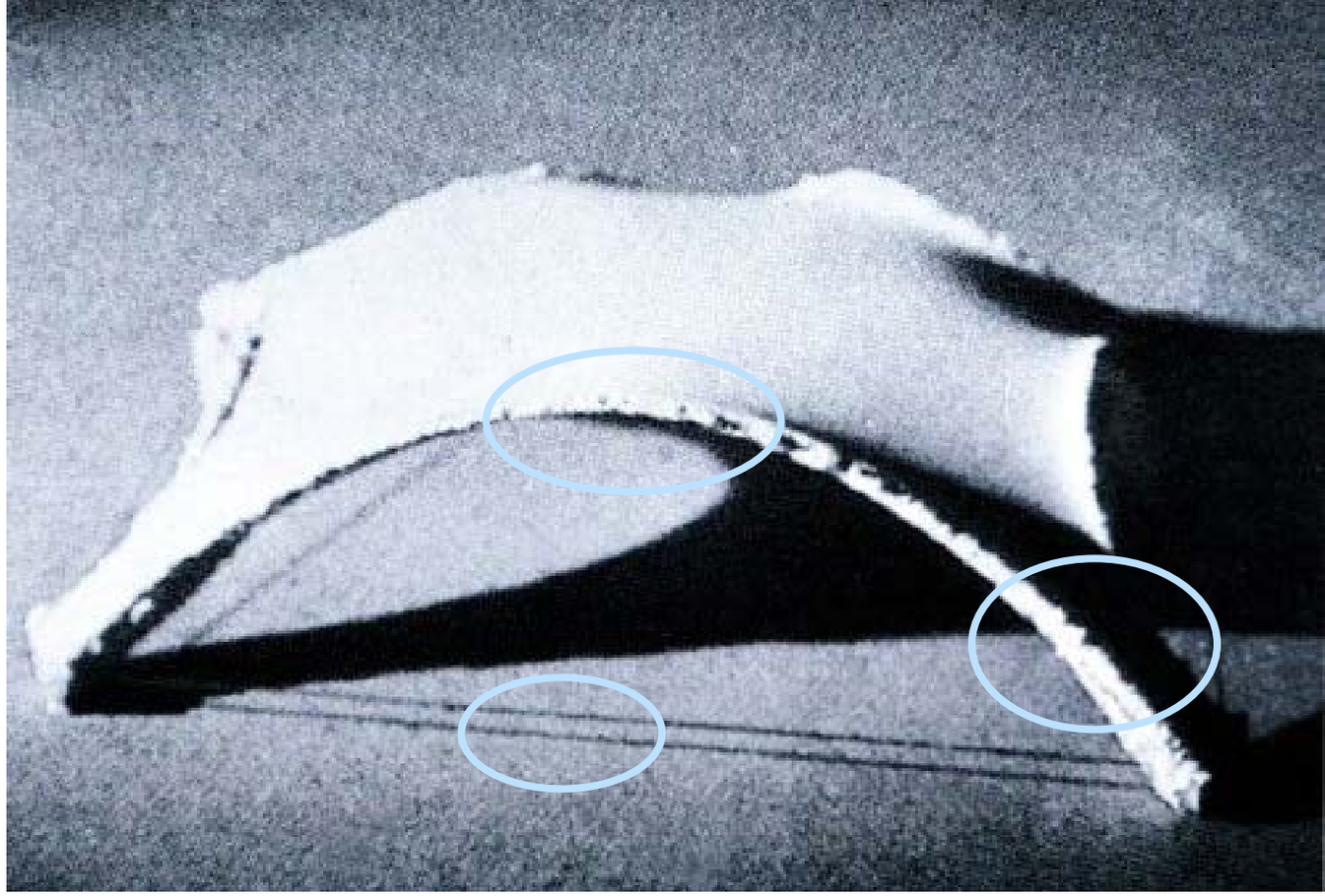
Pavillon Sicli, perspective view+hanging models for form finding

Ice sculptures/hanging cloth models (H. Isler)

Pavillon Sicli, Model (H. Isler, 1958)

Naturtheather Grötzingen (H. Isler, M. Balz 1977)

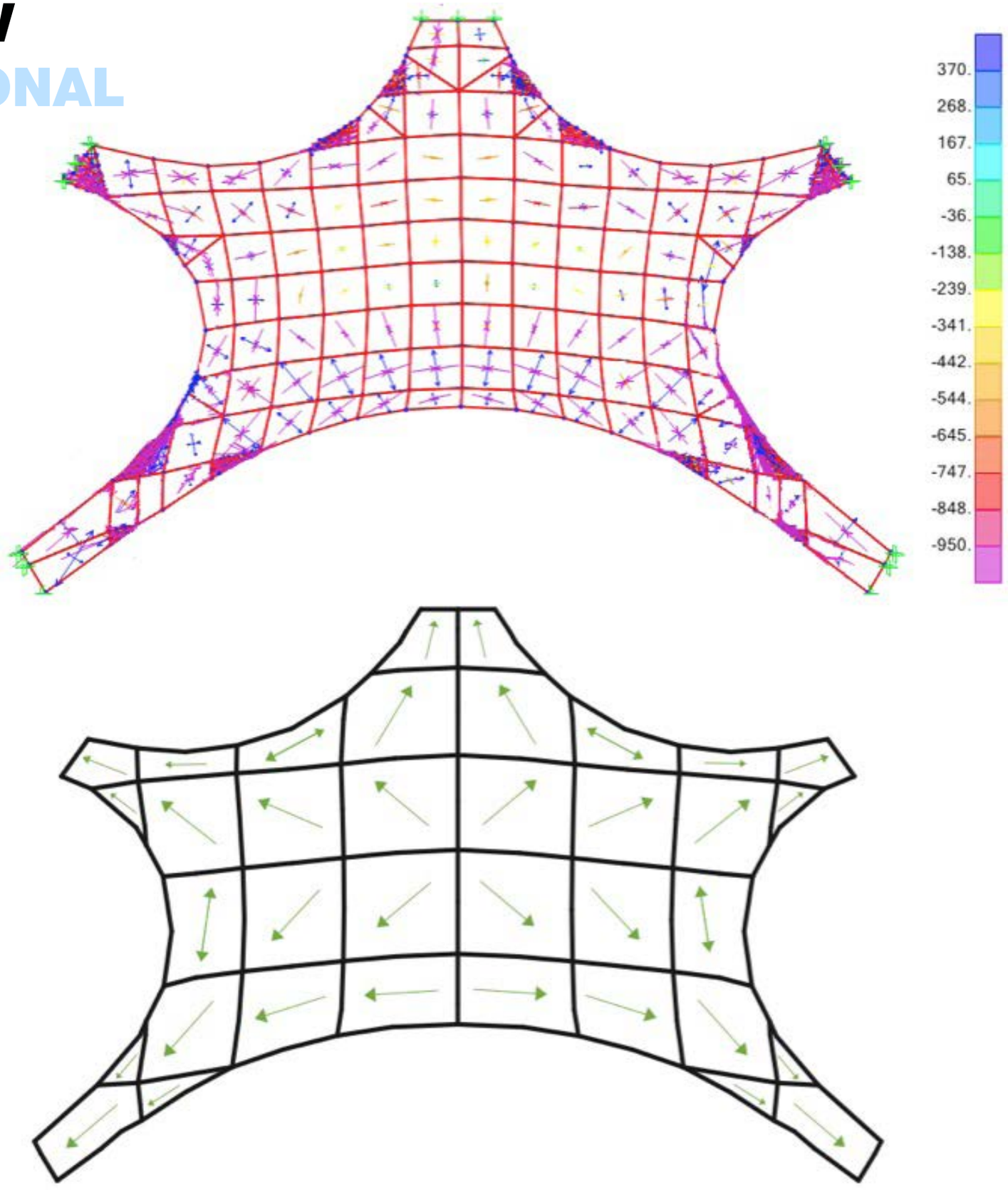
MODELLING
MATERIAL



EDGE - BUCKLING
DOUBLE CURVATURE + STIFFNESS

Naturtheather Grötzingen, formwork edge + Garden centre, Wyss (H. Isler, 1961)

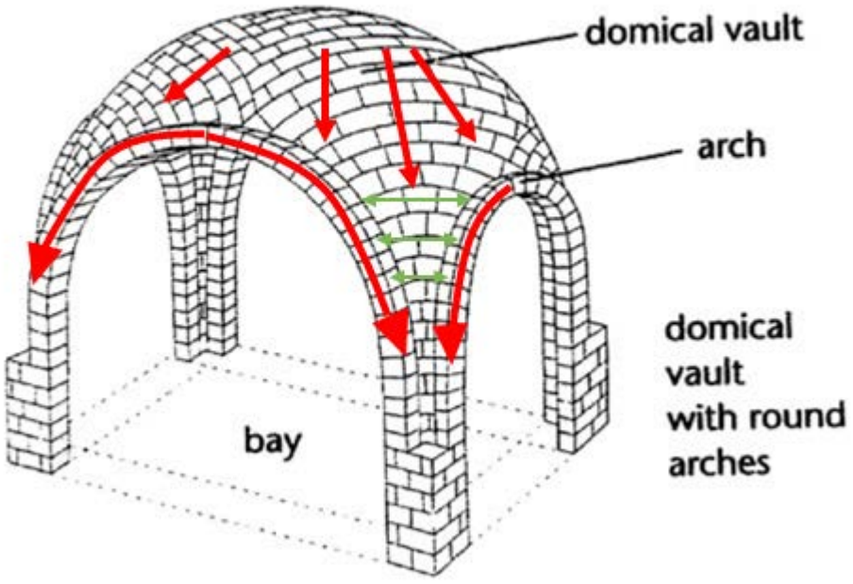
FORCE FLOW
‘TRANSLATIONAL SURFACE’



Naturtheather Grötzingen, force flow diagram

REINFORCEMENT

2-LAYER SYSTEM + SEMI-RIGID EDGE

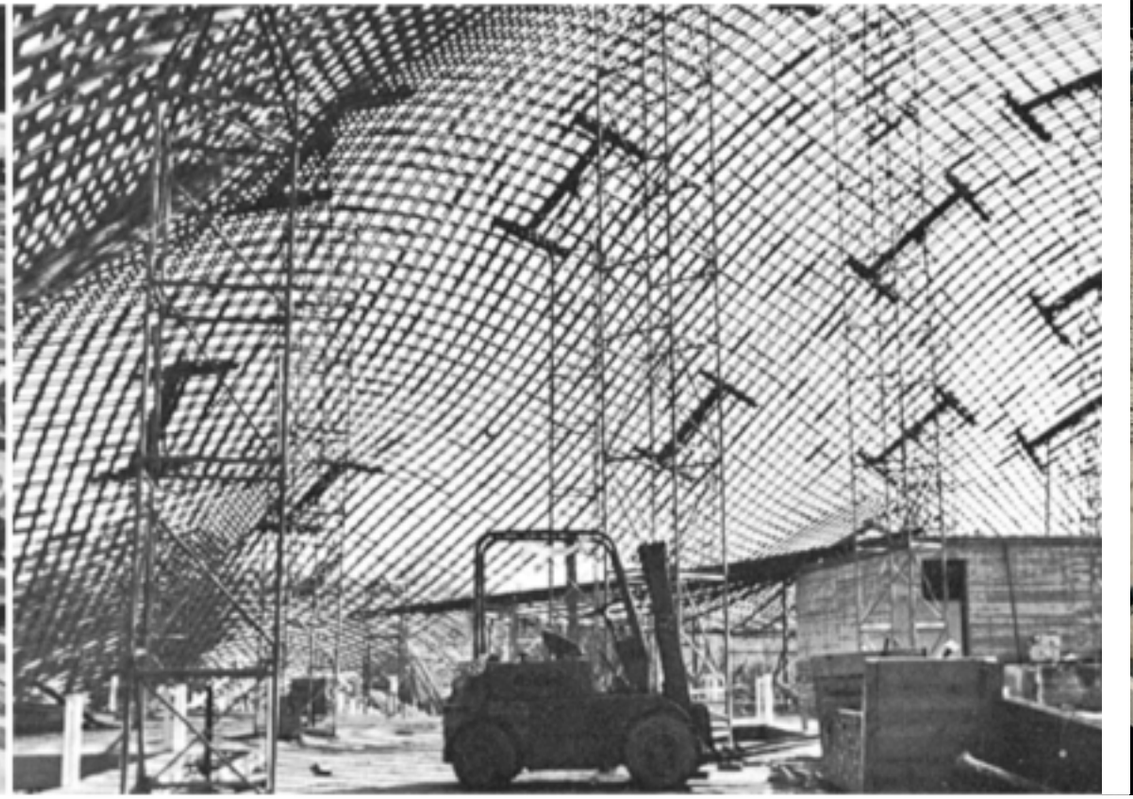


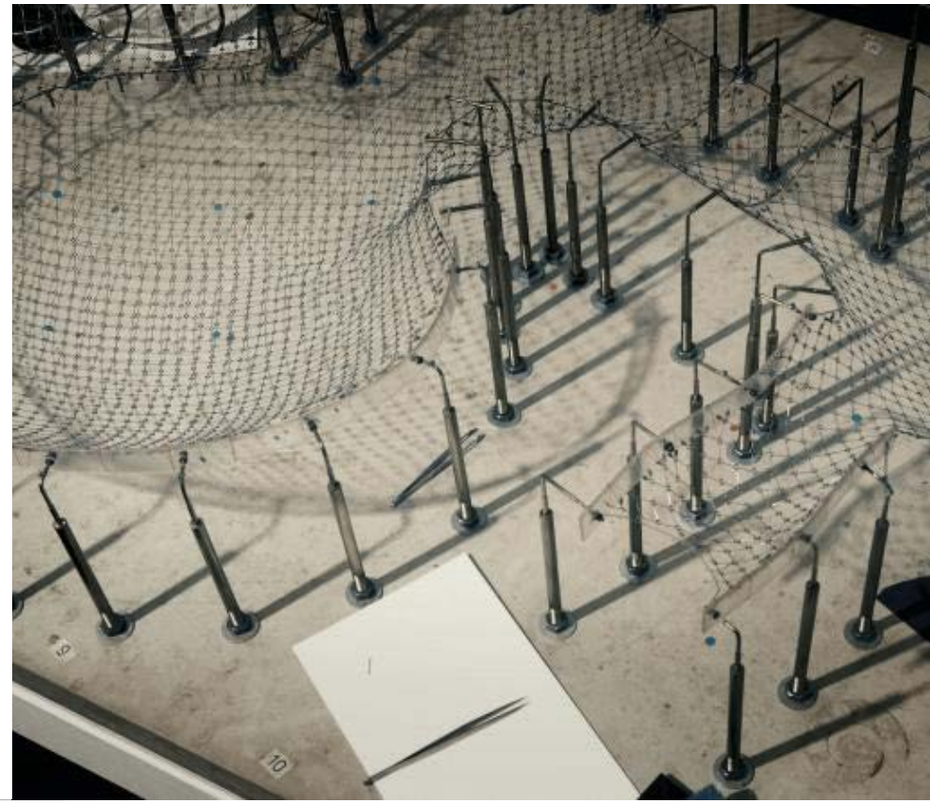
Naturtheather Grötzingen (H. Isler, M. Balz 1977)

Multihalle Mannheim (F. Otto, Mutschler+Langner, 1975)

OPTIMIZATION - POST-PROCESSING

STRESS DISTRIBUTION, CONSTRUCTION TECHNIQUE!!





SHELLS OF TODAY

SOURCES OF INSPIRATION

Droneport, Venice Biennale 2016 (Foster+Partners with BRG and MecoConcept)

Armadillo Vault, Venice Biennale 2016 (BRG)

Gabinete de Arquitectura, Solano Benitez (Golden Lion) Venice Biennale 2016

Japan Pavilion, EXPO 2000, S. Ban, F. Otto+Buro Happold

Japan Pavilion, EXPO 2000, S. Ban, F. Otto+Buro Happold

Rolex Learning Centre, Lausanne (SANAA, SAPS, Bollinger & Grohmann et al. 2010

Rolex Learning Centre, Lausanne (SANAA, SAPS, Bollinger & Grohmann et al. 2000)

Rolex Learning Centre, Lausanne (SANAA, SAPS, Bollinger & Grohmann et al. 2000)

_IMPORT ZURICH

LOGEMENT COOPÉRATIF: NOUVELLES FORMES D'HABITER

Exposition du 22.09.2016 au 14.10.2016
Pavillon Sicli, route des Acacias 45,
1227 Acacias. Genève.

Open air theater, Opole, PL (Florian Jesionowski, 1963)

Summer theater, Szczecin, PL (Flanagan Lawrence, 2018)

Summer theater, Szczecin, PL (Flanagan Lawrence, 2018)

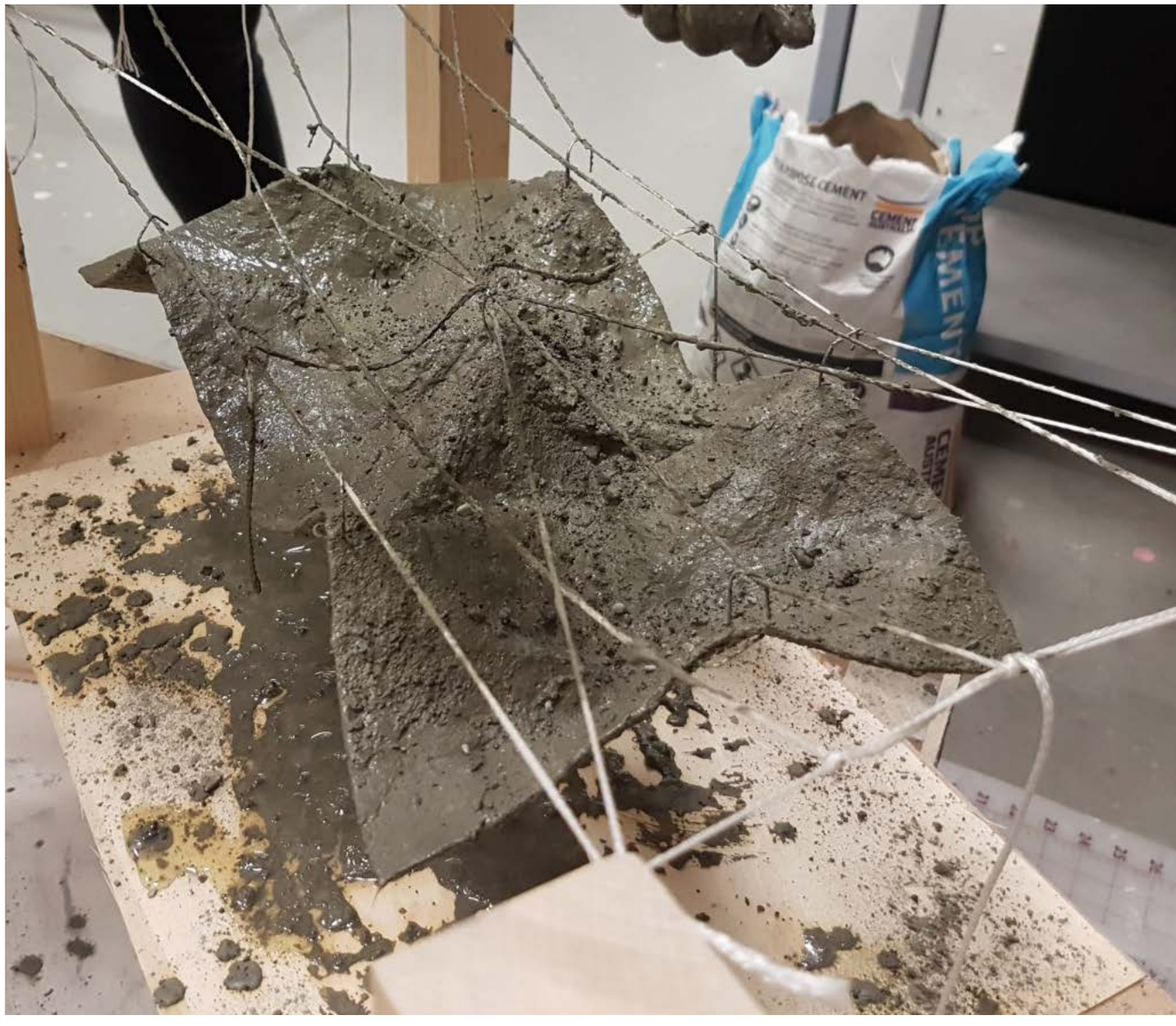
Acoustic Shells, Littlehampton, UK
(Flanagan Lawrence, 2014)

FORM FINDING
IN ACTION

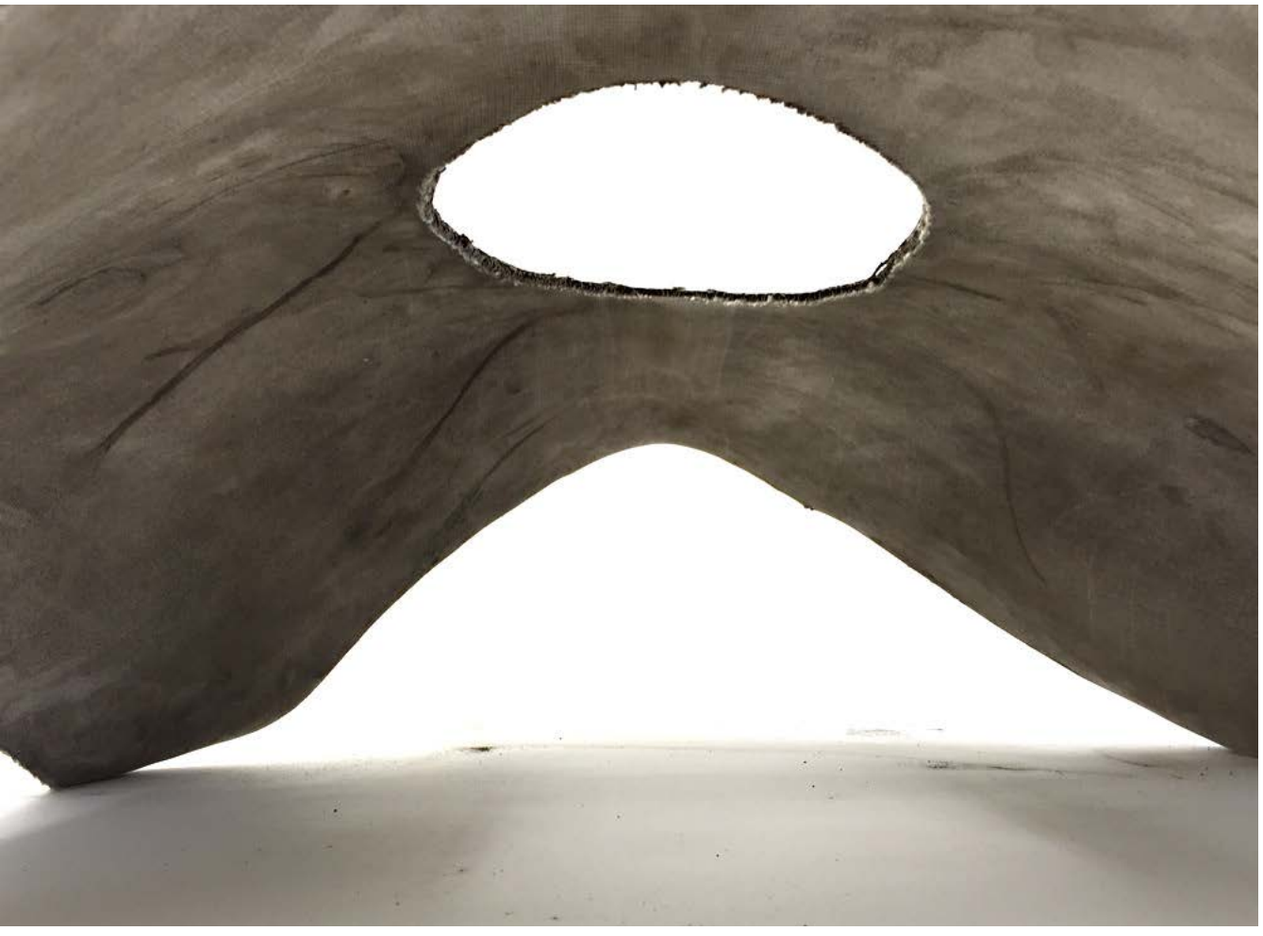
LIMITS

AVAILABLE RESOURCES

SUITABLE EQUIPMENT
MATERIALS, SUPPORTS

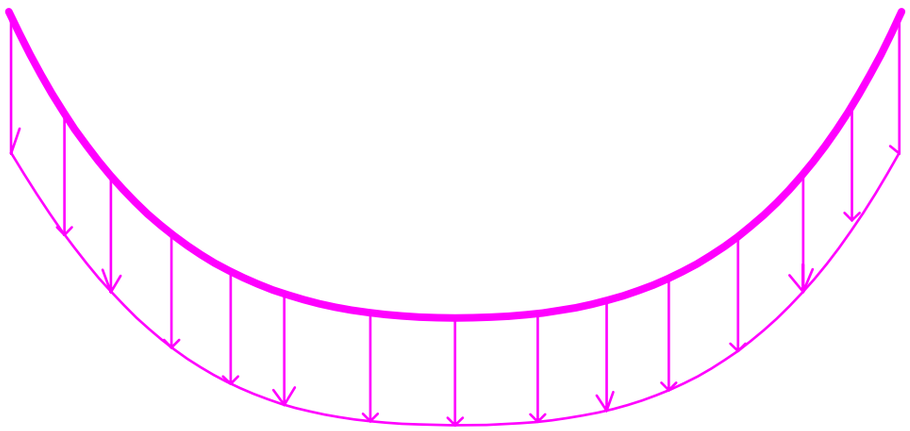


NOTE THE CRITICAL AREAS
BUCKLING!

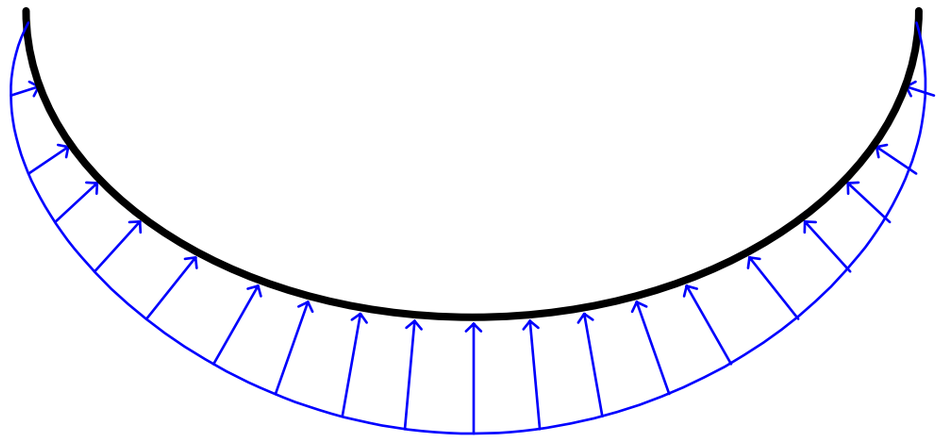


GOOD ENGINEERING SENSE

STATICS - ADAPTIVE GEOMETRY



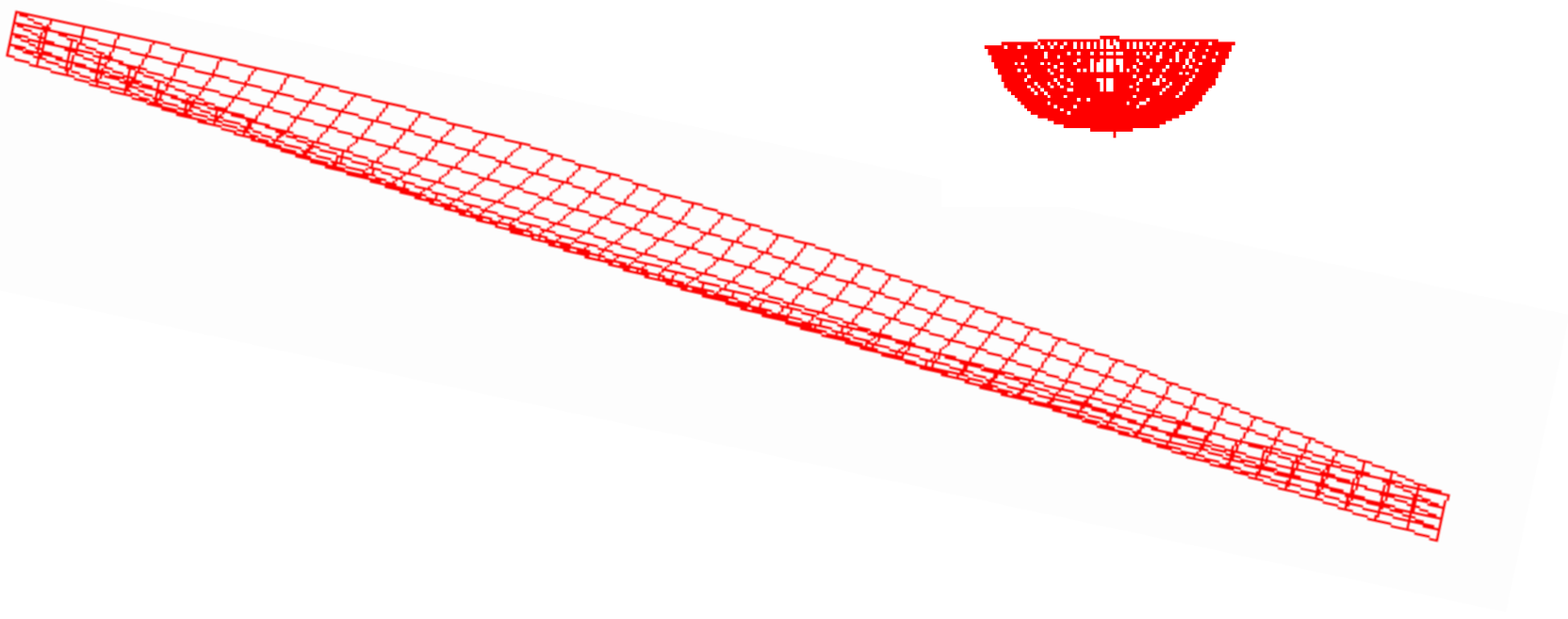
a) dead load - catenary (2D)



b) hidrostatic load (3D)

MEASURING THE MODEL

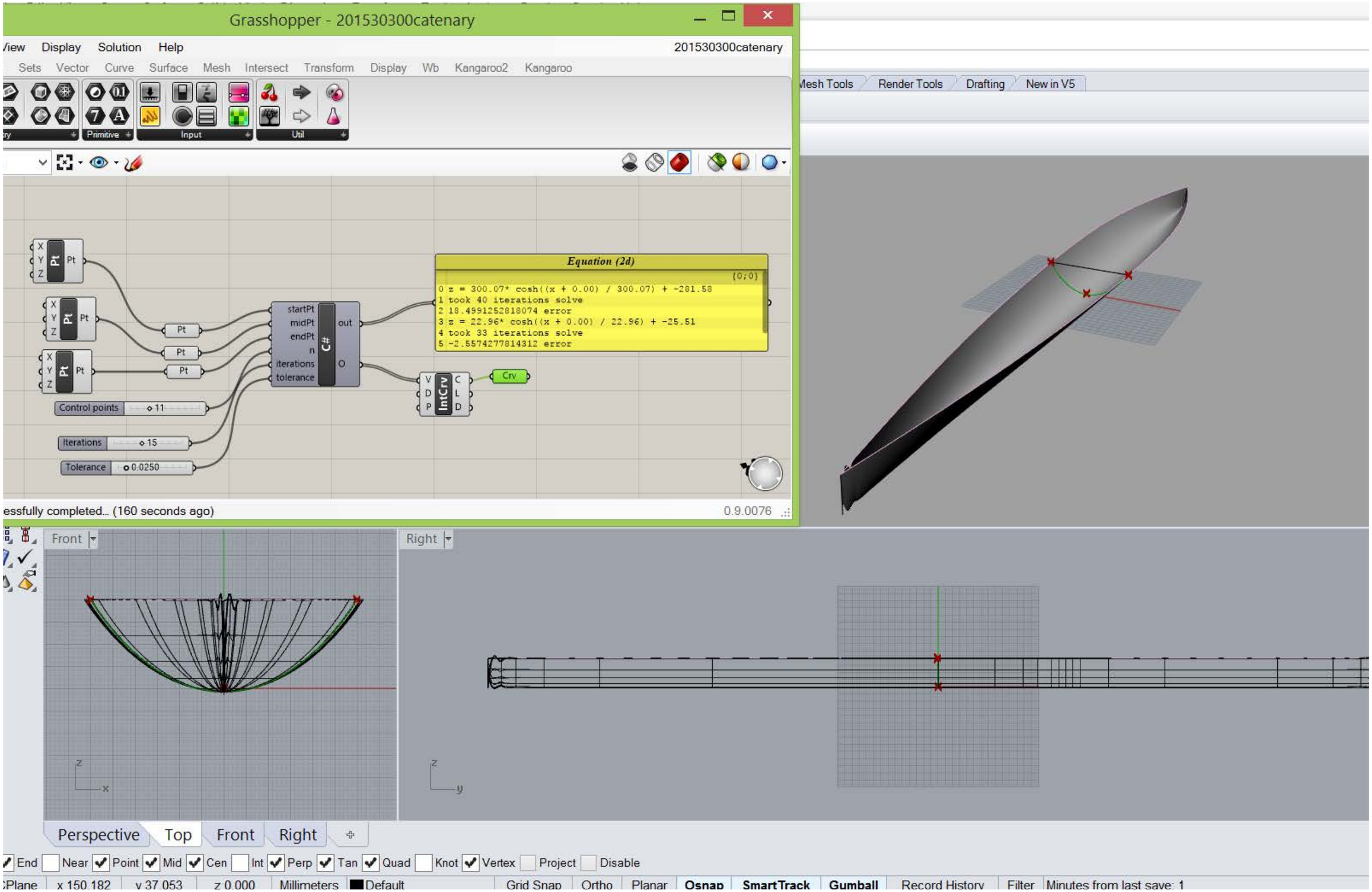
3D SCAN



3D ZEPHYR,
SCANN3D
MEASURE 3D

REFINING YOUR MODEL - OPTIMIZATION, POST-PROCESSING

SMOOTHING, STRESS-DITRIBUTION EVALUATION



Interestingly a structure that defines a new trend is always based on an idea of a more efficient solution. Any trend has followers.

There are two types: one is about to solely imitate the form, which was originally an adequate answer to a specific problem. The result is a structure, that formally closely resembles the original – not completely, since there was a natural desire in the designer to be original - but lacks its meaning, hence it becomes superfluous and even formally incomplete. The other designer understands and re-evaluates the original setting and implements it according to the given circumstances. The thus created structures are not only efficient, but without any further effort they take on a new and aesthetical form.

The first type of followers end up imitating by trying to avoid it, while the others take pleasure in following a good lead, and by doing so, end up creating something unique.

(József Pelikán, MÉI 1964)

THANK YOU FOR YOUR ATTENTION!

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Department of
Mechanics, Materials and Structures