Experimental structures

What is structurally non conventional?

Marine Bagnéris



1 Introduction

2 Why ?

3 How ?

4 On a material viewpoint

Examples of non conventional approaches

5 Conclusion



- ▶ function
 - large span without intermediate supports, foldability, temporary structures, transparency, extreme atmosphere...

▶ economy

- iconic building, lightweight structures, standardisation...
- ▶ philosophy
 - "Less is more", more is more, eco-compatibility, sustainability, self sufficient, life cycle...

Many paradoxes

Challenge

• Acting on one or more design parameters

——• Force

----- Form

----- Structure

----- Material

-----•Technology

• Acting on one or more design parameters



► Time

----- Exploring the past

 Good knowledge of the current mechanical models, buildings practices and available technologies

"I believe that tradition neither be preserved nor converted into a creative impulse. Creative work is expressed in our times in a union of technology and humanity. The role of tradition is that of a catalyst, which furthers a chemical reaction but is no longer detectable in the end result. Tradition can, to be sure, participate in a piece of creation, but it can no longer be creative itself."

Kenzo Tange

- Brunelleschi Dome of Santa Maria del Fiore
 - ----- 42m diameter, 40m hight
 - Octagonal basis 55m high

Large span No scaffoldings



Santa Maria del Fiore – Cathedral of Florence (1295-1472)

Brunelleschi's approach



------ Self-supporting double shell - one ribbed inside and a thin one outside



Pantheon – Roma – 2nd century

- Brunelleschi's approach
 - ----- Brick
 - Self-supporting double shell one ribbed inside and a thin one outside
 - Experimentation on 1/8 scaled models
 - Suspended scaffolding
 - Innovative crane systems to lift material (7t per day)



The dome design by Brunelleschi (1420-1446)

Eladio Dieste

----- Brick

----- Structural curvature

"The resistant virtues of the structure that we make depend on their form; it is through their form that they are stable and not because of an awkward accumulation of materials. There is nothing more noble and elegant from an intellectual viewpoint than this; resistance through form."

Eladio Dieste



Eladio Dieste

----- Brick

----- Structural curvature



- Eladio Dieste
 - ----- Brick
 - ------ Structural curvature
 - ----- Free standing vault





- Eladio Dieste
 - ----- Brick
 - ----- Structural curvature
 - ----- Free standing vault
 - Prestress using tension steel reinforcement





- Eladio Dieste
 - ----- Brick
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Ocean collective

Research and architectural development on brick material

---- Eladio's children





- ----- Fabrico Carola
- ----- Sustainable design





Prestressed stone

- Peter Rice
- Precast elements cut using a digitally controlled machine
- Quickly built
- Stone can lose its imposing and massive appearance when the load conditions are controlled



Pavillon of the Future – Sevilla universal exhibition - 1992

Prestressed stone

- ----- Mamoru Kawagushi
- Composite structural beam steel/stone
 - Prestressed cables inside the stone deck
 - Isostatic bridge very clever structural design



Inachus bridge 1994

Prestressed stone

----- Renzo Piano





Padre Pio Pilgrimage church 1991-2004

- Pier-Luigi Nervi
 - Studied Brunelleschi's work
 - ----- concrete
 - Precast reinforced elements
 - Geometry's studies to build double curved shape



Pier-Luigi Nervi



Small sport stadium – Roma – 1957

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Experimental model for Hangar project 1940 (geodesic lines)

- Pier-Luigi Nervi
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 - ----- Geometry to find structural paths on surface
 - Mechanical paths on surfaces (bending isostatic lines)

1953





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 - ----- concrete
 - Precast reinforced elements
 - ----- Geometry to find structural paths on surface
 - Mechanical paths on surfaces (bending isostatic lines)



1951 - 1953

- Eduardo Torroja
 - ----• concrete
 - Mastering continuous and discontinuous approaches
 - Experimentation on 1/10 scaled models
 - Deflection studies



Fronton de Recoletos - Madrid - 1935

- ▶ Nicolas Esquillan CNIT 1955
 - Inspired by gothic vault ...and Brunelleschi maybe

Concrete

Self-supporting double shell

218m span – 50m high

6.5cm thickness for each shell except on the 3 supports 35cm





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- Cristal Palace 1851 "exhibition of all nations"
 - Iron, glass, laminated timber
 - The bigest, the cheapest
 - 11 months for the complete design process and construction
 - Initiated the move away from traditional construction and methods



- Cristal Palace 1851 "exhibition of all nations"
 - Mass production small element to be easily lifted
 - Stability of the structural frame enabled scaffolding to be avoided
 - Cross-bracing for wind loadings
 - Optimized sections, different material according the flow of forces
 - Clever drainage







Yoshikatsu Tsuboi, Mamoru Kawagushi with KenzoTange

----- Steel cable

- Suspension system inspired by Alliance Arena (1950)
- Semi-rigid suspension system prestressed network of hanging and bracing to provide a bending rigidity
 - Special devices (universal joints, oil dampers for the sound performance)



Peter Rice

- Steel cable Structural Glass
- ----- Transparency
- Large displacements









Bioclimatic greenhouse La Villette 1982-1986

- Peter Rice
 - Embodies both constructive research and invention of the "rotule"
 - Re-interpreting materials and technologies to conceive innovative structures



Bioclimatic greenhouse La Villette 1982-1986

Cable nets

- ----- Frei Otto's work
- -----• Large displacements



2D orientation leads to cable nets and membranes

- Cable nets
 - ----- Frei Otto's work
 - Large displacements
 - ----- See 1st class





3D orientation leads to cable nets and membrane

- Membrane structure
 - ----- Frei Otto's work etc
 - -----• Large displacements
 - ----- See 1st class



Marsyas – Anish Kapoor – UK – 2002

- Membrane structure innovation
 - Tensotherm by BirdAir (composite membrane with nanogel)
 - ----- Insulation
 - ----- Acoustic
 - -----• Lightweight





- Inflated Membrane innovation
 - ---- Tensairity
 - ----- Air as structural component



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Current research fields on material

----- Ultra high performance material

Ductal concrete reinforced by fibres, no cracking...

----- Self healing material

----- Shape memory alloy

- For most developments in structural engineering, nothing is completely new and without precedent
- Collected experience in various fields of building construction and manufacturing engineering together into a single building
- Approach of re-interpreting materials and technologies to conceive innovative structures and hence create unseen shapes