Roof Vaults and National Styles

Early 20\textsuperscript{th} Century

The German approach: analysis and geometry
The Italian approach: ribs, coffers, and buttresses
The "Spanish" approach: double curvature and thinness
Concrete shells and stiffness
Economy of labor vs. efficiency of materials
Complexity of analysis vs. complexity of form
German Tradition

Firm of Dycherhoff and Widmann
F. Dischinger (1887-1953)
U. Finsterwalder (1897-1988)
A. Tedesko (1903-1994)
## Longest Spanning Domes in the World

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<thead>
<tr>
<th>Date</th>
<th>Place</th>
<th>Span (m)</th>
<th>Rise (m)</th>
<th>Weight (metric ton)</th>
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\[ R_y \left( \frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2} \right)^2 w + \frac{12}{h^2} \frac{\partial^4 w}{\partial x^4} = f(p_x, p_y, p_z) \]

\[
\frac{du}{dy} = -a_y \frac{\pi}{L} v + a_y \frac{2}{Eh} N_{xy}
\]

\[
\frac{dv}{dy} = a_y \frac{W}{R_y} + a_y \frac{N_y}{Eh}
\]

\[
\frac{dw}{dy} = a_y \theta
\]

\[
\frac{d\theta}{dy} = -a_y \frac{12}{Eh^3} M_y
\]

\[
\frac{dM_y}{dy} = -a_y \frac{\pi^2}{L^2} \frac{Eh^3}{6} \theta + a_y S_y
\]

\[
\frac{dN_y}{dy} = a_y \frac{\pi}{L} N_{xy} + a_y p_y
\]

\[
\frac{dN_{xy}}{dy} = a_y \frac{\pi^2}{L^2} Eh u + a_y p_x
\]

\[
\frac{dS_y}{dy} = -a_y \frac{N_y}{R_y} + a_y p_z
\]
Ribbed barrels by Anton Tedesko

1941

1948
Describe the method used by the German school for finding forms for roof structures.

Why would such an approach be justified for structural engineering?

Why might it be limiting for structural art?
Italian Tradition

P.L. Nervi (1891-1979)
1D ribs = Stiffness
2D ribs = Stiffness

1D rib = Strength
“[structures] can only be solved correctly through a superior and purely intuitive re-elaboration of the mathematical results” – 
“[my early experiences] had formed in me a habit of searching for solutions that were intrinsically constructionally the most economic, a habit which the many succeeding competition tenders (almost the totality of my projects) have only succeeded in strengthening.” - Nervi
Describe the differences in the ribbing in these two Nervi structures. What are the differences in the way domes and barrels carry loads?
failures in translation
structure, not structural art
Note huge transfer beams at the base.
What makes Nervi’s solution so much more elegant?
What are the scientific reasons, if any, for his aesthetic choices?
Spanish Tradition

*Catalan influence*

A. Gaudi (1852-1926)
E. Torroja (1899-1961)
F. Candela (1910-1997)
E. Dieste (1917-2000)
Church of the Sagrada Familia
Gaudi, 1882 - present
Church of the Colonia Guell
Zarzuella Hippodrome (1935), Eduardo Torroja
Torroja

Nervi
double curvature = stiffness
Algeciras market hall
Locate the double curvature in this shell
Comment on the aesthetics
Xochimilco restaurant

Felix Candela
\[ z = \frac{y^2}{b^2} - \frac{x^2}{a^2} \]
Describe the different approaches Gaudi (left) and Candela (right) took to form-finding? Did material choice have any effect on their choices?
who needs tradition?
Kresge Auditorium (MIT)
ID Number 17362
Description Sydney Opera House
Taken in 2004
Photographer Ian G. Bowie

www.structurae.net
Sails without breaking the bank...
German tradition

Italian tradition

Spanish tradition