Toward Group Optimization for the Practical Design of Building Systems

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Research Objectives

- To apply topology optimization to the field of structural engineering through high-rise building design
- Use a combined approach with both continuum and discrete elements to create practical designs
- Address the importance of achieving a balance between engineering and architecture for efficient, sustainable design

Introduction: Engineering and Architecture

- Historical examples of structures by architects with strong and innovative engineering concepts

Antonio Gaudi[1]

Buckminster Fuller[2]

Felix Candela[3]

[1-3] Multiple websites

  - Gaudi used physical models to calculate sophisticated structures (Sagradia Familia Cathedral, Barcelona, Spain - still under construction)
  - Fuller's philosophical ideas about holistic design, synergetics, and geometry led to innovative structures (Montreal Biosphere, Montreal, Canada, 1967)
  - Candela created thin-shell concrete structures, which are efficient and beautiful (Los manantiales, Xochimilco, Mexico, 1958)
- Goal: overcome dichotomy between architectural aesthetics and engineering efficiency using topology optimization

Basic Topology Optimization Framework

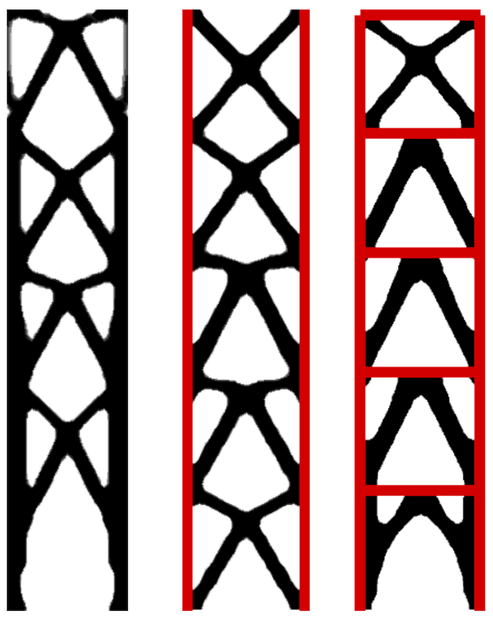
- Minimum compliance criteria

$$\begin{aligned} \min_{\rho,\mathbf{u}} \quad & c(\rho,\mathbf{u}) \\ s.t. \quad & \mathbf{K}(\rho)\mathbf{u} = \mathbf{f} \\ & \int_\Omega \rho \, dV \leq V_s \\ & \rho(\mathbf{x}) \in [0,1] \, \forall \, \mathbf{x} \in \Omega \end{aligned}$$

- Other criteria
  - Deflection (P-Δ)
  - Buckling load
  - Natural frequency

Motivation for Combined Approach

- Incomplete bracing systems form with continuum only models
- Optimal designs give thick "columns" with unrealistic bending stiffness
- Material concentrations along edges are very dense (web-flange behavior)
- Difficult to identify the working points in such designs



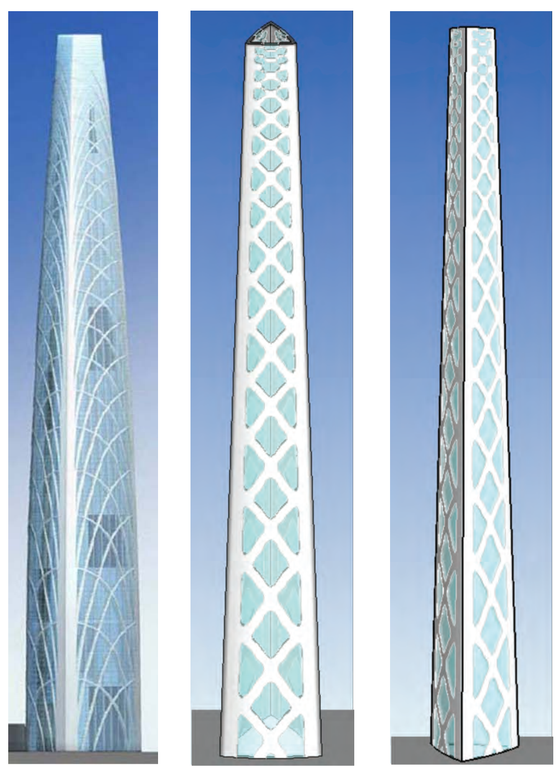
Zendai Competition (China)

Rendering of final design and picture of physical model using topology optimization results (courtesy of SOM)

Optimal Building Systems

SOM Competition Design

Z3 Competition



Conclusions

Topology optimization using a combined approach can be a valuable tool to bridge the gap between engineering and architecture in the design industry. Moreover, resulting designs will be more efficient and sustainable, by optimizing the material consumption.

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References

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