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Altair is focused on the development and broad application of simulation technology to synthesize and optimize designs, processes and decisions for improved business performance. Privately held with more than 2,600 employees, Altair is headquartered in Troy, Michigan, USA and operates more than 45 offices throughout 24 countries. Today, Altair serves more than 5,000 corporate clients across broad industry segments.

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About HyperWorks®

Performance Simulation Technology

HyperWorks is an enterprise simulation solution for rapid design exploration and decision-making. As one of the most comprehensive, open-architecture CAE solutions in the industry, HyperWorks includes best-in-class modeling, analysis, visualization and data management solutions for linear, nonlinear, structural optimization, fluid-structure interaction, and multi-body dynamics applications.

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A Vision of Tomorrow's Architecture: Designing the LAVA Bionic Tower

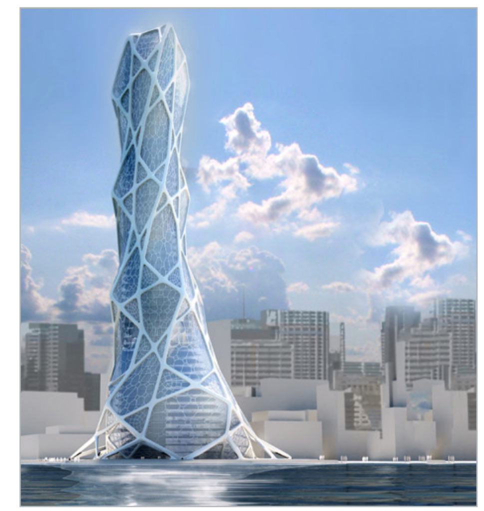


Image courtesy of: LAVA Laboratory for Visionary Architecture

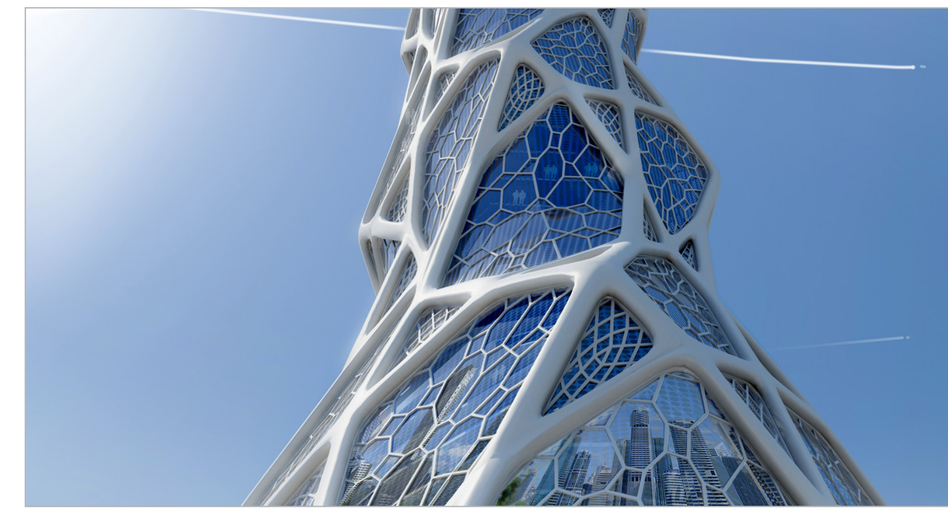


Image courtesy of: LAVA Laboratory for Visionary Architecture

UNIVERSITY OF LEEDS

Key Highlights

Industry
Architecture Engineering and Construction

Challenge
Generate a free-form exoskeleton structure

Altair Solution
Explore design variants with OptiStruct's FE-based topology optimization.

Benefits
- Easy design of complex geometries
- Precise load bearing structure prediction
- Improved structurally feasibility

Designer Profile

Located in West Yorkshire, England, University of Leeds has an impressive history of higher education and notable alumni. University of Leeds partners with international organizations and universities on world-class research and innovation to tackle major challenges in the society. From people to environment, the University of Leeds develops transformational researches and studies that impact the society and future.

James Kingman, graduate of the School of Civil Engineering Master Degree program at the University of Leeds, performs a study that introduces application of structural topology optimization to building and civil engineering structures. His research explores the applications of topology optimization in the field of structural engineering. He selected the Bionic Tower, a high-rise tower proposal in Abu Dhabi designed by the Laboratory for Visionary Architecture (LAVA), as a case study for this research.

LAVA, Laboratory for Visionary Architecture, incorporates patterns of nature organization with future technologies to evolve structures and achieve more efficient architectures with less material. LAVA strives to explore and create new forms of design that enhances reality and reflects the environment in every architectural project. LAVA has completed various projects ranging from installations to urban centers, and furniture to airports.

Keywords: University of Leeds, Altair, AEC, HyperWorks, Topology, OptiStruct, CAD Model FE, Bionic Tower, LAVA

Bionic Tower LAVA Success Story

"The project represents an exciting new use for an existing technology. Topology optimization technology is now at a sufficiently mature stage to be used as a conceptual design tool by both architects and structural engineers on real projects if desired. I hope to see efficient and exciting new structures developed using these tools in the near future."

James Kingman
Structural Engineer

"There is clear evidence that employers of our graduates value highly the skills with the use of HyperWorks that they develop in their study at Leeds"

Vassili Toropov
Professor of Aerospace & Structural Engineering
Leeds University

The Challenge

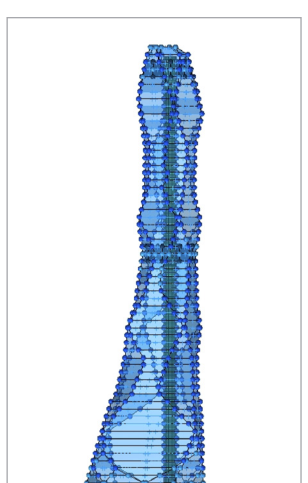
The Bionic Tower is a symbol of LAVA's visions of tomorrow's architecture. The design unifies the nature's organization system with advanced computing technology, to achieve an architectural expression of ultimate lightness, efficiency and sophistication. The structural expression of this architecture is a proposed organic exoskeleton which acts to structurally stabilize the building. In order to achieve the free-form exoskeleton structure, generating a unique structural form that is lightweight and organic in appearance is a major challenge.

The Solution

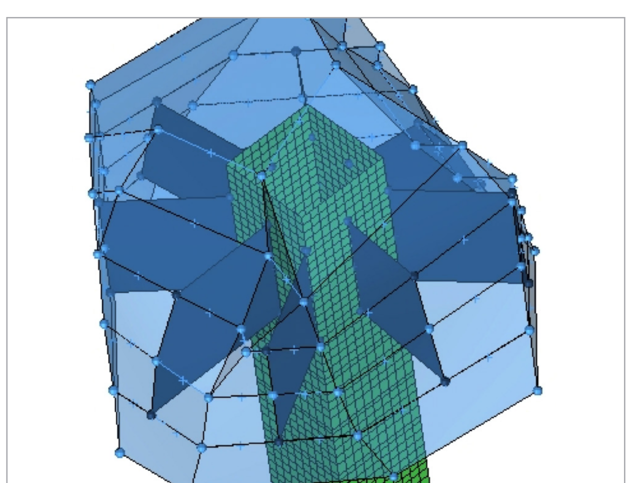
LAVA provided their CAD model for use in the study. Kingman took the geometry and created his own finite element model using Altair HyperWorks. Loading and boundary conditions were applied to the model representing gravity and environmental loading along with idealized foundation support. He conceptualized the building structure as a central core braced by the external exoskeleton. He undertook a series of studies using Optistruct, Altair's structural analysis and optimization solver, to investigate how topology optimization could be used to develop the design of the exoskeleton structure.

The entire building envelope was defined as a designable domain in the topology optimization. In order to attain the required resolution in the topology optimization results and model the structure sufficiently and accurately, a sensitivity study was undertaken and it was found that finite elements with a nominal size of approximately one meter produced satisfactory results. The automatic mesh generation process created a mesh composed of approximately 100,000 finite elements.

In all cases, the structure was optimized to maximize global stiffness while using a finite volume of structural material. The parameters used in the topology optimization algorithm were varied as part of the study in order to investigate the effect on the results and also to aid convergence. It was found that despite the size of the finite element model, the topology optimization studies generally took less than 90 minutes on a standard desktop computer, which is a significantly positive result for large-scale building structures.

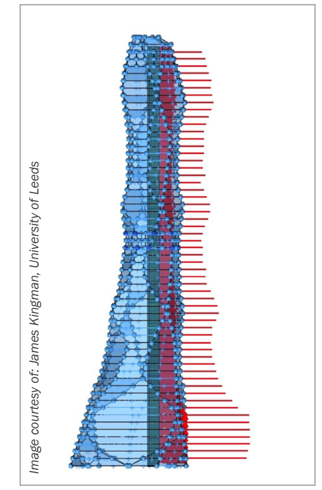


Outriggers placed at level 55-57 and 30-32

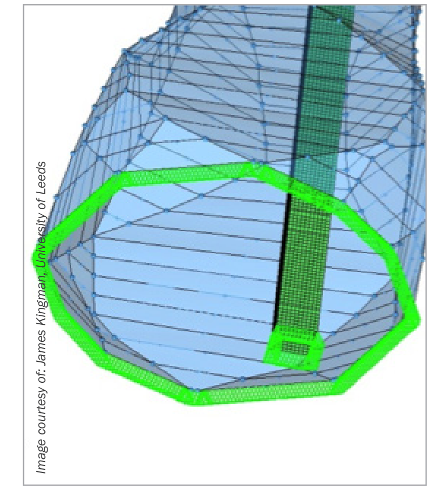


Outriggers are two stories (7 meters) deep

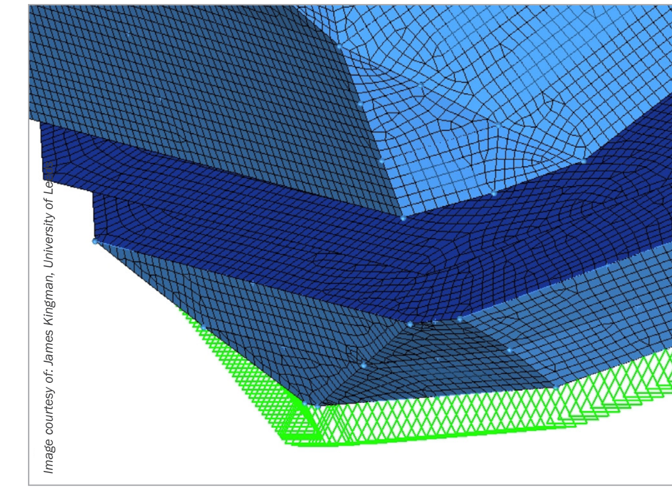
Eight outriggers provided at each level



Lateral wind loading applied directly to the core at each floor level



Core is constrained rigidly



Bottom of exterior shell "pin jointed" to ground

Even though topology optimization is not generally applied to building designs, with more common applications including aerospace and mechanical engineering, it was found to be a very useful tool for designing a high-rise structure with challenging architecture. Kingman found that there is great opportunity for architects and structural engineers to explore topology optimization as an intelligent collaborative tool.

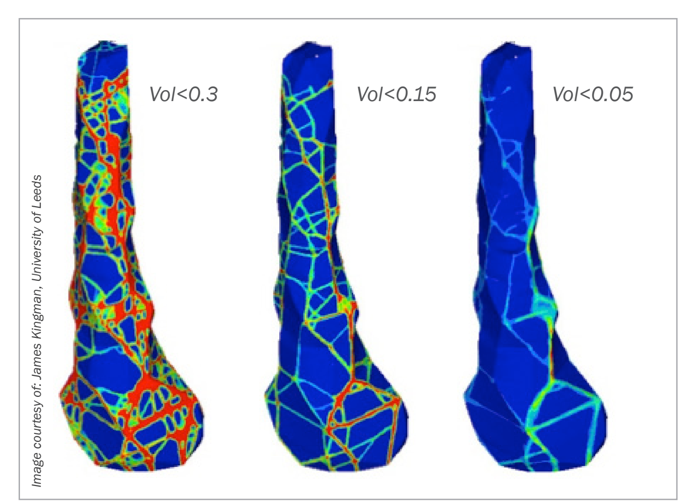
The Result

The results of the topology optimization studies were interesting both architecturally and structurally. When gravity loading was considered in isolation, a structure similar to tree roots emerged; whereas when wind loading was considered, the emerging structure had a much more skeletal appearance.

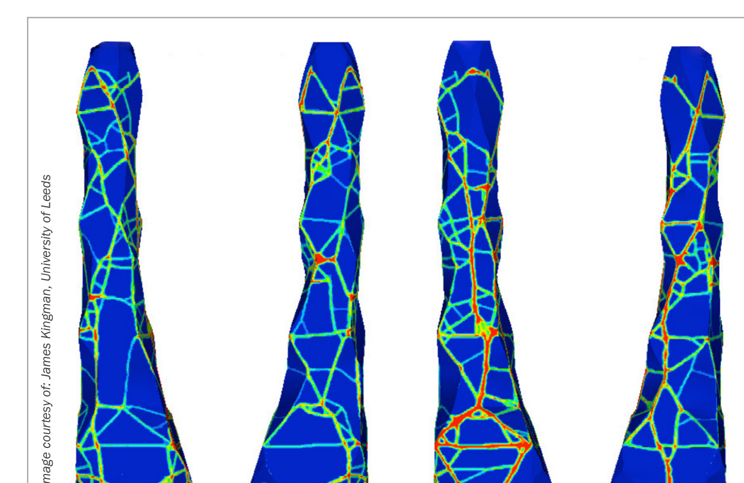
Varying the relative magnitudes of the two loads gave rise to numerous optimal "compromises" between the two extremes. This enables the structural engineer to assess and examine the sensitivity of the optimal structure to the relative magnitude of the two load cases. By gradually reducing the permissible volume of material in the final design, the most critical load paths could be identified down the exterior envelope of the building. Varying the permissible volume of material is suggested as a very powerful tool for structural engineers to understand complex load paths.

Topology optimization was found to be widely applicable to the unique problems of designing a high-rise structure with challenging architectural requirements.

It was found that the topology optimization technique is at a sufficient stage of maturity for rapid studies to be conducted as is required in early stage design. Moreover, facilitating the use topology optimization at an early stage in the design process allows architects and structural engineers to explore multiple concepts.



Volume Fraction of the exterior shell was varied in order to identify an emergent design and the key elements



Side views of the optimization results with volfrac value <0.15