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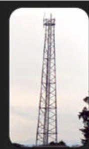
A Novel Topology For Lattice Telecommunication Towers developed through a Computational Morphogenesis Process



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1 - INTRODUCTION

Broadcasting television and radio systems, signal-transmission for the provision of wireless internet, telecommunication and two-radio services, necessitate the use of antennas and dish-reflectors which are more economically mounted on ***lattice guyed masts or self-supported (SS) towers***. This structures can be generally characterized as light, tall and flexible.

GLOBAL INSIGHTS OF THE STRUCTURE

AESTHETICS

- The lattice morphology has been a defining characteristic.
- Almost as visually intrusive as they were several decades ago.
- Of course this depends on the solidity of the structure.
- Solidity will depend on the type of structural members and the exoskeleton topology.
- Such structures have obviously escaped the attention of Engineers and Architects.

LOCAL INSIGHTS OF THE STRUCTURE

STRUCTURAL MEMBERS

- Typically use right angle sections (RAS) or circular hollow sections (CHS).
- RAS lead to high solidity and wind drag, poor aesthetic value and eccentric connections.
- CHS lead to reduced solidity and wind drag, improved aesthetic value and concentrically loaded connections.
- ***Elliptical hollow sections (EHS) were rarely or never used in the past.***
- EHS can significantly reduce the solidity of the structure in the along wind direction and can improve the aesthetic value of the tower.

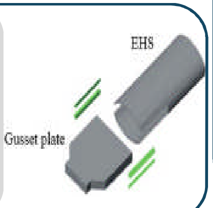
2 - THE CHALLENGE

Can we use computational structural topology optimization (STO) to create ***a new exoskeleton for lattice self-supported towers*** that will possess ***improved structural characteristics***, ***high aesthetic value*** but at the same time ***maintain its functional utility***?

High solidity & poor aesthetic value

Bracing members orientation and intermediate joint

Connection column-beam or column-bracing



3 - STRUCTURAL TOPOLOGY OPTIMIZATION (STO)

- The tool which enables SIMP algorithm to produce skeleton structures or members with improved weight and stiffness characteristics as well as high aesthetic value.
- Achieve through optimum material distribution within a 2D or 3D designed domain representing the circumference geometry of a structure. (Altair's OptiStruct)
- Density plots: Red = 100% - Blue = 0%.

4 - TAPERED 2D CONCEPTUAL LAYOUT OF STO ANALYSIS

Numerous optimization analyses were performed on 2D and 3D domains of different shapes. This provided the most consistent and realistic results was the fully tapered domain presented within ***Section 5***. Their validity was verified against the optimal cantilever bracing (OCB) of Stromberg et al. (2012). All angles deemed to these of Stromberg's OCB.

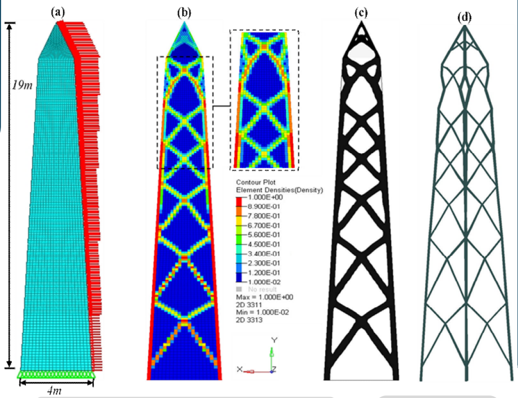
STO ANALYSIS DETAILS

DESCRIPTION: Fully tapered 2D designed domain
HEIGHT: 19m (17m+2m Cap)
BASE WIDTH: 4m
LOADING SCENARIO: Distributed load - changed while optimizing the topology
SUPPORTS : Full base fixed
EDGE LINES SLOPE (17m from bottom to the cap): 1:17
FUNCTION OBJECTIVE: Weighted compliance
CONSTRAINT: Volume fraction

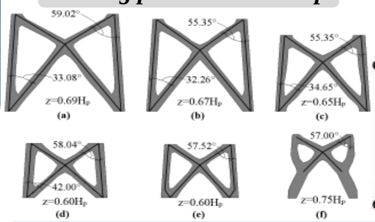
5 - MORPHOGENESIS PROCESS

OptiStruct geometry transformed to 3D line CAD model into Oasys GSA and embraced with EHS. Then compared against a ***conventional tower model UA*** (comprised of RAS members).

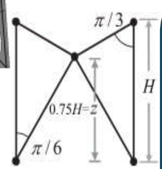
(a)2D domain (b)Analysis output: element-density plot (c)Rendering plot (d)GSA model OT



Bracing panels: bottom-top

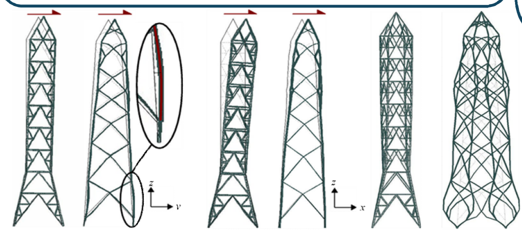


OCB by Stromberg



6 - Model OT VS Model UA

Comparing tower OT with UA: 11% lighter, 4-5% higher f_i in the two bending modes, 0.8% lower f_i in the torsional mode (highly distorted shape), higher modal stiffness in all modes.



(a) Bending mode 1 ***(b) Bending mode 2*** ***(c)Torsional mode***

8 - CONCLUSIVE REMARKS

- The new exoskeleton has improved weight, stiffness and other structural characteristics.
- High aesthetic value has been achieved due to the intriguing topology, slender form, use of EHS and not being visually distracting with dense members.
- Antenna cap has been proved effective for the design.
- STO is effectively used to create exoskeleton structures.

9 – FUTURE WORK

- Test the tower under dynamic loadings (including wind simulation using CFD).
- Wind performance and local effects when iced cross-sections.
- Incorporate horizontal bracings into the model to improve its torsional response.
- Apply the concept of deployable structures.

Model	UA	UA	OT	OT
Mode	f_i (Hz)	k_i (N/m)	f_i (Hz)	k_i (N/m)
(a)	7.12	1.0E+6	7.41	1.9E+6
(b)	7.14	1.1E+6	7.52	1.6E+6
(c)	14.5	8.0E+6	14.4	9.5E+6

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Nielsen, M.G and Støttrup-Andersen, U. 2006. Advantages of using tubular profiles for telecommunication structures. In: *Tubular Structures XI Willibald, S. and Packer, J.A., 31 August/2 September, Quebec City*. London: Taylor & Francis Group plc, pp. 45-51.

Stromberg, L.L., Beghini, A., Baker, F.W. and Paulino, G.H. 2012. Topology optimization for braced frames: Combining continuum and beam/column elements. *Engineering Structures*. 37(No issue number), pp. 106-124.