Temple Steeple Seismic Design

CHART Engineering . April 2012

1 THE CHALLENGE

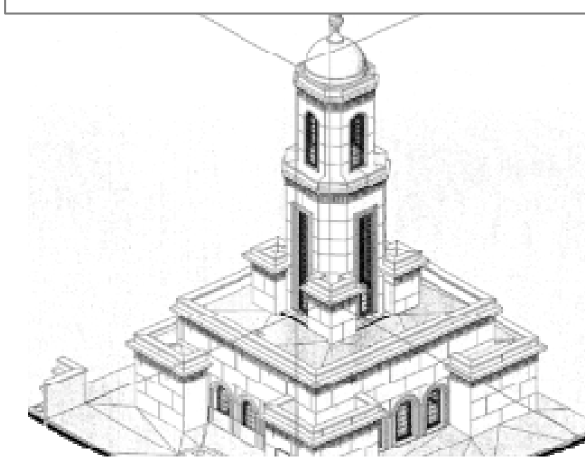
Design a temple steeple located in a high seismic area while optimizing cost and keeping to architectural constraints.

ARCHITECTURAL CONSTRAINTS

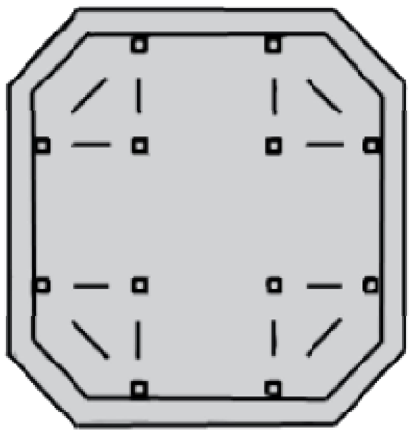
- No steel framing crossing large windows
- One beam of light from bottom to top
- Octagonal steeple shape
- Angel Moroni
- Heavy Cladding

SEISMIC CONSTRAINTS

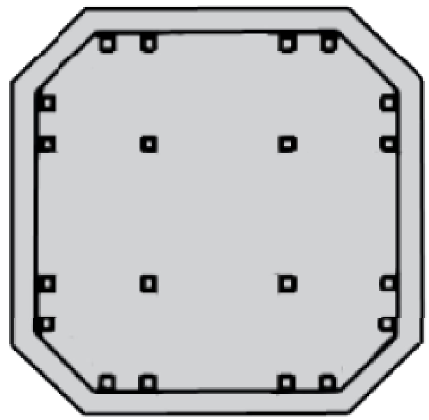
- High seismic activity area
- Seismic category E
- Minimized deflection
- Safe for Maximum Considered Earthquake



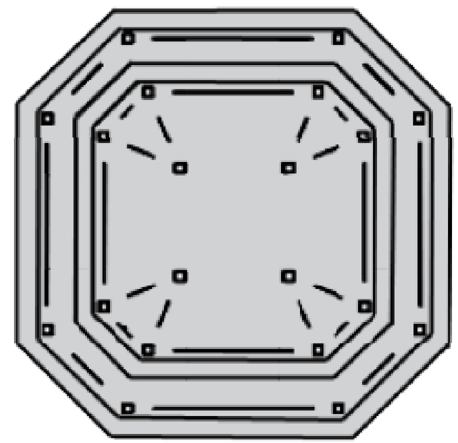
2 THE PROCESS



Ineffective design because of gap between members and cladding.

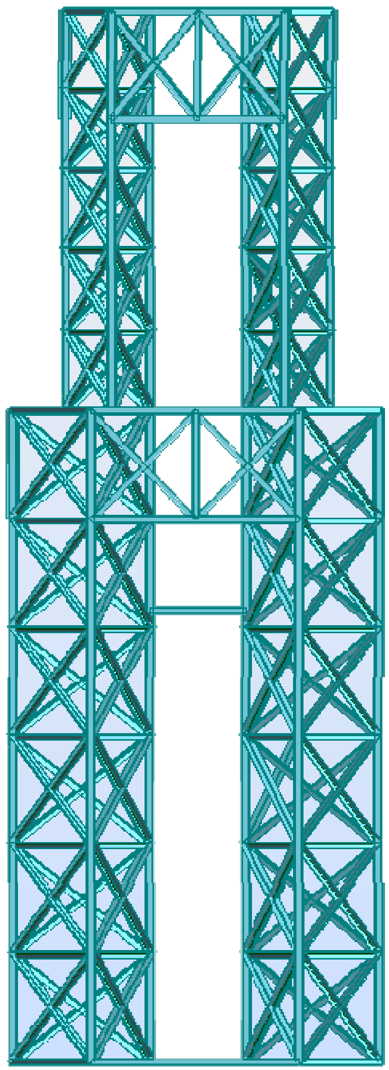


Ineffective use of steel: not cost efficient.



Allows cladding to be attached at top while reducing steel members.

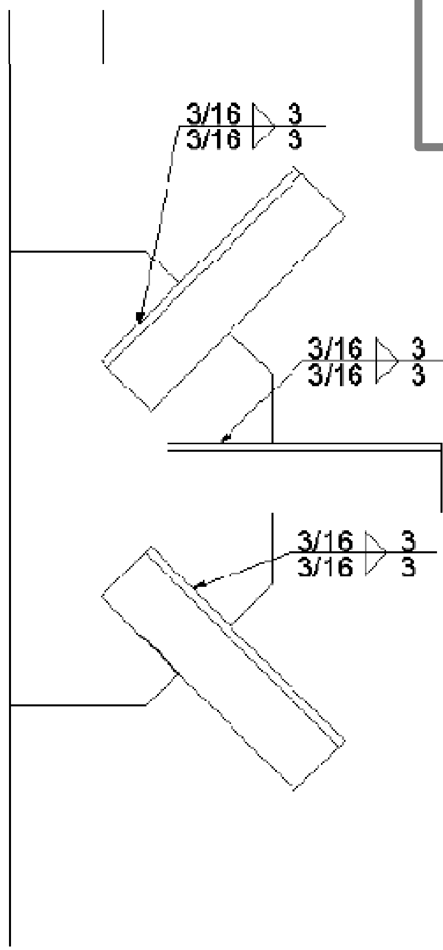
The steeple was designed as a special concentrically braced frame, using the two-stage analysis approach from ASCE 7-10.



The two-stage approach required certain conditions to be met. This approach was desirable Because it resulted in a lower seismic force.

- Period of base structure cannot be 1.1 times more than period of top structure
- Base structure and steeple must have separate R and p values
- The ratio of R/p of the base to R/p of the steeple must be less than 1

Period Requirement	T_{base}	0.18
	$T_{steeple}$	0.13
	$1.1*T_{steeple}$	0.143
R and P Requirement	$R_{steeple}$	6
	$\rho_{steeple}$	1.3
R and P Ratio Requirement	R/ρ_{base}	0.85
	$R/\rho_{steeple}$	4.62
	Ratio	0.83



Connections for special concentrically braced frames are very difficult to design and require many AISC standards to be met.

As simplification reduces cost, three-inch welds were found to be sufficient for the largest loads and were thus used for all connections.

$$E_m = E_{mh} + E_v$$

$$E_{mh} = \Omega_o * Q_E$$

$$E_v = 0.2 * S_{DS} * D$$

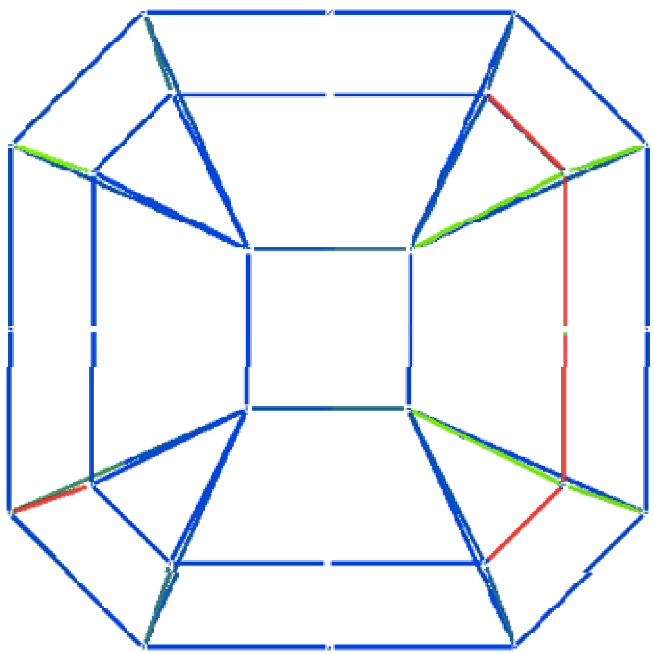
Seismic force is computed by the sum of horizontal and vertical components.

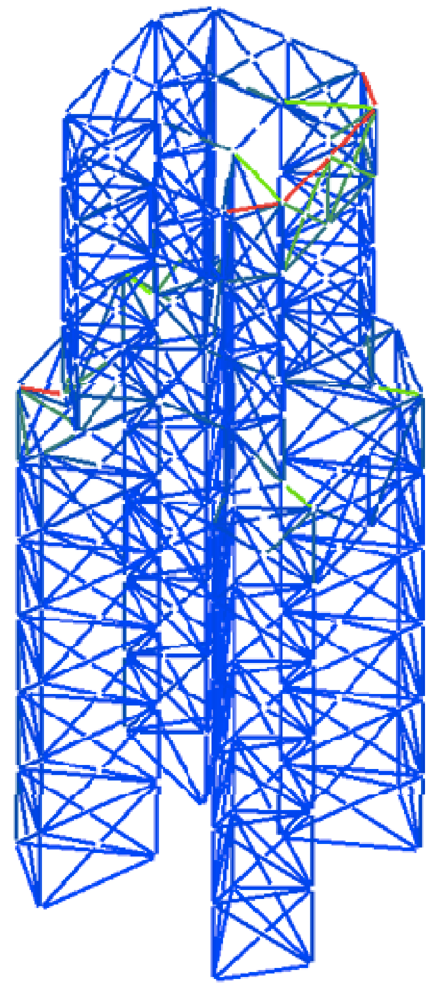
Other variables rely on parameters such as soil properties, height of tower, and other seismic constraints.

After calculations , the seismic force was computed as 34.9 kips.

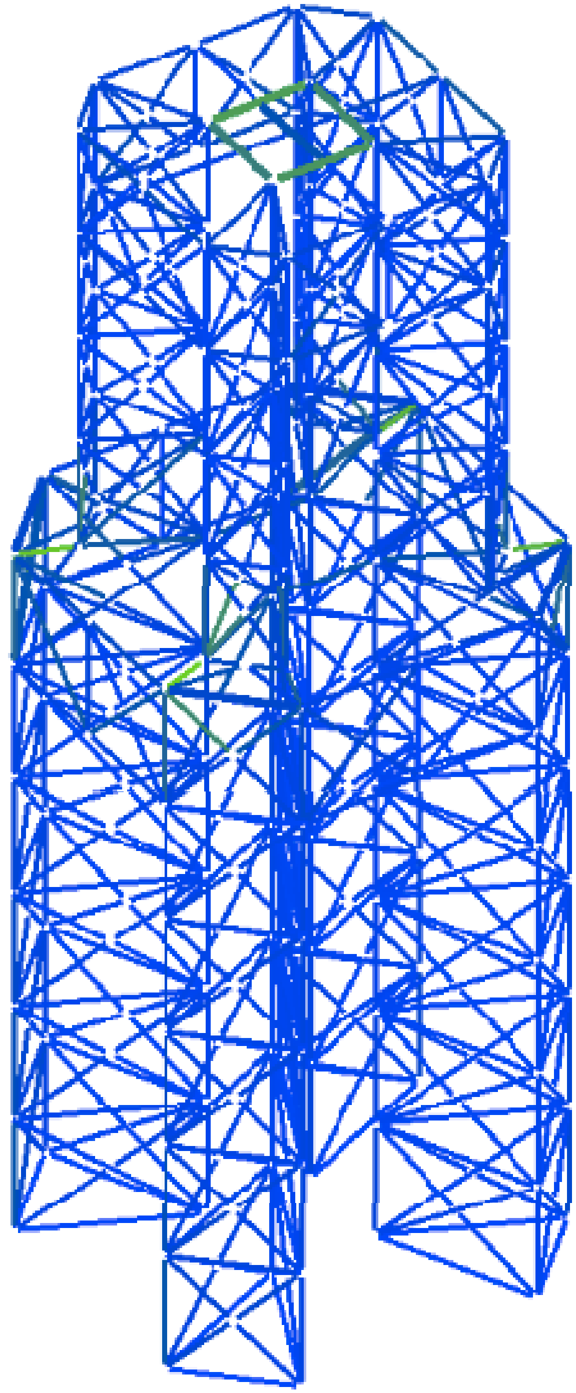
3 THE ANALYSIS

Visual Analysis was used to test the design under loading: Both from dead weight and seismic loading.

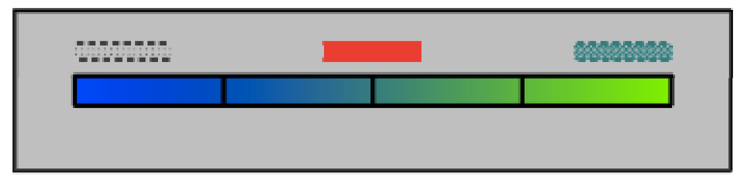


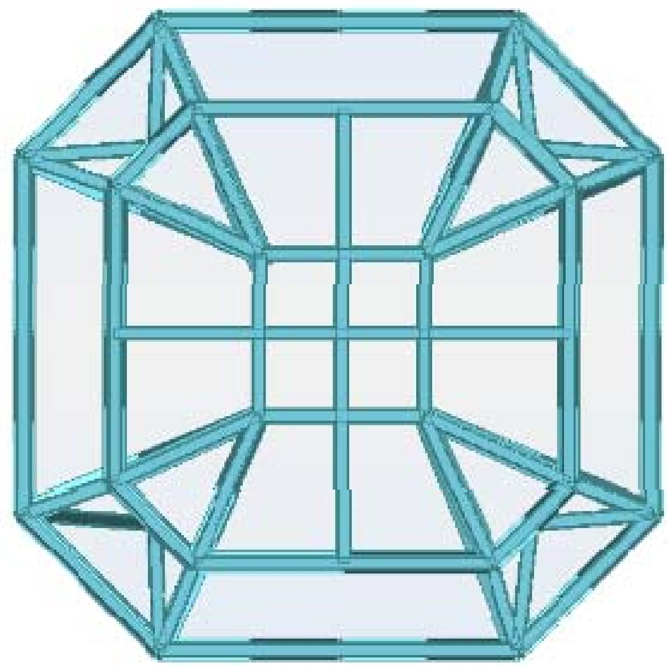


Our prepared design had failure in two main locations, the top of the tower and where the two levels meet.

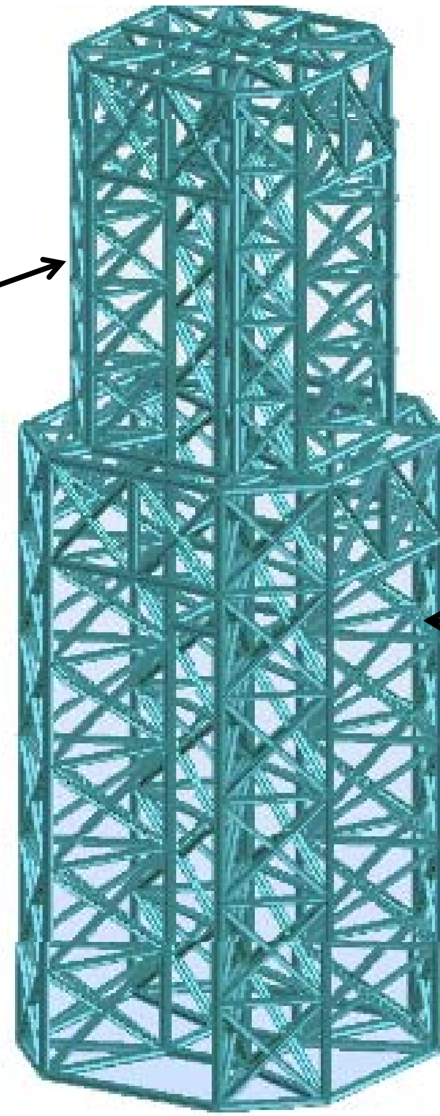


Adding just a few more members gave a sturdy design, while allowing all local steel to remain.





4 THE SOLUTION



HSS4x4x5/16 were used as the columns and bracing at critical locations.

2L3x3x3/16 were used for all cross bracing.

Cost Analysis

Optimizing cost was a large part of the overall consideration for design. There are a few main ways to reduce cost in a design. They are:

- Reduce steel used
- Use local materials
- Type of connections
- Simplify design

Labor costs are the most significant in any steel project. We reduced these costs by

- Only using two steel member sizes
- Using welded connections out of the country do not cost significantly more than bolted connections

- We also used 100% local steel, reducing steel ordering costs significantly

5 THE FUTURE

The design could be improved upon by continuing to analyze the steel structure to se which steel members are unnecessary. This could further reduce cost.

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