# Seismic Design of Steel Steeple

# RVHB Engineering

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# Problem Statement

- The Church of Jesus Christ of Latter-day Saints has decided to build a temple in an area with high seismic activity. This temple must be designed to endure horizontal loads caused by earthquake ground motions while maintaining an aesthetic architecture.

# Constraints

- Architectural
  - No shadows cast on the steeple windows or visible structural elements
- Sustainability-
  - Temple cannot be closed for extended amounts of time to repair earthquake damage
- Constructability
  - Use steel shape sizes locally available near the site.

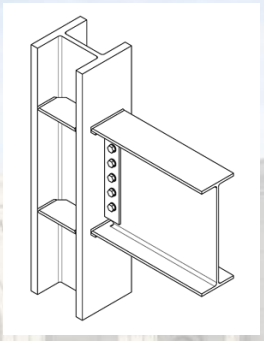
# Modern Tools Implemented

- Calculations
  - Mathcad / Excel
- Structural Analysis
  - SAP2000
- Design Modeling
  - Revit

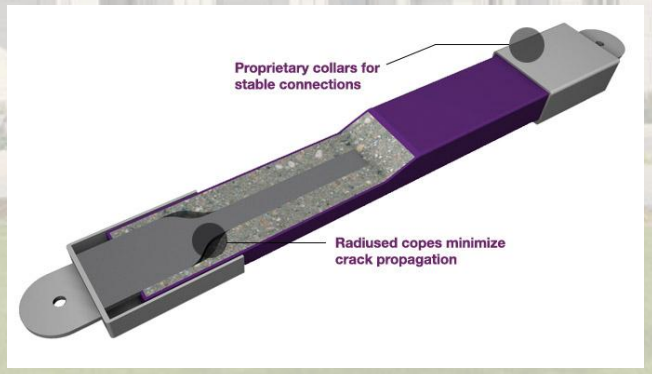
# Research

- Lateral Force Resisting Systems
  - **Special Concentric Braced Frame**

  - **Moment Frame**

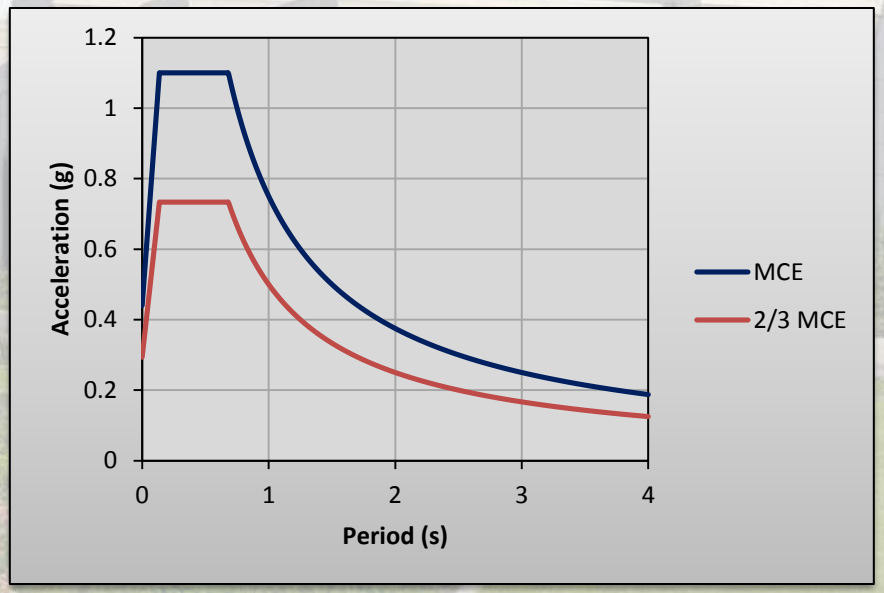


  - **Buckling Restrained Braced Frame**



# Consideration of Design Approaches

## Response Spectrum For the Site




## Equivalent Lateral Force

| Steeple ELF | | | | | |
|---|---|---|---|---|---|
| System | Level | w(kip) | h(ft) | Fx | $V_{base}$ (kip) |
| MF | 1 | 49.4 | 26 | *5.45* | *14.85* |
| (R=8) | 2 | 49.4 | 42 | *9.41* | |
| SCBF | 1 | 49.4 | 26 | 8.66 | 22.64 |
| (R=6) | 2 | 49.4 | 42 | 13.98 | |
| BRBF | 1 | 49.4 | 26 | 6.31 | 16.98 |
| (R=8) | 2 | 49.4 | 42 | 10.67 | |

# Consideration of Design Approaches

**Design as Non Structural Component**

F = 150 kip

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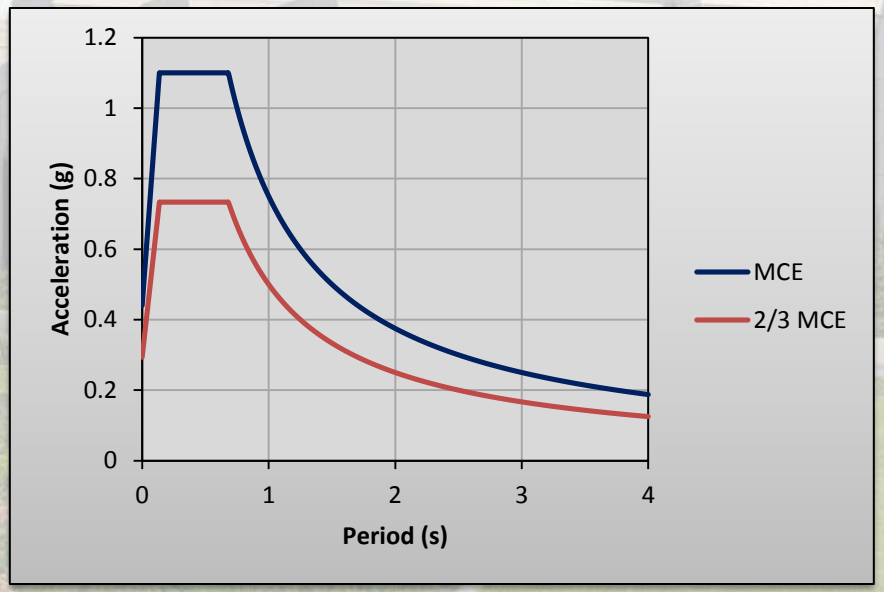


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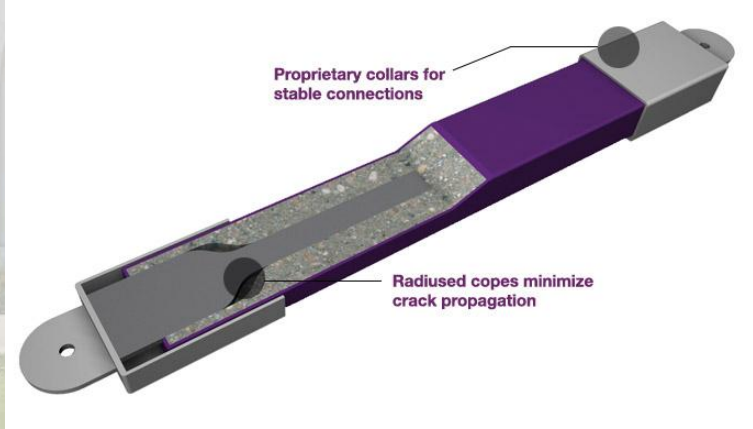
# Selection

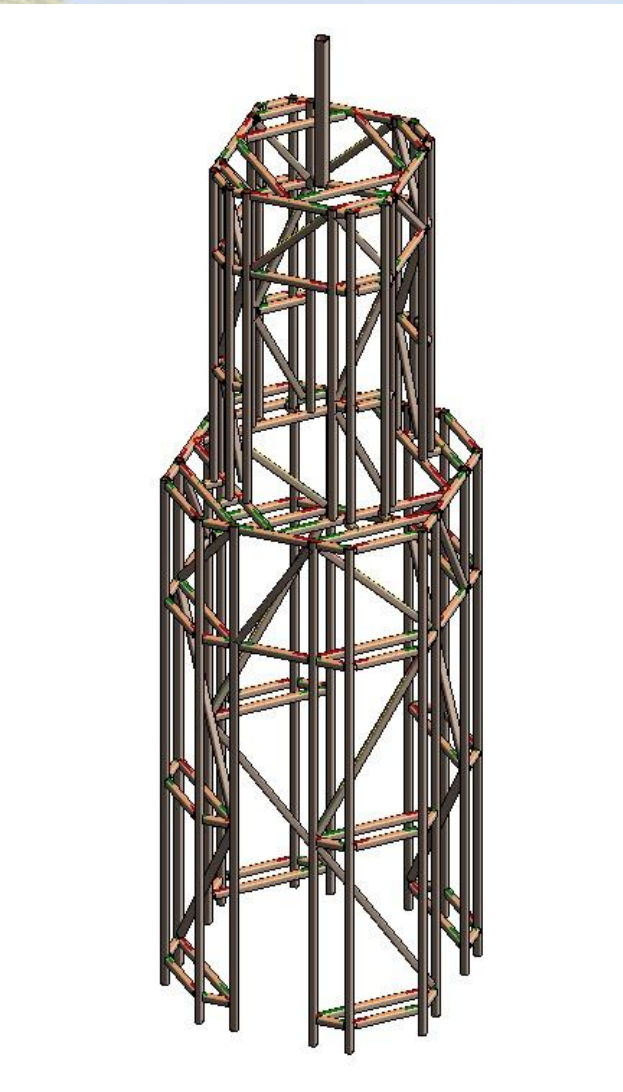
- Lateral Force Resisting Systems
  - **Special Concentric Braced Frame**
    - **Buckling would damage cladding an other members**
  - **Moment Frame**
    - **Steeple is to tall and skinny for MF to be effective without very large member sizes**
  - **Buckling Restrained Braced Frame**
    - **Chosen system**

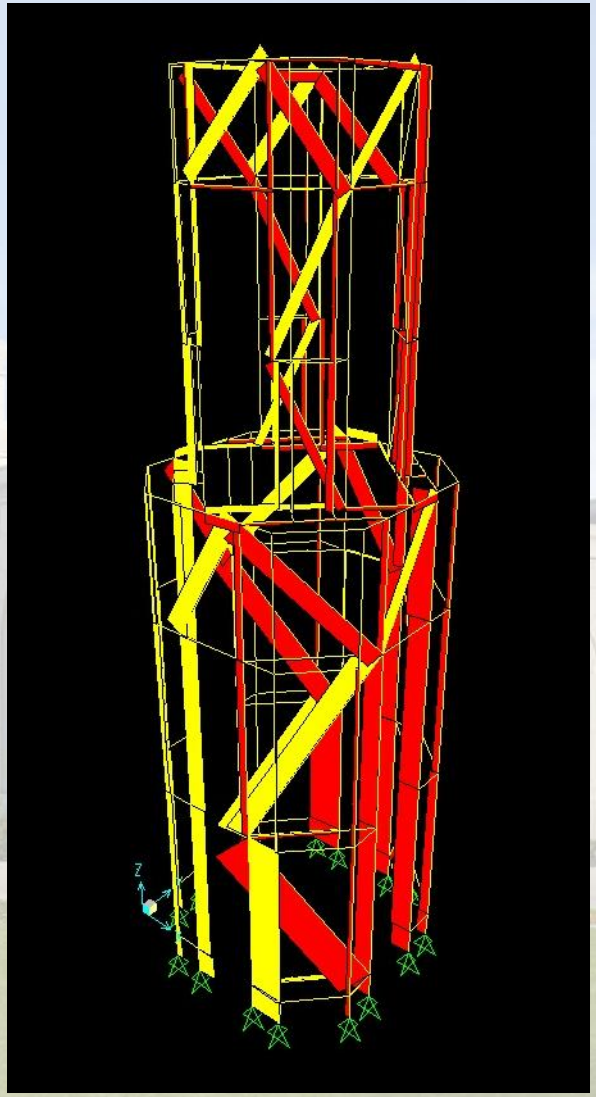
# Why BRBFs?

- Steel Core surrounded by Concrete
  - Concrete Prevents Steel Core From Buckling
  - Both Compression and Tension Yielding
  - Cyclic Yielding Dissipates Energy
- Pros and Cons
  - High Performance
  - Low EQ Damage
  - Costly



# Final Design





# Deflections

| Deflection of Alternatives under Design Earthquake | |
|---|---|
| Shape | Deflection (in) |
| HSS 4x4x5/16 | 0.358 |
| HSS 3x3x1/4 | 0.936 |
| Combination of Both Shapes | 0.413 |

# Cost

| Cost Evaluation | |
|---|---|
| **Design** | |
| Design Work (15, 6hr weeks @ 100/hr ) | $ 9,000.00 |
| **Materials** | |
| Bracing | $ 4,000.00 |
| Steel ($700/ton) | $ 8,750.00 |
| **Construction** | |
| Labor (2 week construction) | $ 4,000.00 |
| **Total** | $ 25,750.00 |

| Savings | |
|---|---|
| Damaged Cladding (Avoided) | $ 1,050.00 |
| Replacement of Steel (Avoided) | $ 1,750.00 |
| Replacement of Braces (Avoided) | $ 1,000.00 |
| Labor Repair (Avoided) | $ 1,000.00 |
| **Total** | $ 4,800.00 |


Questions?