50 PERCENT MILESTONE REPORT:

TEMPLE STEEPLE FOR THE CHURCH OF JESUS CHRIST OF LATTER-DAY SAINTS

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GENERAL INFORMATION

VISION STATEMENT

RVHB Engineering is dedicated to providing safe, reliable, sustainable, and innovative solutions to modern engineering problems. We commit to providing cost-effective designs tailored to client's individual needs. RVHB Engineering employs four qualified engineers in training who are committed to providing quality work in a timely manner.

PURPOSE

The Church of Jesus Christ of Latter-day Saints has over 14 million members worldwide. Temples are an important part in the worship services of these members and must be accessible to patrons in various locations throughout the world. In this circumstance, the temple must be designed to perform under the local seismic loads. The purpose of this project is to provide these members with a sustainable temple structure.

OBJECTIVE

Understanding the effect of earthquakes on structural systems is crucial when designing structures in areas with high seismic activity. The Church of Jesus Christ of Latter-day Saints has decided to build a temple in one of these areas. By nature temples must be designed to endure gravity and horizontal loads due to ground motion while maintaining an aesthetic architecture. The steeple of one of these temples must be designed to meet seismic performance criteria at an optimal cost. The steeple must also fit the current architectural constraints

SCOPE OF WORK SUMMARY

A comparison between different seismic designs fitting current architectural requirements will be performed. Architectural constraints that will be used in analysis are exterior cladding, window placement and the statue of Angel Moroni. After preliminary consideration, three structural framing systems will be considered in the design. Two types of system designs will be taken into consideration. A two-stage approach will be conducted in accordance with ASCE 7-10 Section 12.2.3.2. A component design in accordance with ASCS 7-10 Section 13 will also be conducted.

Each system will be analyzed under a Maximum Considered Earthquake (MCE) and under the Design Basis Earthquake (2/3 MCE). The Response Modification Factors (R) for each system will be determined. Each design will be modeled in Revit Structure and analyzed using RAM structural analysis software. A cost analysis will also be conducted using Autodesk Quantity Takeoff along with Microsoft Excel. Cost for materials, labor, and construction equipment will be included in the cost analysis.

ANALYSIS

EQUIVALENT LATERAL FORCES

The Steeple was analyzed using a two stage approach (ASCE 7-10 Section 12.2.3.2). The equivalent lateral force method was used to determine the forces acting on the steeple. The steeple was broken into two "stories" with the equivalent lateral forces acting on the top of each story. The forces act at an elevation of 26ft and 42ft relative to the bottom of the steeple. The steeple was also analyzed as a component (ASCE 7-10 Chapter 13) with the equivalent force acting through the center of mass of the structure.

It was determined that a two stage approach would provide more accurate results as lateral forces could be applied to two different sections. The two stage approach also produced equivalent lateral forces much higher than that of the component approach (1.2 kips). The results of the two stage approach are shown below in Table 1 for the following systems: Moment Frames (MF) Special Concentrically Braced Frames (SCBF) and Buckling Restrained Braced Frames (BRBF). The acceleration response spectra for the site was also plotted (Figure 1).

Table 1: Results from Equivalent Lateral Force Method

Steeple ELF						
System	Level	w(kip)	h(ft)	wh^k	Cvx	Fx
MF	1	18.45	26	756.45	0.37	*2.03*
	2	18.45	42	1306.70	0.63	*3.51*
SCBF	1	18.45	26	479.70	0.38	*3.23*
	2	18.45	42	774.90	0.62	*5.22*
BRBF	1	18.45	26	656.92	0.37	*2.36*
	2	18.45	42	1111.45	0.63	*3.99*

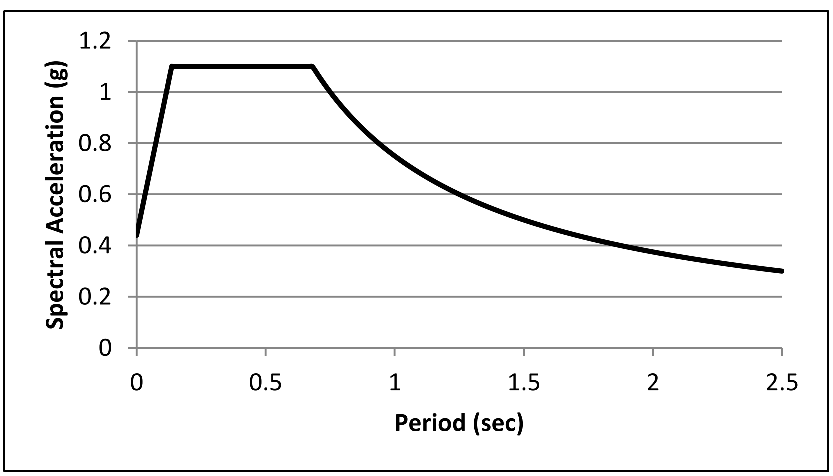

Figure 1: Site Specific Acceleration Response Spectra

SYSTEM GEOMETRY

Architectural requirements prohibited the placement of steel that would either be visible through the windows or cast a shadow when the steeple light tube running through the middle of the steeple was turned on. For this reason we decided to work primary on the corners of the structure to provide lateral bracing. The sections containing the windows will be constructed using moment frames. The three systems described earlier (MF, SCBF, BRBF) will be designed in the corner section on each story. The geometries for each are shown below as Figures 2 and 3. Note that SCBF design will be similar to the BRBF design in Figure 2 with "x"

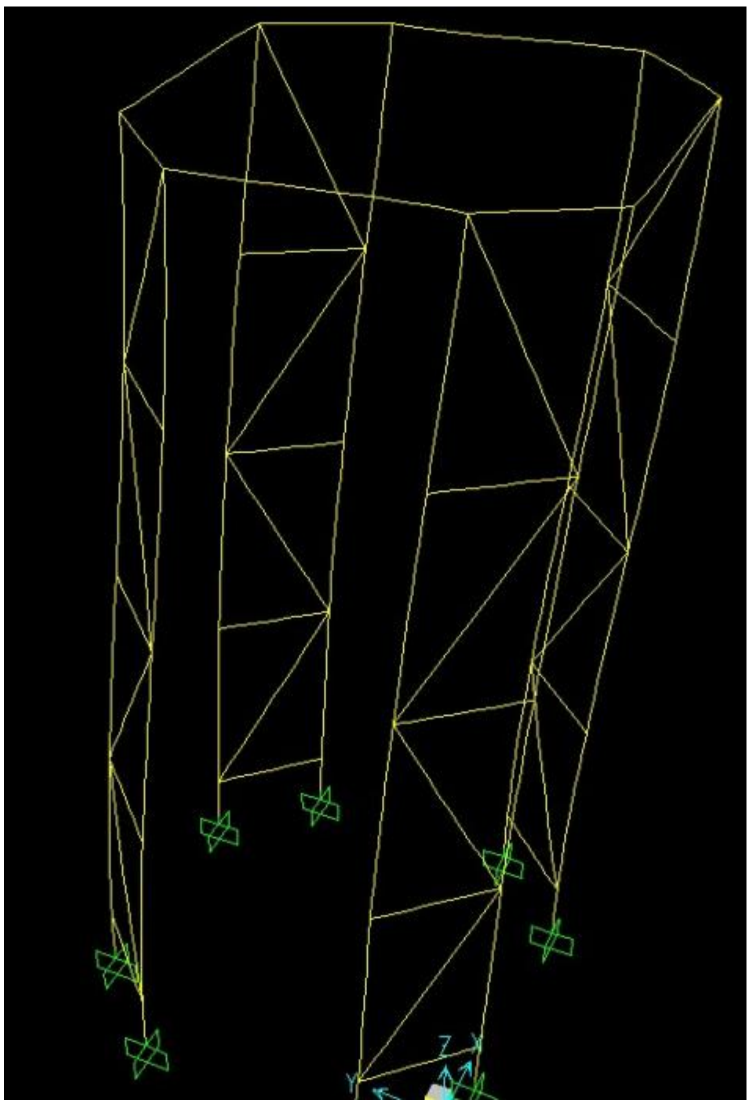

Figure 2: BRBF design, Similar SCBF design to be Designed

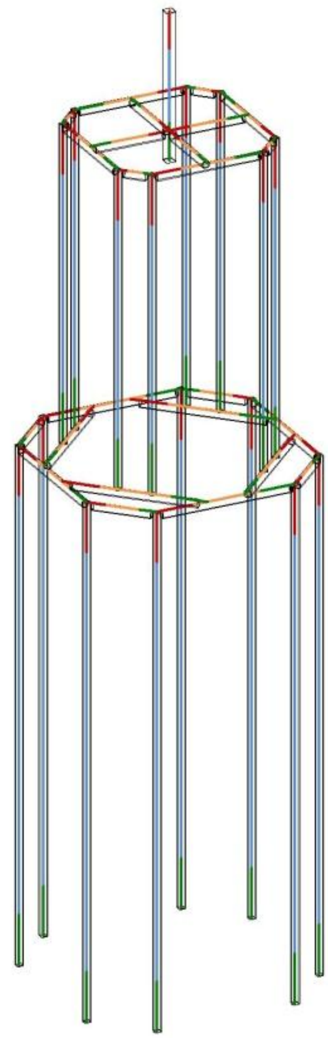

Figure 3: Moment Frame Design

FUTURE WORK

Future work for this project includes analyzing each structure under the equivalent lateral loads to obtain the demands in each member. Steel shapes will then be chosen for adequate design. Connections will also be designed for each system and a recommendation will then be made on the appropriate system to use for the site based on performance and cost.