SPERO

"TO HOPE"

University of California, Berkeley

2021 Undergraduate Seismic Design Competition

GEOTECHNICAL ANALYSIS

The project site location incurs seismic risk from a combination of the Seattle Fault System (SFS) and the Cascadia Subduction Zone (CSZ). The CSZ is capable of an 8.0-9.0 magnitude earthquake every 500 years and the SFS has a return period of 100 years for magnitude 5.0 or greater. Seismic hazard deaggregation (Fig. 2) indicates the CSZ to be the largest risk contributor despite having an average distance of 105 km from the site location for the structure.

The liquefaction potential as a result of the regional seismicity lies primarily in the first layer of SP fill that extends 55 feet downwards. Potential mitigation techniques to remedy this problem include dynamic compaction which proves effective for sandy fill near the surface, vibro stone columns which provide extra strength and drainage, and jet grouting which suits best for soil at depth. Assuming liquefaction mitigation is conducted, a site classification of E would be assigned per a Vs30 value of 176 m/s and an N of 8.5 according to ASCE 7-16. Taking these factors into account the implemented pile foundation likely extends between 100 and 120 feet deep.

A site specific response spectrum was developed for our Risk Category IV structure by cross referencing parameters defined by ASCE 7-16 and the ATC Hazard Tool. From this, a seed motion from Centerville Beach Naval Facility was chosen due to the similarity in seismic source and Vs30 value. This and the provided seed motions were scaled to create the pseudo-spectral acceleration response spectra shown in Fig. 1.

Fig. 1:

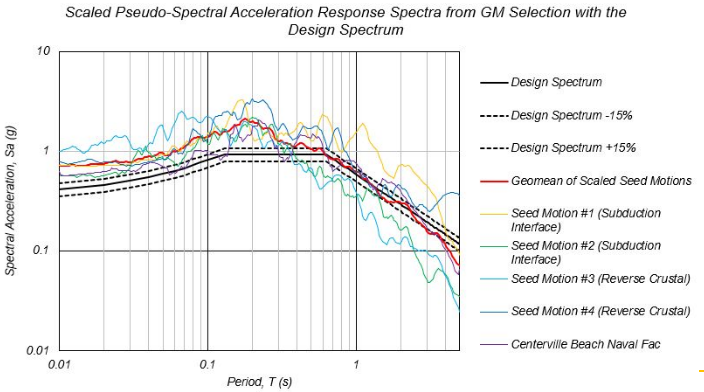
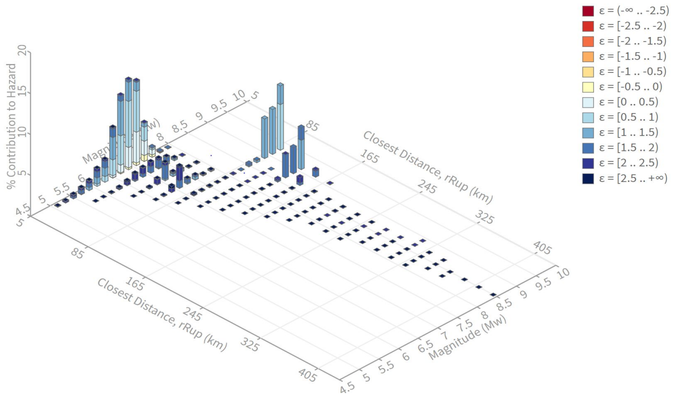
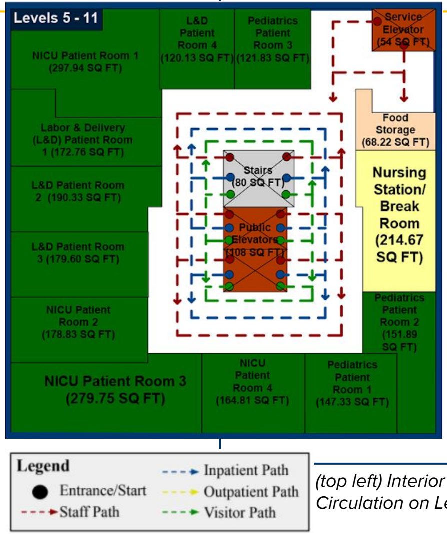
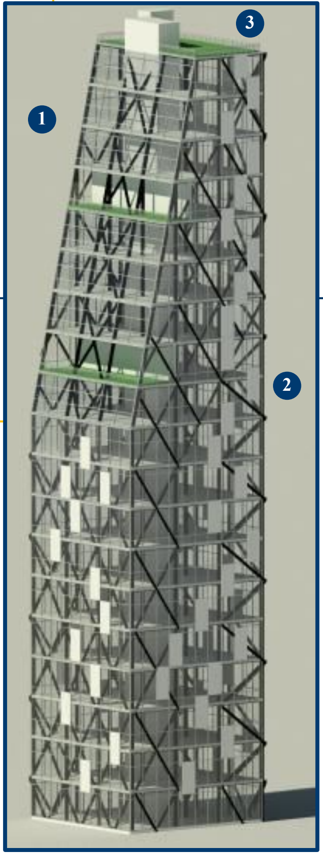


Fig. 2: T=1.0 sec Deaggregation Plot



ARCHITECTURAL DESIGN





(top left) Interior Rendering of Balcony Garden on Level 16; (bottom left) Internal Circulation on Levels 5-11; (right) Post-Retrofit Architectural Rendering of Spero

Facade | Spero is holistically designed to stand as a landmark of hope in Seattle. This is achieved through: 1) glass curtain walls, 2) translucent panels, and 3) green spaces. Glass curtain walls promote occupant well-being and happiness by allowing ample daylighting and quality views of the neighborhood. The green and blue hues of the translucent panels mimic Seattle's serene water and year-round greenery. The balcony and rooftop gardens not only serve as an area of relaxation to patients and visitors alike, but also contribute to energy savings by providing shade and reducing the heat island effect. Ultimately, the facade produces a fusion of the industrial and the natural, promoting healing and inspiring hope for all that sees it.

LEED Gold Certification | The facility supports Seattle's future sustainable goals by seeking LEED gold certification. The most noteworthy features implemented are as follows. First, a wetland treatment system will recover sewage and rainwater for non-potable water reuse. Second, enrollment to Seattle City Light's "Green Up Program" will help finance the expansion of local renewable energy production. Finally, balcony and rooftop gardens consisting of native plants will contribute towards rehabilitating the local ecosystem and limiting the heat island effect, to name a few benefits.

Internal Operations | The hospital's internal layout highly considers the impact of the Covid pandemic. Multiple floors have been set aside specifically for Covid patients, and have been delegated to the middle part of the tower where patients are less likely to come into contact with outpatients. Moreover, the floors have been designed with circular movement paths to effectively control flow in the floors, allow for easier wayfinding, and lower the chance of patients and staff crossing paths with each other.

STRUCTURAL DESIGN

In order to obtain predictions for our design's structural behavior, **a wireframe model with asymmetrical bracing and area loads on each floor** was built within the SAP2000 software. Properties for columns, beams, and bracing were determined by the deliverable guidelines. The analysis of the existing hospital determined the number of modes needed to reach **90% modal mass participation, the maximum interstory drift ratios, the maximum forces and bending moments, and the critical members within the model.**

The hospital addition was established through an **iterative design process** and built on top of the existing model. After testing several different designs, it was decided that using a similar bracing system as the original structure would **simplify the transfer of loads** between the extension and the existing hospital. The X-braces on the frame are composed of **0.16" by 0.16" members**. After some preliminary analysis it was determined which members in our original design were necessary or not. Floor members are **0.12" by 0.12" arranged in a 2" grid**. The girders transfer the vertical load to the columns which are **evenly spaced every 4"** throughout the extension.

After placing area loads on the tower addition, 8 **time-history analyses** were performed using the given time history files. Using the calculated results, the team was able to determine the **predicted roof drift** and **peak roof acceleration** that the tower experienced in each ground motion.

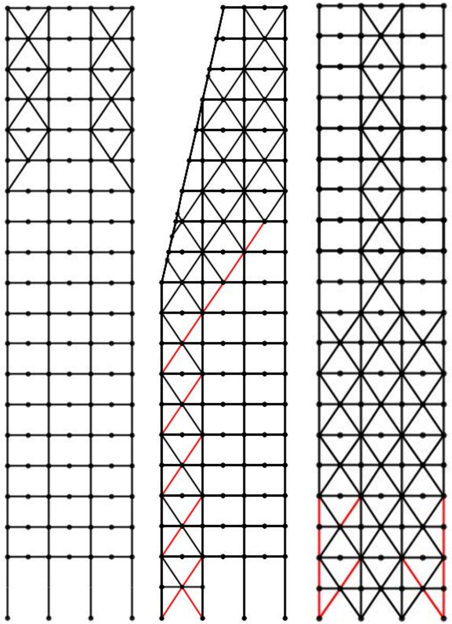
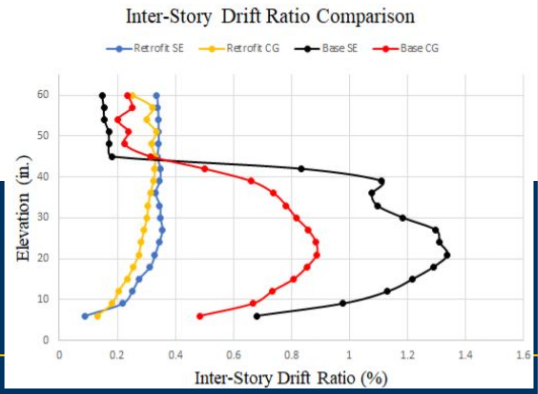


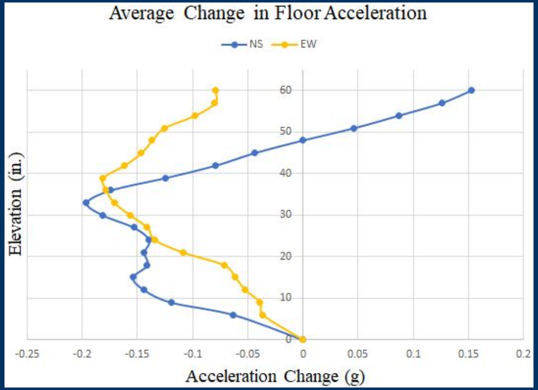
Table 1: *Comparison of Weights Between Phases of Structure*

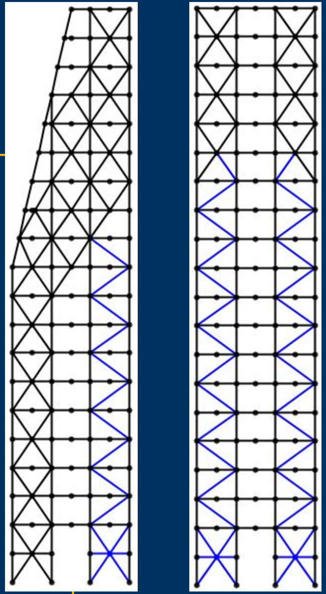
Values	Existing	Addition	Retrofit	Total
Total Floor Area [in^2]	1296	1152	N/A	2448
Wood Weight [lbs]	0.19	0.26	0.04	0.49
Total Volume [in^3]	42	55.8	7.5	105.3

(top) East, North/South, and West Elevation views

RETROFITTING ANALYSIS







Our retrofitting scheme had three primary objectives: reduce the structure's torsional response, transition load away from failing members, and decrease acceleration response. Inter-story drift ratios, demand/capacity (DC) ratios, and floor accelerations were the metrics used to determine the retrofit effectiveness.

Traditional retrofit schemes for steel structures include the addition of concentrically braced frames (CBFs), dampers, shear walls, or steel moment frames. Our scheme mimics the first of these options with a single floor bracing system comprised of 0.16"x0.16" members. Soft story bracing deviates from the rest of the retrofit to provide resistance to buckling of the braces and the adjacent columns.

This scheme was successful in most aspects of our objectives. Inter-story drift ratios reduced at both the center of gravity and the south-east column and became more uniform, indicating a reduction in torsion. The failing members, identified previously, experienced a reduction of 63% in DC ratios. Moreover, all members passed design checks as specified in NDS 2015. Average floor accelerations experienced a reduction after implementation of the retrofit scheme, however accelerations of the roof and 18th floor did increase slightly.

(top) IDR Comparison; *(bottom)* Floor Acceleration Changes; (right) North/South and East Elevation Retrofit Additions