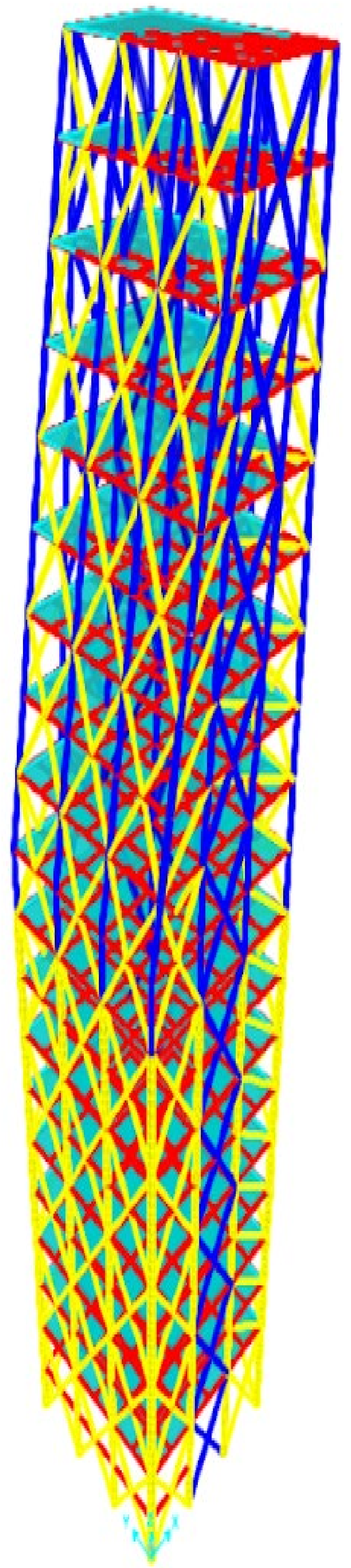
University at Buffalo

Emerald City Medical Center



University at Buffalo-The State University of New York

-2021 EERI Seismic Design Competition-

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Construction Manager: Ernesto Cruz Martinez

Lead Architect: Delaram Haghdel

Design Coordinator: Anthony DeCola

To our sponsors, Thank You!

Emerald City Medical Center

Geotechnical & Seismicity Considerations

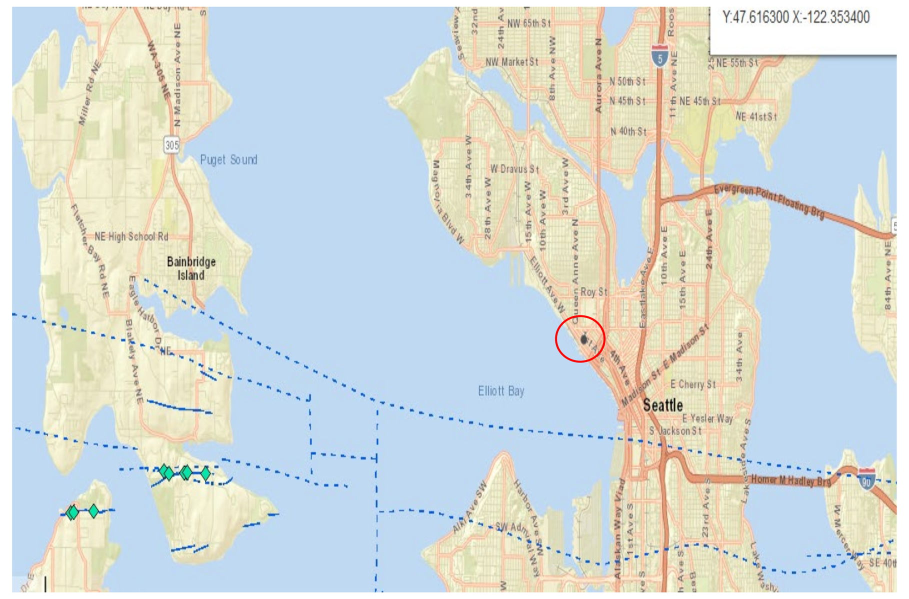
Objectives

- Assess Regional Geologic Conditions
- Identify sources of potential future ground motions
- Assess of subsurface conditions at the proposed site
- Provide Geotechnical Design Recommendations
- Interpret Probabilistic Seismic Hazard Data
- Select and Scale Ground Motions for Structural Design

Methodology

Assess Regional Geologic Conditions

- Utilize USGS Maps, Historic Geologic Records, Washington State Dept of Nat Resources GIS
- Purpose:
  - Identify depositional method and age of deposits
  - Depositional Method: Influences strength, GSD
  - Liquefaction Potential: Age & GSD
  - Provide additional confidence in in-situ data
  - Supplement lack of data/information



Approximate Site Location and Nearby Faults (Dashed Blue), From: Wash. DNR , ESRI

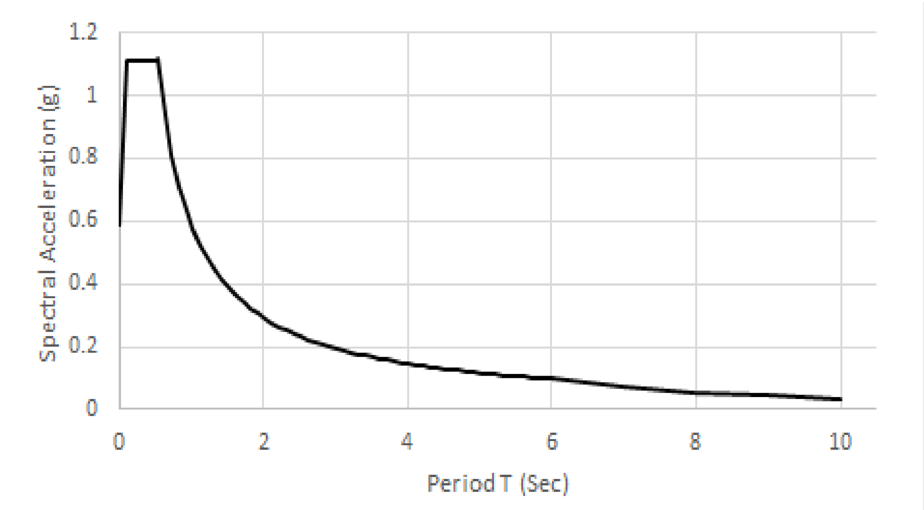
Methodology

Identify Future Sources of Ground Motions

- Consult the following Sources:
  - Washington DNR GIS
  - Pacific Northwest Seismic Network(PNSN)
  - City of Seattle Office of Emergency Mgmt.
- Identify sources of shaking during design life of the structure
  - Expected Magnitudes
  - Recurrence Intervals

Assess Site Subsurface Conditions

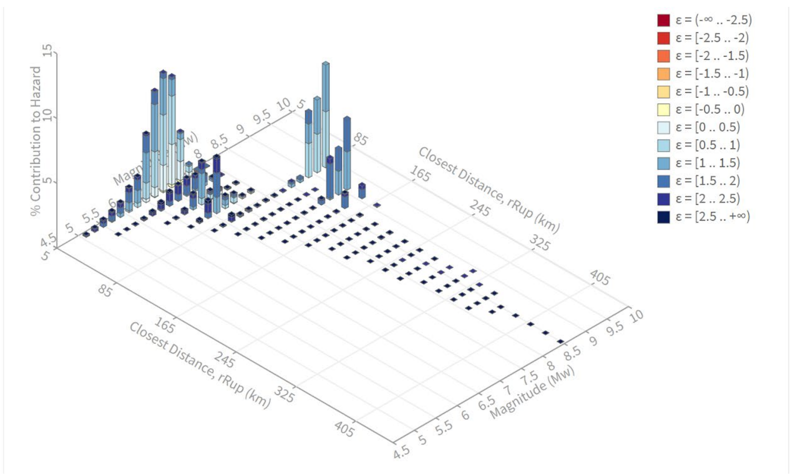
- Utilize the provided drill log and P-S log
- Qualitatively assess the strength of soils to inform:
  - Foundation Design
  - Liquefaction Potential
  - Ground Improvement Method
- Determine Seismic Site Classification using ASCE 7-16
  - Obtain parameters for Design Response Spectrum
  - Used ATC Hazard By Locations Tool with site coordinates, risk category (det. using ASCE 7), and seismic site class (found by ASCE 7 and Drill Log)



Design Response Spectrum prepared using ASCE 7-16

Interpret Probabilistic Seismic Hazard Data

- Utilize USGS Unified Hazard Tool to generate probabilistic seismic hazard plots
- Purpose:
  - Identify potential sources of ground motion
  - Used in conjunction with response spectrum to select and scale ground motions



Deaggregation Plot for T=1.0sec, from USGS

Results & Recommendations

Regional Geologic Conditions

- Puget Sound Lowland & Seattle Basin
- Influenced by repeated glaciations past 2.5m.y.
  - Clays: Stiff and over-consolidated
- Regrading operations (20th Century)=>Artificial Fill
  - Large deposits near Elliott Bay and Waterfront
  - Composition & Compaction method varies greatly

Identify Future Sources of Ground Motions

- Seattle Fault
- South Whidbey Island
- Cascadian Subduction Zone (CSZ)

Site Subsurface Conditions

- Liquefaction Potential (Moderate)
  - High Water Table & Loose granular fill
  - Recommended Ground Improvement: Vibro-replacement/Stone Columns
- Foundation Design
  - Gravelly Sand would impede drivability of piles
  - Cast-in-place (CIP) Piles
  - End bearing in dense sand
- Excavation Design
  - Sheet Pile Walls
    - Excavation Wall Stability
    - High Water Table an Issue
  - Drainage ditches along sidewalls in pit

Select & Scale Ground Motions for Structural Design

	T=1.0 Second			T=2.0 Seconds		
Source:	M	R (km)	Percent Of Hazard (%)	M	R (km)	Percent of Hazard (%)
Nearby Faults (Seattle Fault)	6.87	8.54	23.81	6.89	8.4	28.34
Interfaces (CSZ)	8.95	125.46	32.05	8.95	125.46	39.49
Other Sources			32.07			28.24

Results from Seismic Hazard Deaggregation for Proposed Site

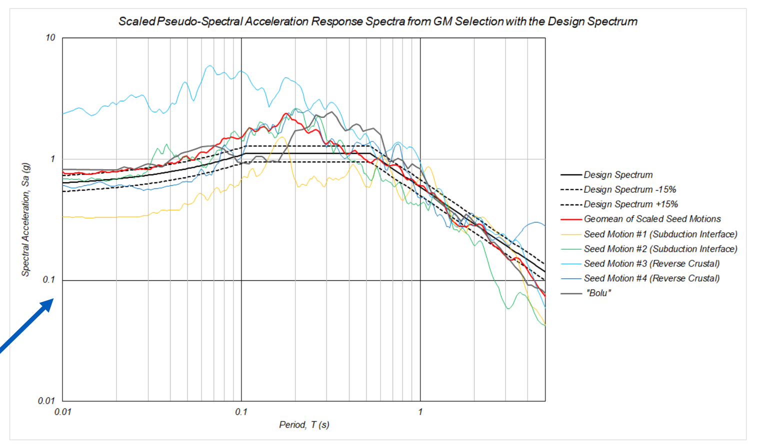
"Convert" hazard percentages to represent two hazard sources

Earthquake Location	Magnitude	Rupture Distance (km)	Vs30 (m/s)	Rupture Type
2001 Arequipa, Peru	8.4	76.7	573	Subduction (interface)
2010 Maule, Chile	8.8	64.6	621	Subduction (Interface)
2011 Tohoku, Japan	9	63.6	593	Subduction (Interface)

Earthquake Location	Magnitude	Rupture Distance (km)	Vs30 (m/s)	Rupture Type
1985 Nahanni, Canada	6.76	9.6	605	Crustal (Reverse)
1978 Tabas, Iran	7.35	2.05	767	Crustal (Reverse)

Select Seed Motions for similar magnitude, rupture distance, Vs30, and Rupture Type

Utilize seed motion data to search PEER Database and scale to match response spectrum



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Existing Structural Assessment and Structural Design of Addition

Objectives

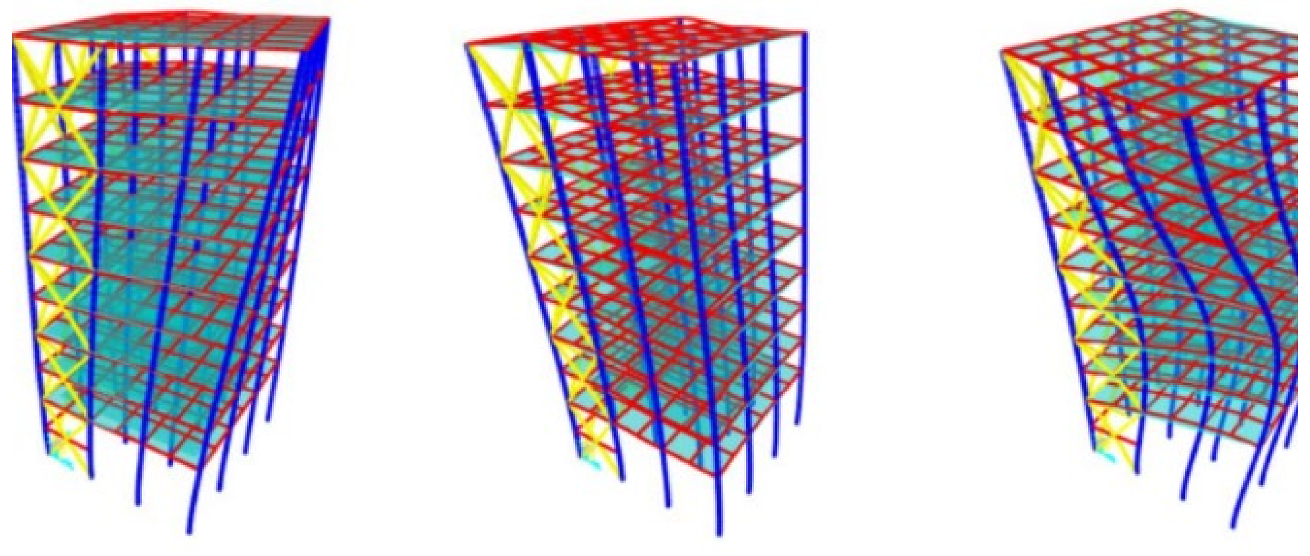
- Model and Assess existing Structure using SAP 2000
- Calculate capacity of structural members using American Wood Councill NDS
- Determine whether the existing structure fails given the calculated member capacities and a maximum Interstory Drift Ratio of 5 percent

Methodology

Used SAP 2000 to input and perform a linear time history analysis on the effects of ground motions, self weight, and applied dead load

Purpose:

- Determine the peak Interstory Drift Ratios for the structure
- Analyze mode shapes to determine the dominant mode of the structure and how many modes are to be considered for 90 percent mass participation
- Determine peak loadings and accelerations on the structure



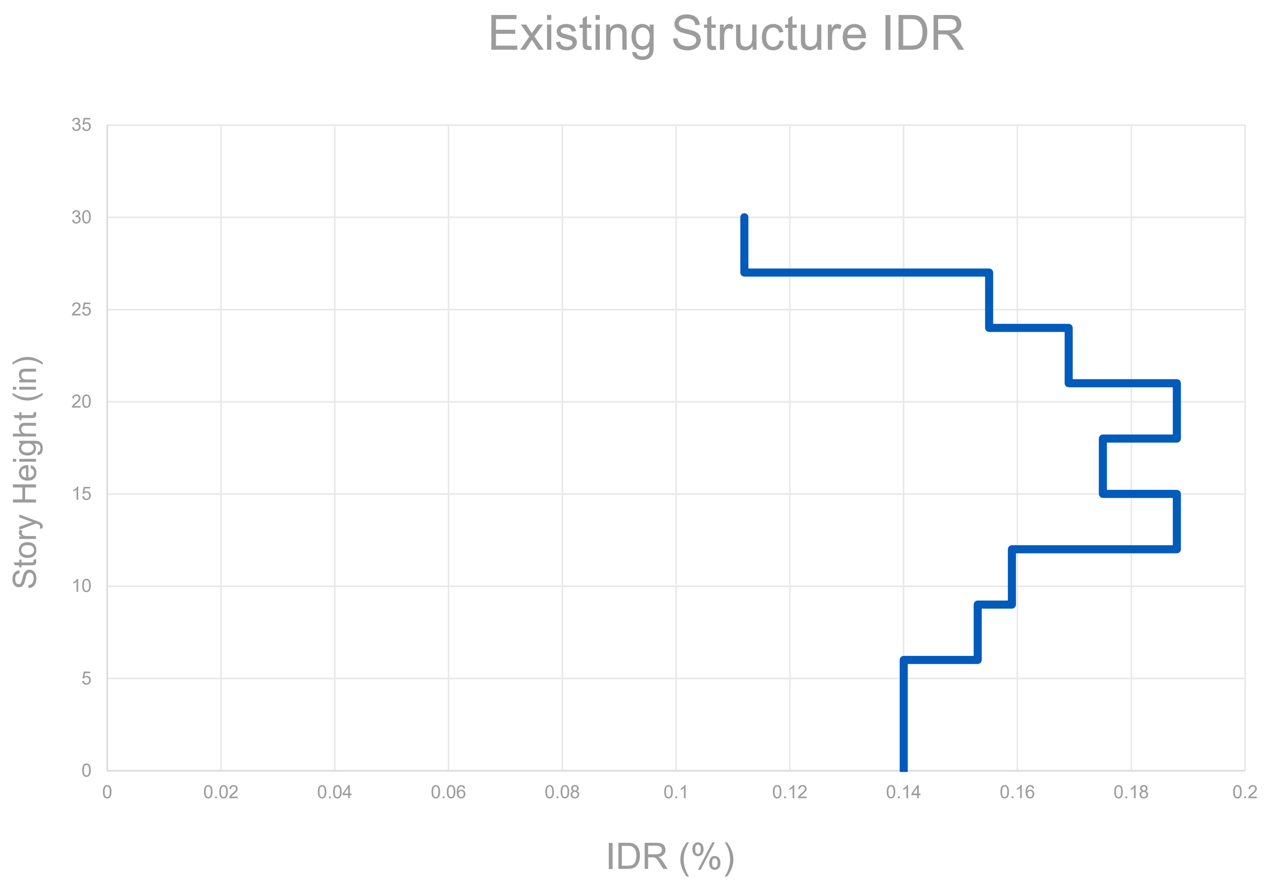
Mode Shapes of Existing Structure.

Methods

American Wood Council National Design Specification was used to determine overall capacities in shear, flexure and axial loads

Purpose:

- Find demand: Capacity ratios for the structure to determine whether individual members have reached their failure threshold
- Determine whether or not the entire structure would be at risk of failure based on the failure of critical members



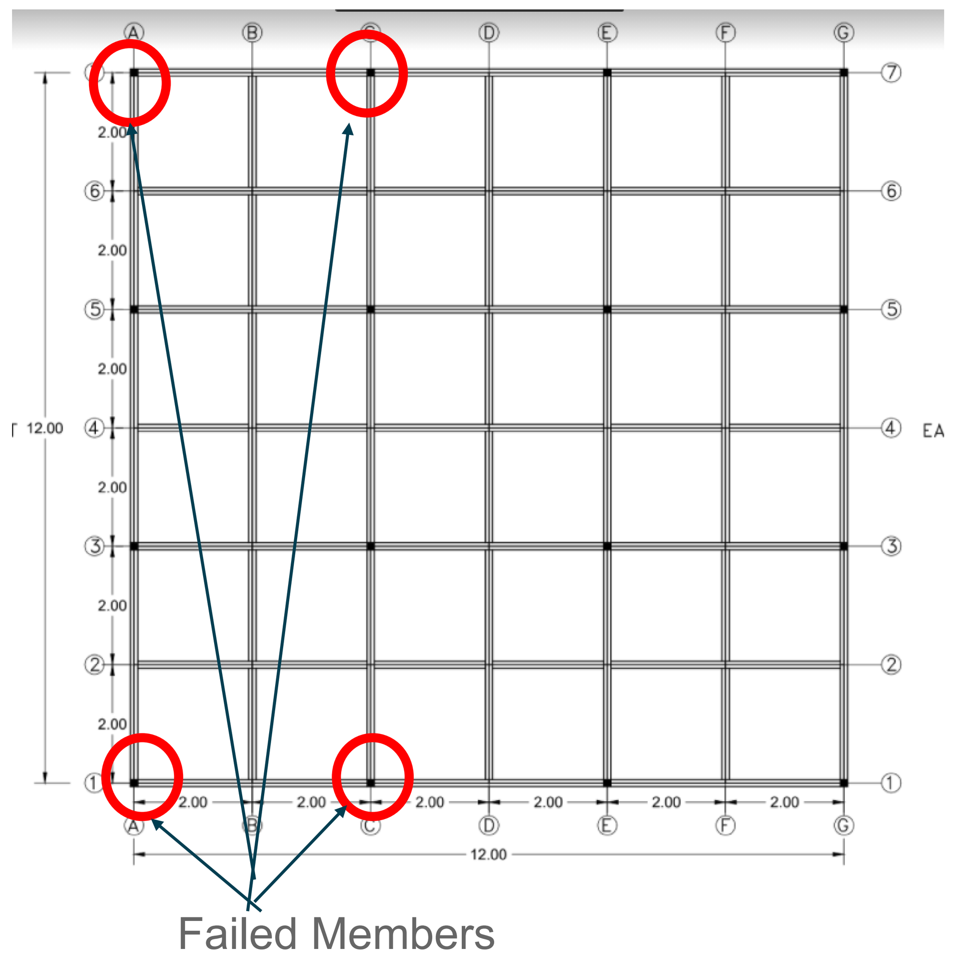
Interstory Drift Ratios For Existing Structure

Results

-All IDR Ratios Found to be Below the 5% Limit

-Demand:Capacity Ratios>1 for Columns A1 and C1 and A9 and C9 under Seismic load and self weight

- All members adequate in shear and flexural strength
- Structure has minimal resistance to torsion when subjected to North-South Shaking



Identified Critical Members

Conclusion

Based on the failures of Columns A1 and C1, we deemed that the existing structure would experience total failure due to the progressive failure of load bearing members between grids a and c. Our team recommended that the existing building be retrofitted to allow for additional bracing on the central and eastern bays of the structure once the addition is designed and constructed.

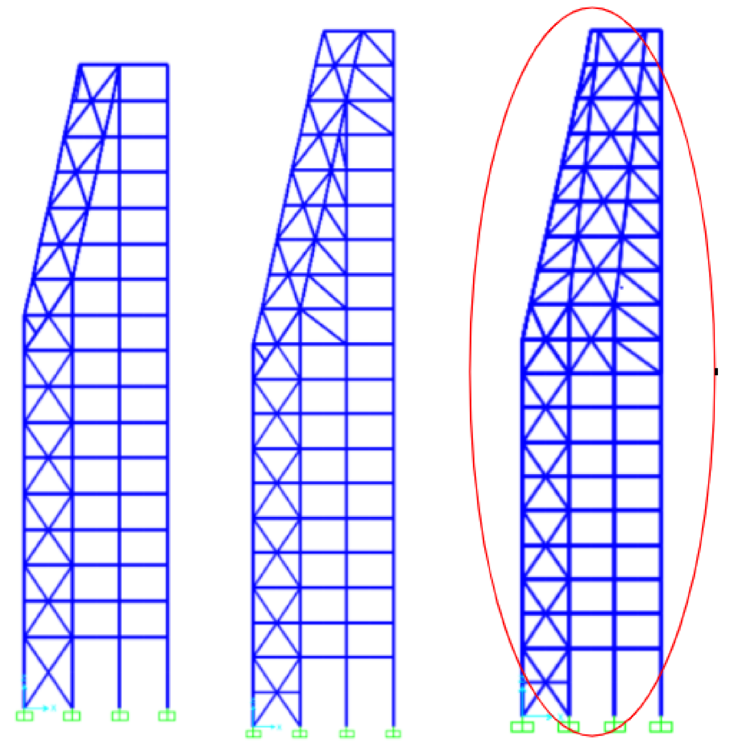
Design of Structural Addition

Main Considered Alternatives

- Super Braces with atiffened core to draw loading to the main bracing scheme of the lower structure and reduce weight. Tested for 17 and 19 floor configurations
- Added bracing to super braced core to draw loading back to columns on the eastern columns of the building
- Angled bracing with stiffened core to allow for reduction of eccentricity of the building and add stiffness once the lower structure was to be braced

Design Performance

- All Configurations deemed to fail under axial load. Design #1 sees large amounts of torsion and axial loads on columns A1 and C1
- Design #2 dissipates more force to the columns on the east face of the structure but still overloads all columns and was deemed insufficient in torsion once the structure is retrofitted
- Design #3 deemed to be the most feasible option based on its overall stiffness and inclusion of torsional considerations



Considered Additions

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Architectural & Environmental Considerations

Objectives

- Design façade of structure with consideration of Seattle and the surrounding area
- Floor Design with consideration for day-to-day operations and COVID-19 restrictions
- Planning for acquisition of LEED BD+C credentials

Methodology

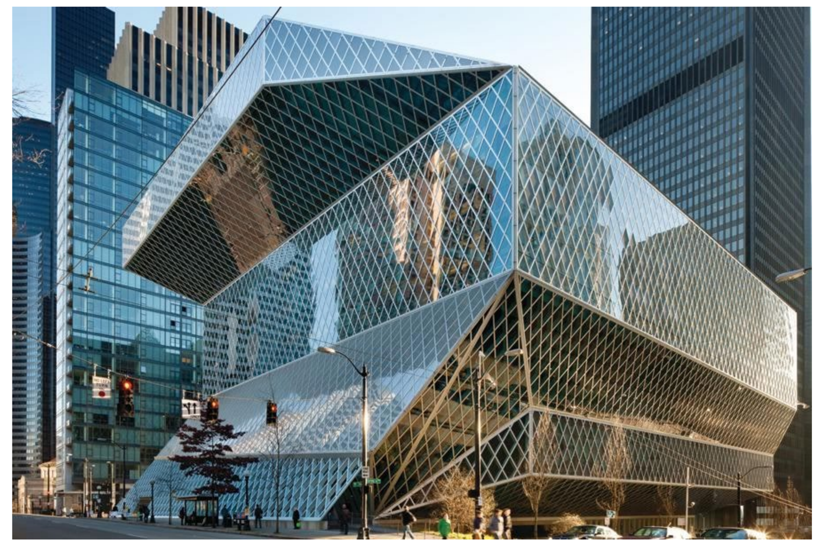
Initial research into Seattle history as well as local and international sites which may be used as inspiration for design were prioritized. Furthermore, research into acquisition of LEED credentials was done throughout the time given so that we could best plan to gain the maximum number of credits.

Seattle's F5 Tower pictured above

Research

Our first task was to research sites locally and internationally which, from our point of view, could inspire our building and the locals. Our main goal was to bring a pristine and lively look to the Seattle skyline so that the hospital not only symbolized a place for healing from illnesses but also an architectural marvel. The below mentioned and pictured sites were used as inspiration for our building.

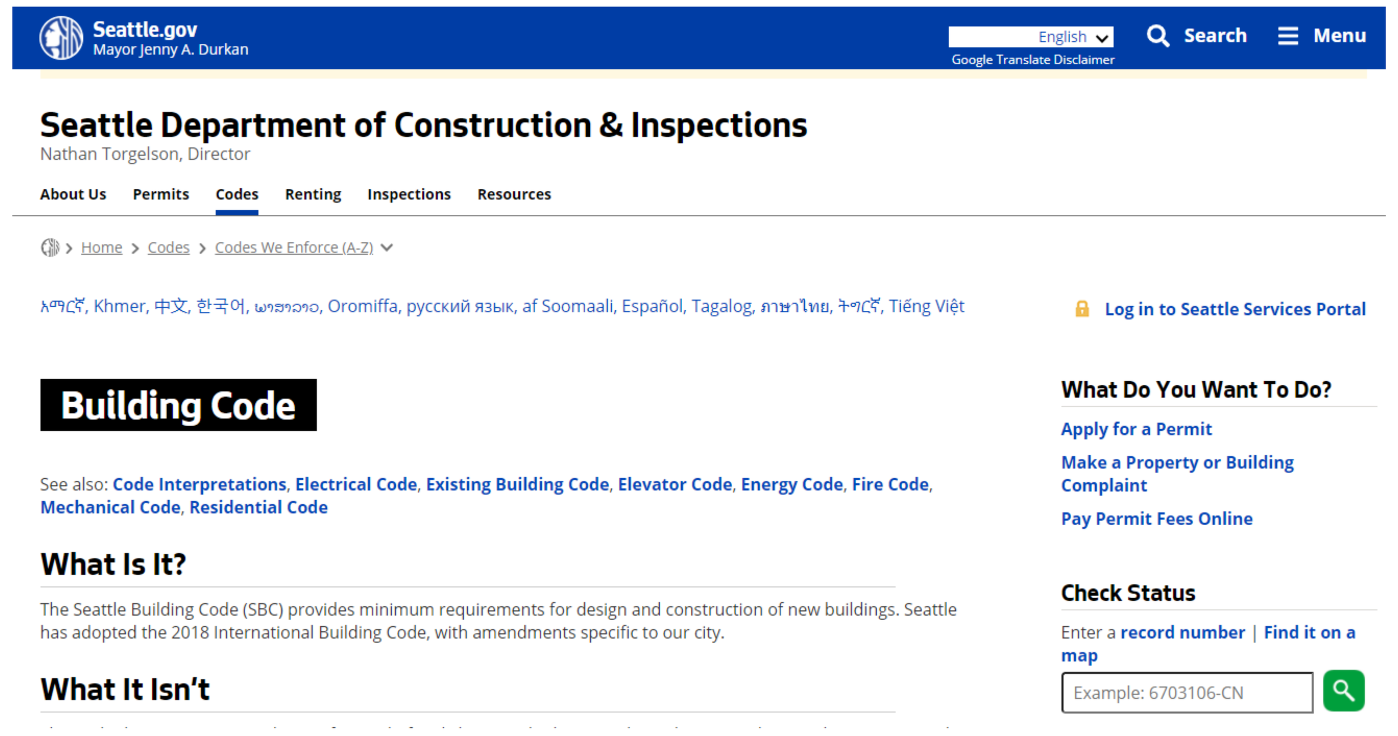
- ❖ Seattle Public Library
- ❖ Columbia Tower
- ❖ F5 Tower
- ❖ Deutsche Post Tower

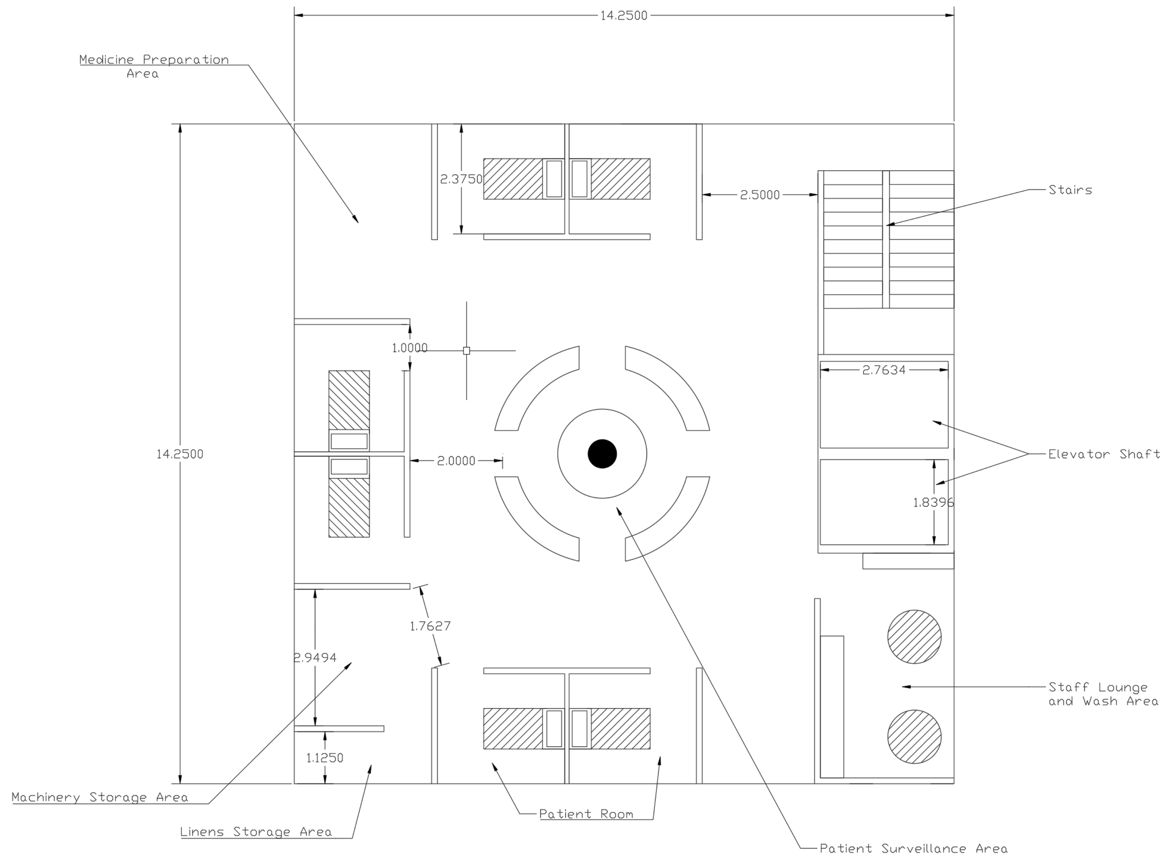


Seattle Public Library

Deutsche Post Tower

Columbia Tower



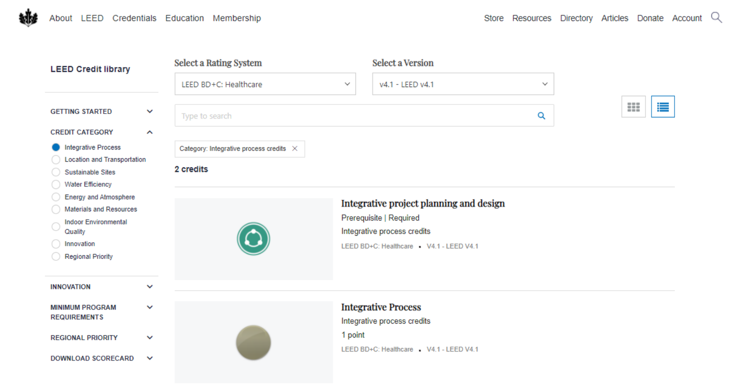


Floor Design

The next part of the deliverable was the design of the floor with respect to hospital operations. Our main goal was to not only provide a good floor plan but also to maintain COVID and state guidelines, to accomplish this we asked for help from medical professionals who have been active during the pandemic as well as the Washington State Department of Health where we got guidance for spacing requirements as well as safety and building codes.

LEED BD+C

Our final task for this deliverable was the acquisition of the LEED credentials which was aided by the site provided to the teams by the SLC.



Final Render

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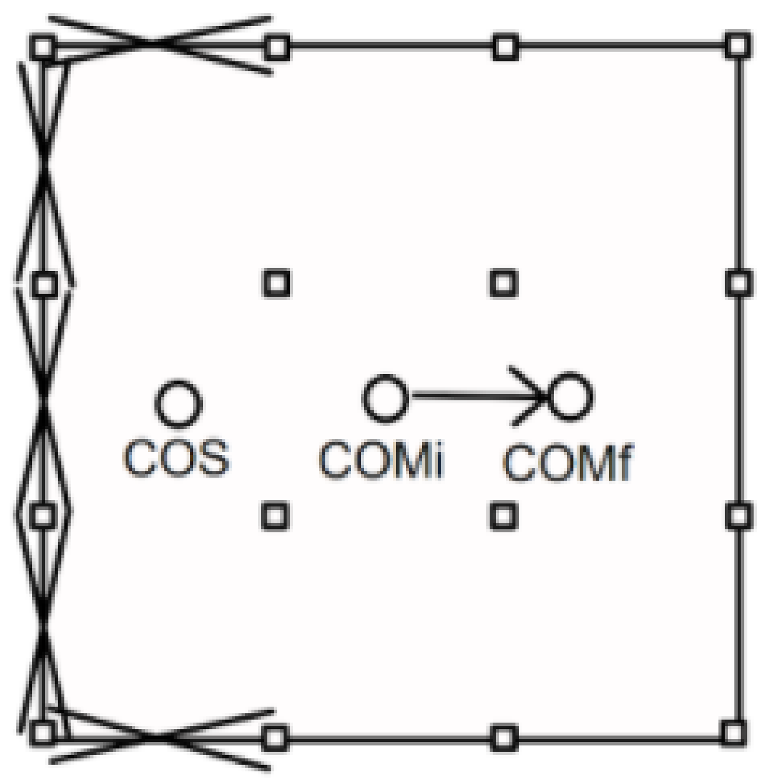
Structural Retrofit

Objectives

- After Finalizing the addition, stiffening of the existing structure in order to provide adequate stiffness and load path to the ground
- Perform iterative analysis to adjust Member sizes and add bracing
- Finalize floor area and

Design Considerations/Assumptions

- Floor width shrinkage of .67 inches per floor according to structural specification
- Weight of wood members deemed to be negligible compared to applied loads. Therefore the center of mass is shifted at .33 inches per floor.
- Eccentricity Created by the difference between the center of mass and center of stiffness Torsional effects considered in our final design



Design Considerations for Structural Addition and Retrofit

Considered Retrofit Techniques

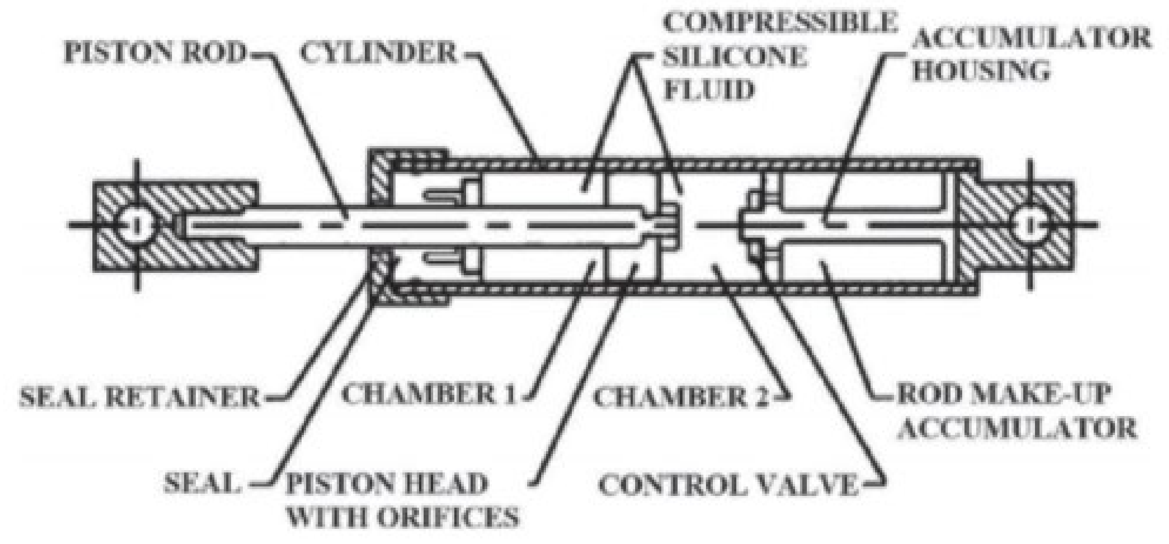
-Viscous Dampers-
-Considered for the retrofit and addition
-Not used in final design due to the existing structure being a braced frame
-Would be most effective in a moment frame. Deemed too costly to remove bracing and add in rather than stiffen the structure through added bracing

Base Isolation
- High upfront cost
-Not allowed by the rules of this competition

Column Jacketing
- Common Practice in Reinforced concrete buildings
- Added steel reinforcement and outer core to columns to increase section size and overall capacity in axial forces

Polymer Fiber Concrete
-Common method to strengthen concrete using a polymer concrete composite or steel
-Difficult to estimate strength increases in wood model

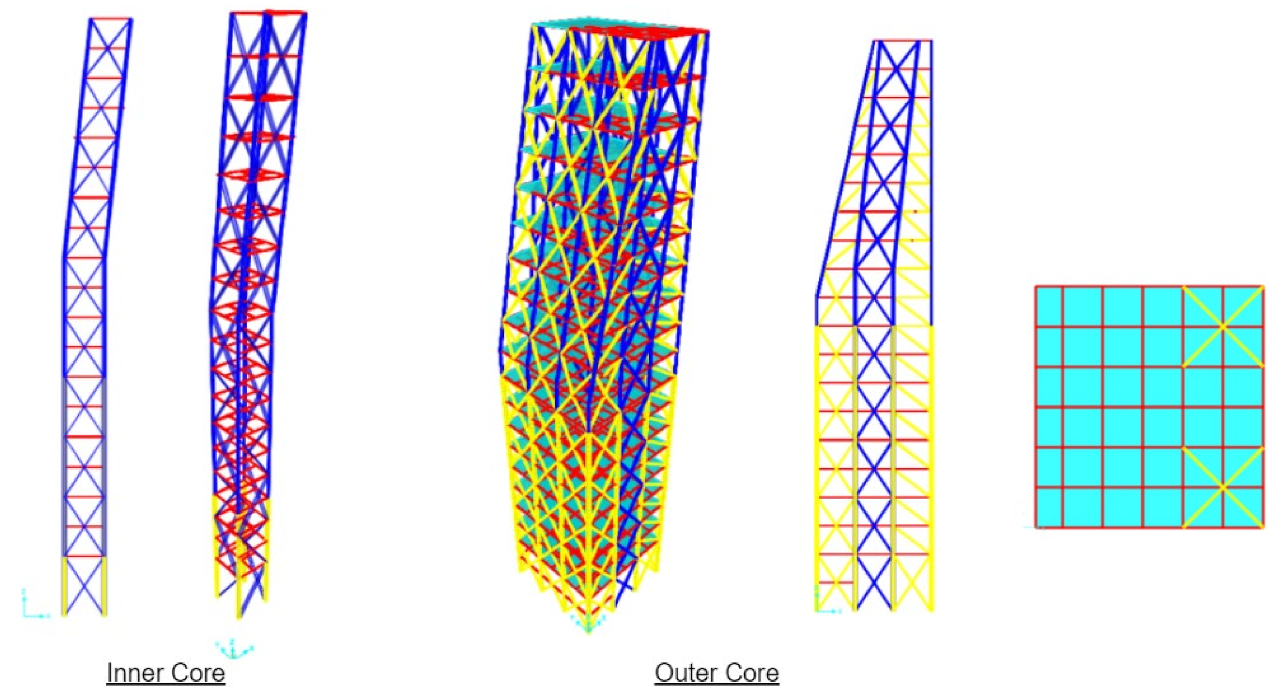
Buckling Restrained Bracing
-allows for similar compressive and tensile strengths of each brace through the steel core and tube sections
- Decided not to use as it would be too difficult to adjust material properties in SAP



Typical Viscous Damper (Taylor Devices)

Design Iterations

- Column sizes adjusted and capacities recalculated for different section sizes and effective lengths to provide adequate strength
- Built up bracing sections tested as Sections of 4, 2 and a single brace to find adequate capacities
- Center of Stiffness found for all iterations when subjected to North-South Shaking to determine design with lowest eccentricities and torsional effects



Finalized Structural Model

Design Details

- Tube in tube structure
- Continued bracing from all bays of the addition to the ground to draw load to each column equally
- Column sections increased from .2X.2 inches to .3X.3 for the inner core and .35 X.35 for outer core to account for increases in axial loading
- Built up bracing sections removed due to adequate capacity and to reduce weight

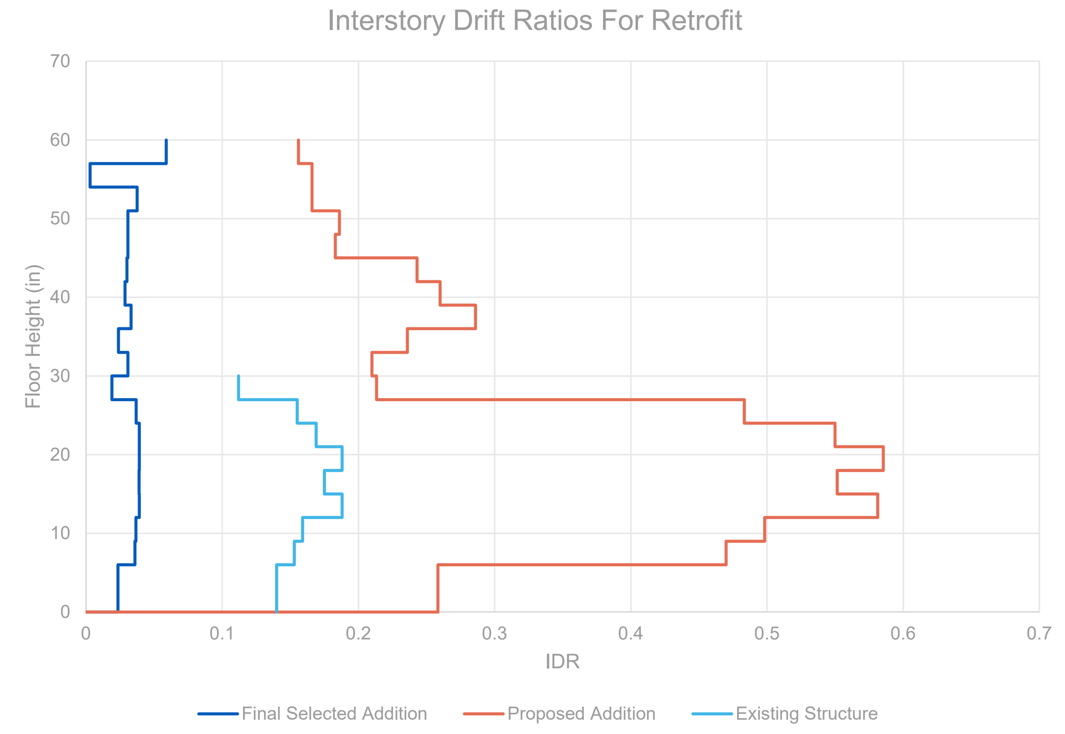
Analysis Results

-Main Mode Shapes found to be translational

- Maximum Demand:Capacity Ratios
  - -Axial-.361
  - -Shear- .00388
  - Torsional-.0949

- Interstory Drift Ratios reduced by a factor of 8.43 between addition to final building

- Floor area maximized to 2304 sq in



Final Interstory Drift Ratios

Bouvier, Charlotte A.(2003)- Techniques of Seismic Retrofitting for Concrete Structures. Massachusetts Institute of Technology

Constantinou, Michael C., Taylor, Douglas P (2010). Fluid Dampers for Applications of Seismic Energy Dissipation and Seismic Isolation. Taylor Devices

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