Structural Engineering and Mechanics

Graduate Program

CIVIL & ENVIRONMENTAL ENGINEERING

UNIVERSITY of WASHINGTON

Program Overview

- Overview
- Research
- Facilities
- Degree Programs
- Courses
- TA opportunities

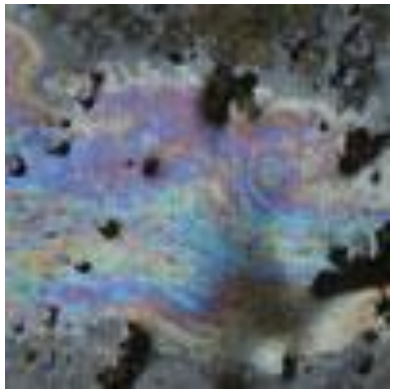
College of Engineering

AERONAUTICS AND ASTRONAUTICS	BIOENGINEERING	CHEMICAL ENGINEERING
CIVIL AND ENVIRONMENTAL ENGINEERING	COLLEGE OF ENGINEERING UNIVERSITY of WASHINGTON	COMPUTER SCIENCE AND ENGINEERING
ELECTRICAL ENGINEERING		HUMAN CENTERED DESIGN AND ENGINEERING
INDUSTRIAL AND SYSTEMS ENGINEERING	MATERIALS SCIENCE AND ENGINEERING	MECHANICAL ENGINEERING

Civil & Environmental Engineering

Within our department, we have six areas of study

Construction



Environmental

Geotechnical

Hydrology & Hydrodynamics

Structures

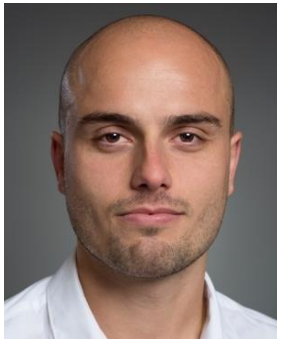
Transportation

108 Incoming Graduate Students

7 Construction
14 Environmental
7 Geotech
15 H&H
38 Structures
28 Transportation

Structural Engineering and Mechanics Faculty

Jeff Berman
Steel Structures
Structural Control



Paolo Calvi
Concrete Structures
Forensic Analysis

Marc Eberhard
Concrete Structures
Earthquake Engineering

Dawn Lehman
Concrete Structures
Performance-Based Seismic Design

Laura Lowes
Constitutive Theory
Numerical Modeling

Peter Mackenzie
Structural Stability
Numerical Modeling

Greg Miller
Solid Mechanics
Computational Methods

Mike Motley
Fluid-Structure Interaction Probabilistic Design

Charles Roeder
Steel and Composite Structures
Seismic Design

John Stanton
Concrete Structures
Seismic Isolation

Richard Wiebe
Nonlinear Dynamics
Experimental Mechanics

Close Collaborators

Geotechnical Engineering

Pedro Arduino
Computational Geomechanics

Mike Gomez
Bio-mediated Soil Improvement

Steven Kramer
Goetechnical Eq. Engineering

Brett Maurer
Soil Liquefaction Paleoseismology

Joseph Warthman
Engineering Geology Landslides

Construction and Systems Engineering

Jessica Kaminsky
Developing Communities

Amy Kim
Engineering and Energy

Joe Mahoney
Transportation and Construction

Stephen Muench
Transportation Infrastructure and Sustainability

Dorothy Reed
Wind Engineering Resilient Infrastructure

Research

- Research projects expected to hire students in the near future are listed in the following slides.
- It is expected that additional projects may be added in the future.

Impacts of Cascadia Subduction Zone M9 Earthquake

Faculty: Eberhard, Berman, Maurer (geo), Kramer (geo)

Funding: NSF, WSDOT, USGS

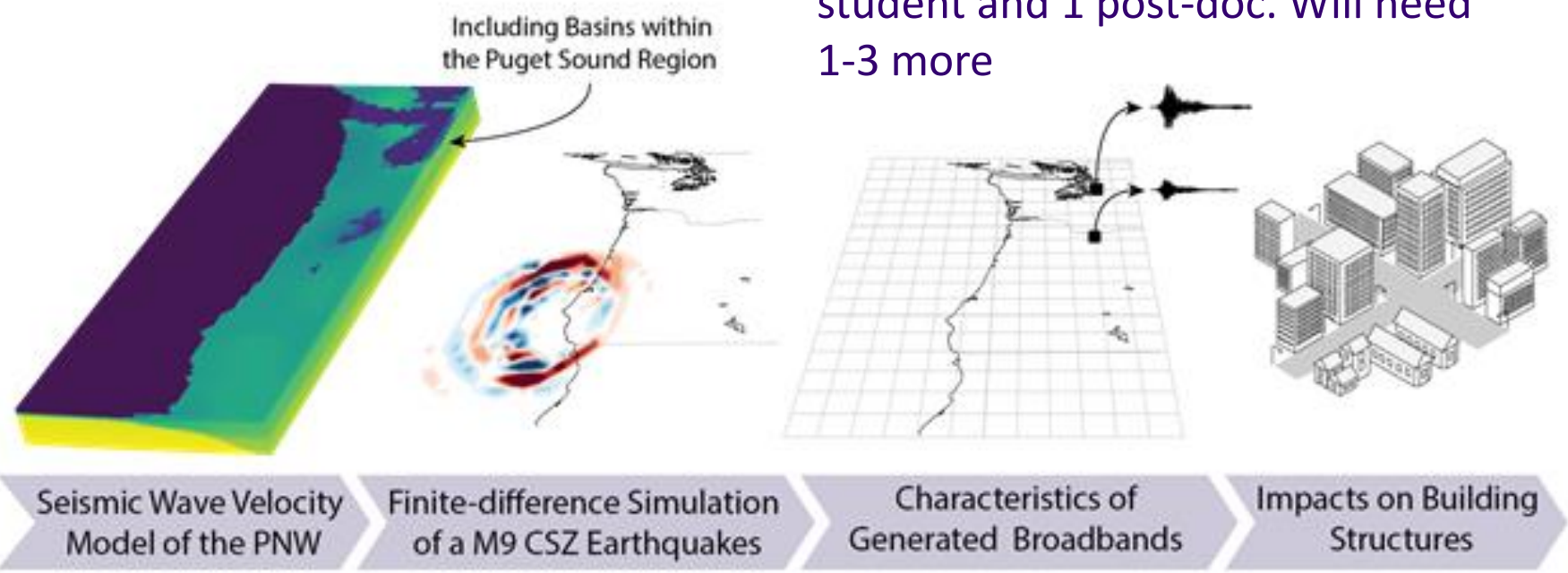
Objectives: What will CSZ M9 do to Infrastructure?

- Bridges, soil types, location

Approach:

- Analyses of systems to get demands on components
- Tests to determine component capacities

Students: Currently 1 graduate student and 1 post-doc. Will need 1-3 more

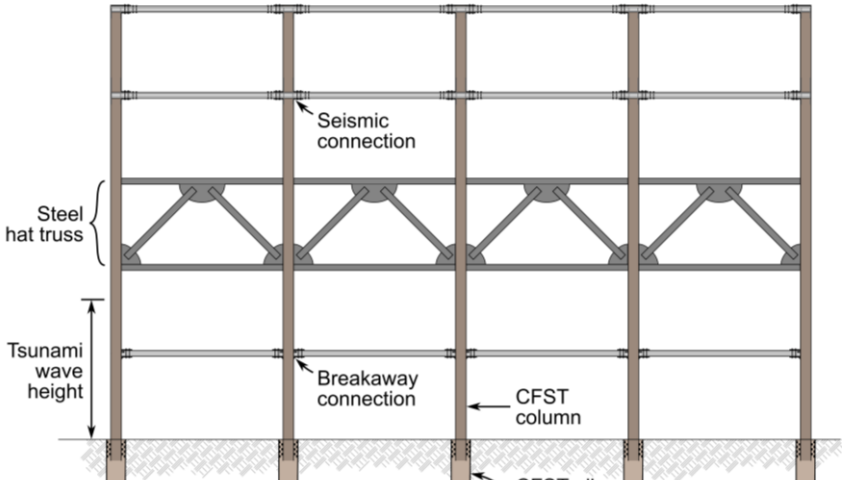


New Structural System for VES

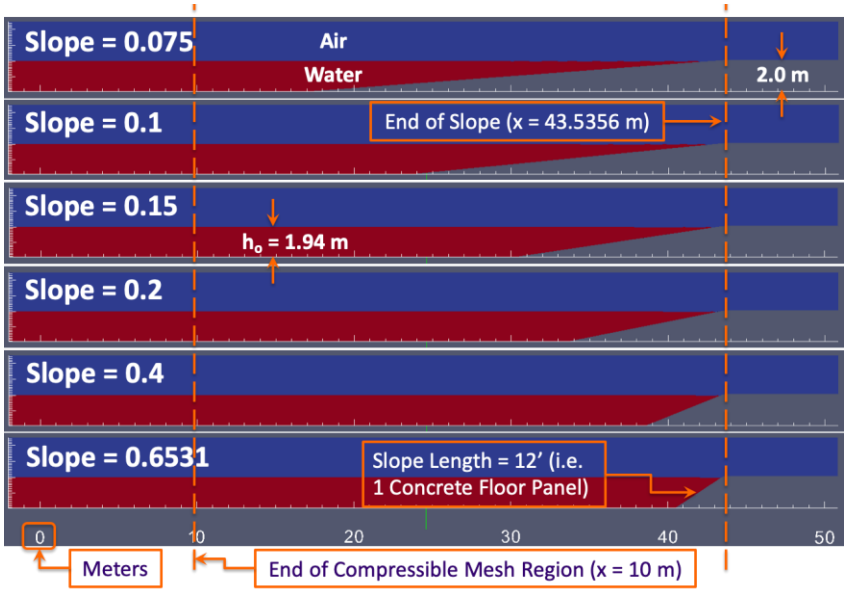
Title: Vertical Evacuation Structures Subjected to Sequential Earthquake and Tsunami Loadings. Lehman, Roeder & Motley. NSF

Research Objectives & Research Approach: Develop new system for earthquake and tsunami resistant structures. Testing of new slab-CFT column systems in UW structures lab. Testing of wall and new CFTs in OSU lab. Simulation of structures including structure-fluid interaction using OpenSees & OpenFoam

Students: Currently 3 graduate students. Hiring another 2 students in AY 2019-2020.



New Structural System



Simulation of Structure in Flume

3D Printing of Fiber-Reinforced Concrete

Faculty: Lehman and Ganter (ME)

Funding: Pactrans (NSF pending)

Objectives & Approach:

Investigate the fresh-state and hardened engineering properties of fiber reinforced cementitious material (FRCM) components using extrusion-based 3D printing.

- Design and fabricate material extrusion-based 3D printer for construction of FRCM components.
- Develop a quality control protocol to investigate voids and fiber alignment of 3D printed FRCM components using x-ray tomography
- Investigate fresh-state & properties of 3DP FRCMs

Students: Currently 1 ME graduate students. Possibly hiring 1 students in AY 2019-2020.

New Concrete Printer

Chevron Concentrically Braced Frames with Yielding Beams

Faculty: Lehman, Berman & Roeder **Funding**: AISC

Research Objectives & Approach: Permit yielding in chevron braced frames.

- Experimentally investigate the seismic response of allowing yielding of beams to optimize size. One-story and three-story frames tested with different beam sizes
- Use finite element analyses to investigate untested parameters
- Investigate dynamic response of 3, 6 and 9 story provisions

Students: Possibly hiring 1 student in AY 2019-2020.

Investigation of Hollow PSC Pile-columns

Faculty: Stanton and Calvi.

Funding Agency: WSDOT.

Problem: Hollow prestressed concrete columns, built in the 1960s are vulnerable to earthquakes by spalling internally.

Goal: Investigate behavior and design a retrofit concept, using experimental and computational methods.

Methods: Create a ductile fuse in the column directly below the cross-beam. Use it to reduce the forces elsewhere to a tolerable level. Test the fuse. Use computer models to investigate forces in other parts of the structure.

Students: Currently 2 CEE graduate students. Possibly hiring 1 student in AY 2019-2020.

Pile-column under test

High Speed Rail in Seismic Regions

Faculty: Stanton and Eberhard.

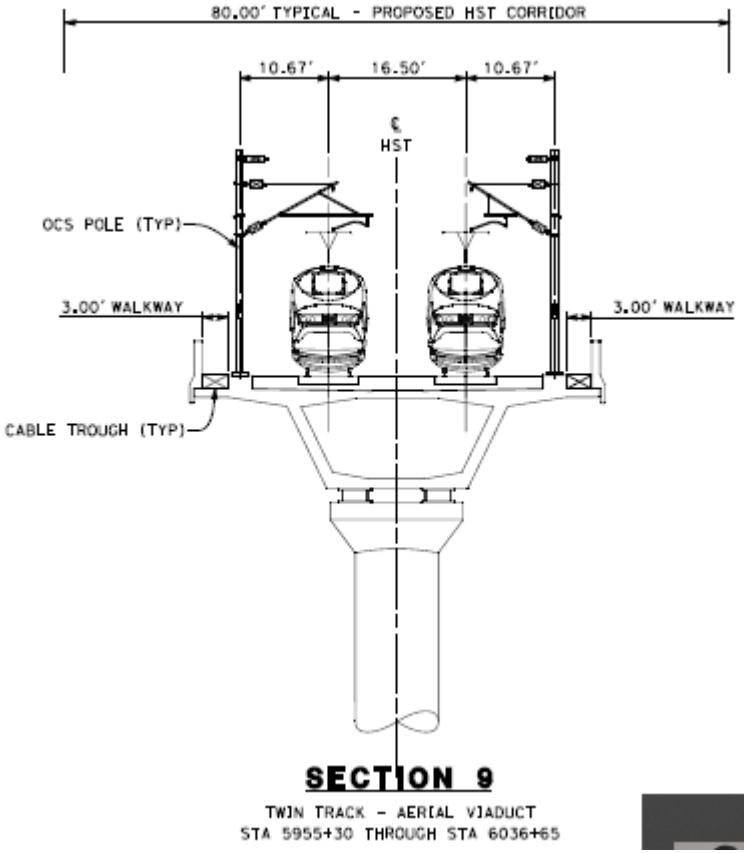
Funding Agency: FIU ABC Center, PEER.

Problem: High Speed Rail imposes stringent demands, seismic and otherwise.

Goal: Investigate existing HSR raised structures, develop high-performance structural systems for seismic regions.

Methods: Discussions with HSR authorities, designers, contractors, literature review to establish current methods. Design and computational modeling to investigate performance of new structural systems.

Students: Currently 1 CEE graduate student. Possibly hiring 1 student in AY 2019-2020.



HSR – Raised Structure

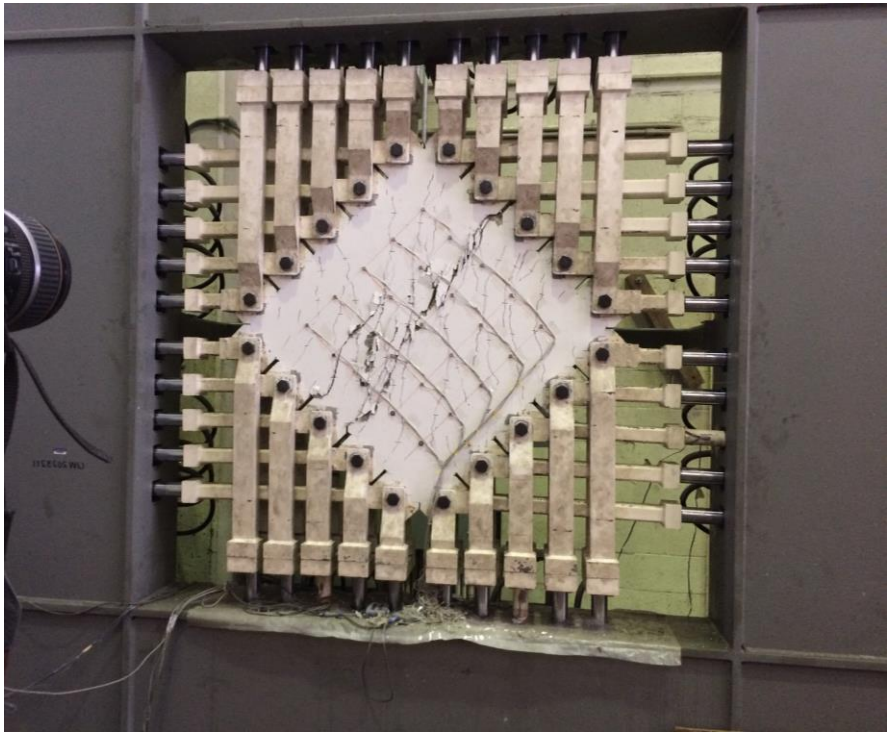
Ultra-High-Performance Concrete – Shear Strength

Faculty: Calvi and Stanton.

Funding Agency: FIU ABC Center.

Problem: **S**hear behavior of UHPC is unknown.

Goal: Investigate behavior of UHPC in shear and other combined stress states. Develop preliminary constitutive model.



UW Panel tester

Methods: Use UW "Panel tester", developed by Calvi, to impose biaxial load states. Use measured responses to characterize material constitutive behavior.

Students: Project just starting. Likely hiring 1 student in AY 2019-2020.

Local Effects & Global Structural Dynamics in Extreme Environments

Faculty: Wiebe

Funding Agency: AFOSR.

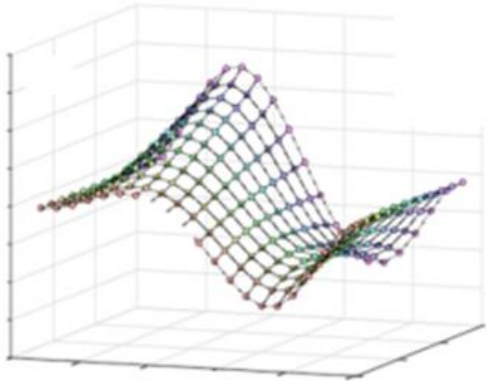
Problem: We need better predictive capability to design high-speed aircraft. High-speed flight tests are expensive, and simulation is slow.

Goal: Develop fast + efficient reduced order models for structural dynamics and damage progression.

Buckled Aero-Structures on SR-71

Methods: High-fidelity FEM coupled with efficient simplified models. Experimental validation.

Students: One postdoc, 2 graduate students. Hiring 1 next year.



Facilities

- Large-Scale Structural Research Lab
- CT Scanning facility
- NHERI RAPID Post-Disaster Rapid Response Research Facility
- Structural Vibrations Laboratory
- More Details at:
  - https://www.ce.washington.edu/research/facilities

Program Overview

Master's Degree Program

Both programs offer the flexibility to tailor a program in structural engineering to fit specific needs through both introductory and advanced electives

General Program Requirements

3 required fundamental courses

4-5 500-level structural engineering electives

0-3 credits of structures seminar

Non-thesis Program

- 15 remaining course credits – 5 courses
  - Any 500-level SEM course, approved 400-level SEM courses, approved electives outside of SEM

Research/Thesis Program

- 9 credits of CEE 700 (thesis)
- 6 remaining coursework credits – 2 courses
  - Any 500-level SEM course, approved 400-level SEM courses, approved electives outside of SEM

Students can transfer up to 6 credits of comparable coursework toward their degrees

Ph.D. Degree Program

Ph.D. Requirements

MSCE

Ph.D. Qualifying Exam

Additional Coursework

General Examination

Dissertation

Final Examination

Usually takes 4-5 years (including MSCE)

Unofficial requirement:

Find a research project

Courses

SEM Courses

Structural Analysis

- CESG 501: Structural Mechanics, 6 credits, (Autumn)
- CESG 502: Structural Dynamics, 3 credits, (Winter)
- CESG 504: Finite Element Methods in Structural Mechanics, 3 credits, (Spring)
- CESG 505: Engineering Computing (Autumn)
- CESG 506: Nonlinear Analysis of Structural Systems (Spring)
- CESG 507-1: Structural Stability (Winter – Every other year)
- CESG 507-2: Elasticity (Winter – Every other year)
- CESG 508: Materials Modeling, (Winter)
- CESG 509: Reliability and Design (Autumn)

Structural Design

- CESG 521: Advanced Reinforced Concrete (Autumn)
- CESG 522: Prestressed Concrete Design (Winter)
- CESG 523: Advanced Structural Systems (Spring)
- CESG 524: Advanced Steel (Winter)
- CESG 526: Earthquake Engineering I (Spring)
- CESG 527: Earthquake Engineering II (Autumn)
- CESG 528: Wind Engineering Design (Spring)
- CESG 529: Bridge Engineering (Winter)
- CESG 599: Advanced Steel II (Summer)

SEM Courses

Structural Analysis

- **CESG 501: Structural Mechanics, 6 credits, (Autumn)** ***REQUIRED CORE***
- **CESG 502: Structural Dynamics, 3 credits, (Winter)**
- **CESG 504: Finite Element Methods in Structural Mechanics, 3 credits, (Spring)**
- CESG 505: Engineering Computing (Autumn)
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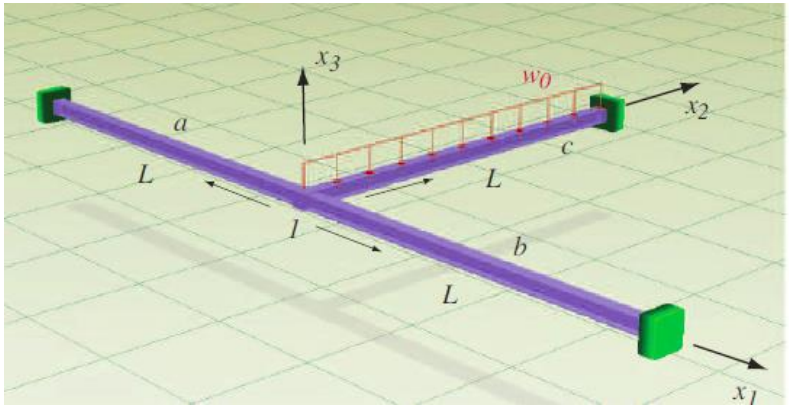
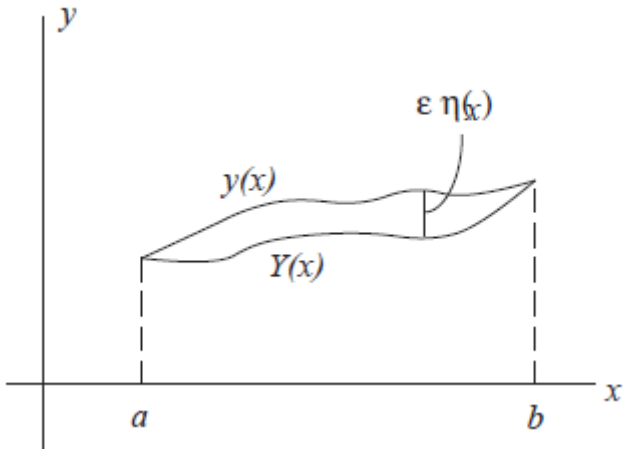
SEM Courses

CESG 501: Structural Mechanics *(Wiebe)*



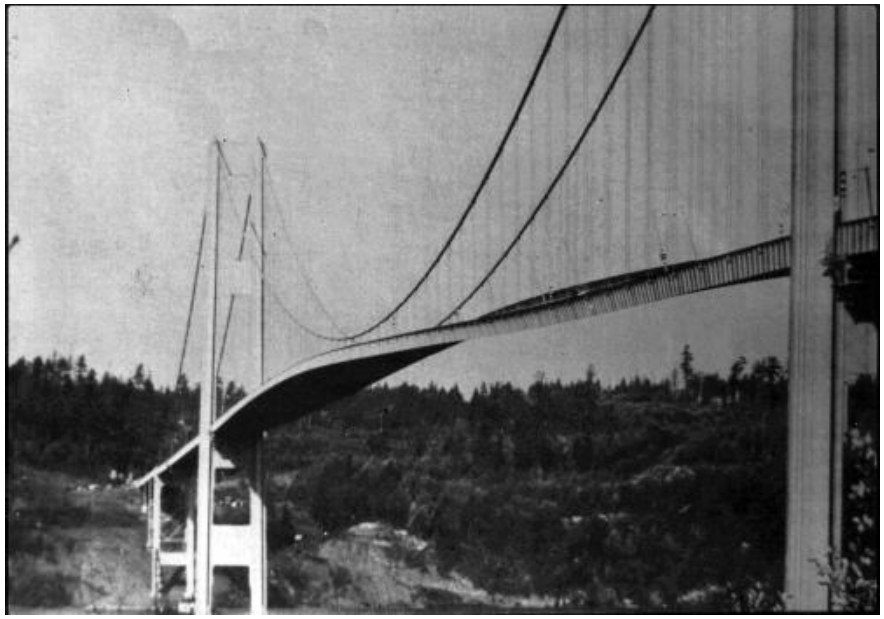


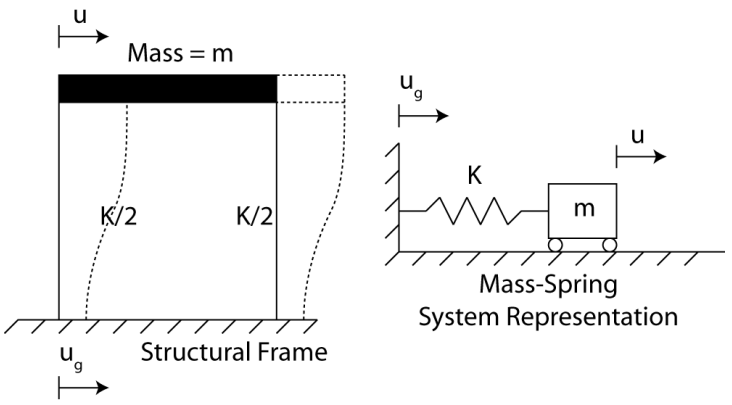
- Direct and variational formulations of stiffness method.
- Beams, trusses, frames
- Buckling of systems
- Driver's license on integral and variational methods for mechanics.
- background for later coursework

- **4-credits**

SEM Courses

CESG 502: Structural Dynamics *(Calvi)*

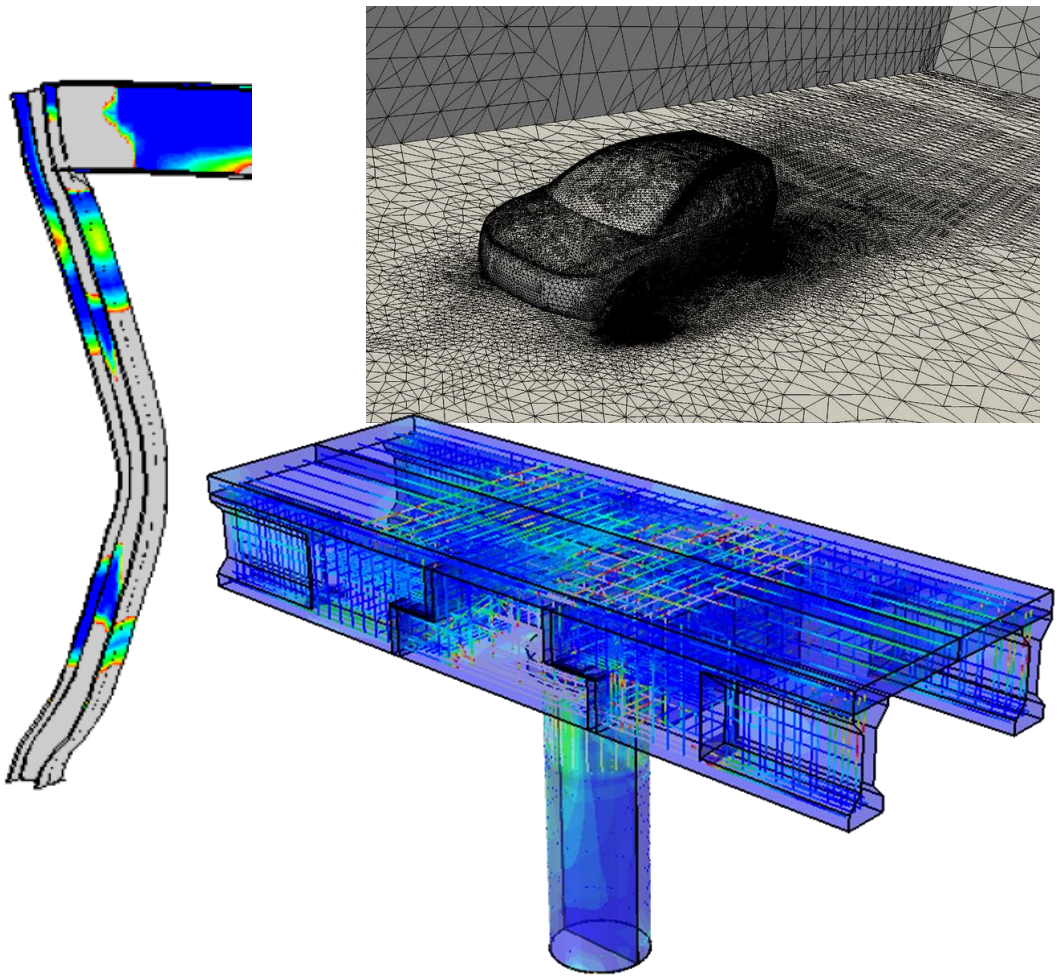




- Study of the dynamic vibration of deformable bodies and structures, including free and forced vibrations of linear, single, and multiple degree of freedom systems and the effects of damping.
- Analysis in the time and frequency domains by time history and by response spectrum methods.
- Numerical methods for solutions of linear dynamic systems.
- Free and forced vibrations of continuous systems and wave propagation in rods and beams.
- **4-credits**

SEM Courses

CESG 504: Finite Element Methods in Structural Mechanics *(Motley)*



- Extension of the matrix methods of structural analysis to the solution of multi-dimensional structural mechanics problems by use of finite element approximations.
- Discussion of convergence and bounding and extension to investigation of stability and finite deformations.
- 4-credits

SEM Courses

Structural Analysis

- CESG 501: Structural Mechanics, 6 credits, (Autumn)
- CESG 502: Structural Dynamics, 3 credits, (Winter)
- CESG 504: Finite Element Methods in Structural Mechanics, 3 credits, (Spring)
- **CESG 505: Engineering Computing (Autumn)**
- **CESG 506: Nonlinear Analysis of Structural Systems (Spring)**
- **CESG 507-1: Structural Stability (Winter – Every other year)**
- **CESG 507-2: Elasticity (Winter – Every other year)**
- **CESG 508: Materials Modeling, (Winter)**
- **CESG 509: Reliability and Design (Autumn)**

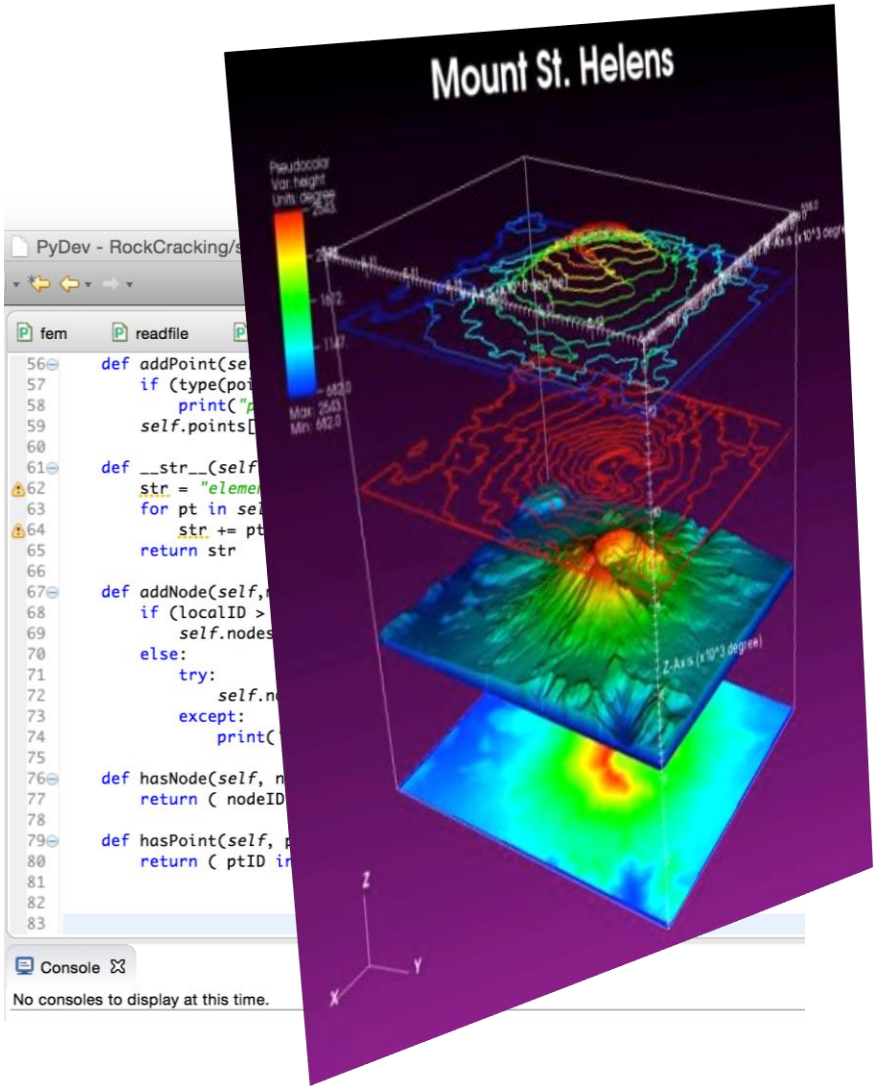
ANALYSIS ELECTIVES

Structural Design

- CESG 521: Advanced Reinforced Concrete (Autumn)
- CESG 522: Prestressed Concrete Design (Winter)
- CESG 523: Advanced Structural Systems (Spring)
- CESG 524: Advanced Steel (Winter)
- CESG 526: Earthquake Engineering I (Spring)
- CESG 527: Earthquake Engineering II (Autumn)
- CESG 528: Wind Engineering Design (Spring)
- CESG 529: Bridge Engineering (Winter)
- CESG 599: Advanced Steel II (Summer)

SEM Courses

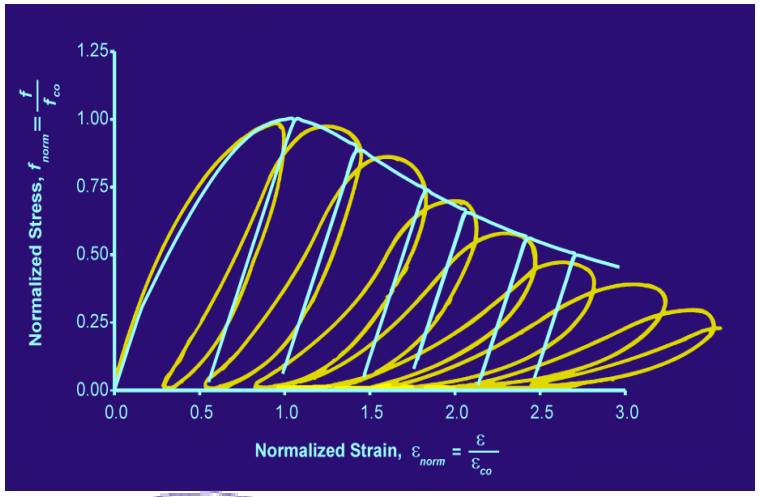
CESG 505: Engineering Computing *(Mackenzie)*

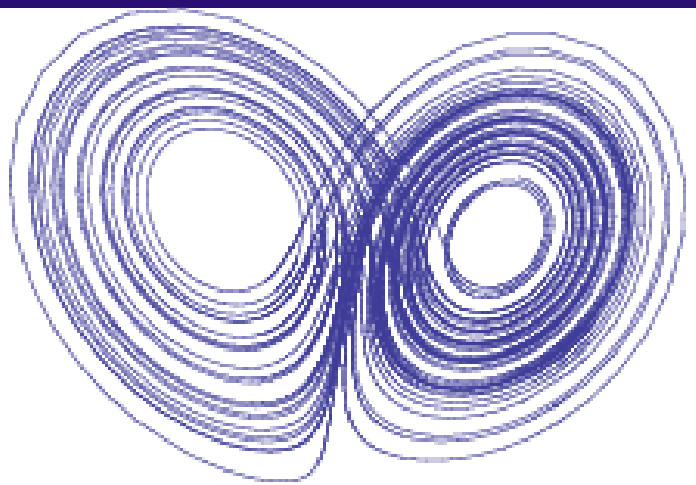


- Applied computing in civil and environmental engineering contexts.
- Programming in python (procedures, OOP, scripting and more)
- SQL database systems for collecting, managing, and analyzing large data sets (experimental, sensor, and synthetic data).
- Distributed computing.
- Image processing and Visualization concepts

SEM Courses

CESG 506: Nonlinear Analysis of Structural Systems *(Motley)*

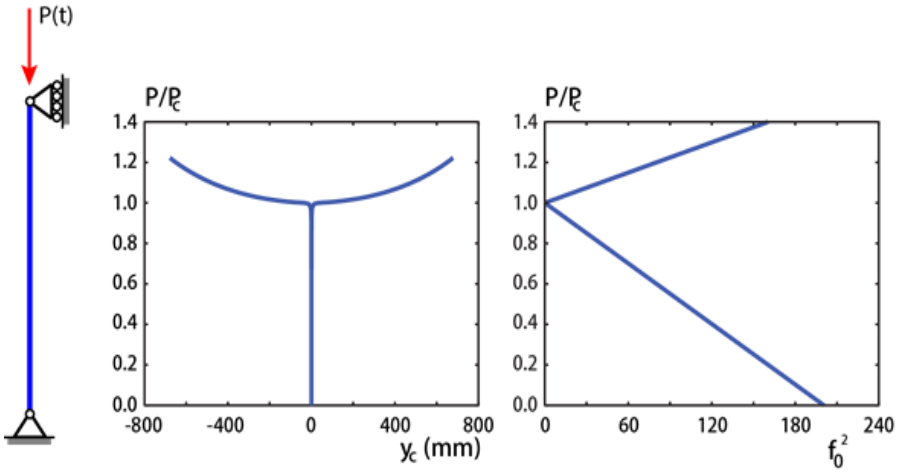


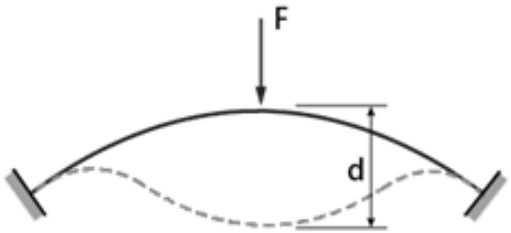


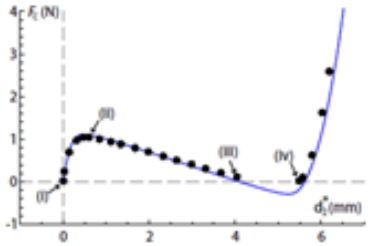
- Formulation, solution, and interpretation of nonlinear numerical models of structural systems.
- Solutions procedures for nonlinear system; truss, frame and continuum element formulations including material and geometric nonlinearities.
- Matlab programming of solution algorithms and element formulations. Use of commercial software.

SEM Courses

CESG 507-1: Structural Stability *(Wiebe)*



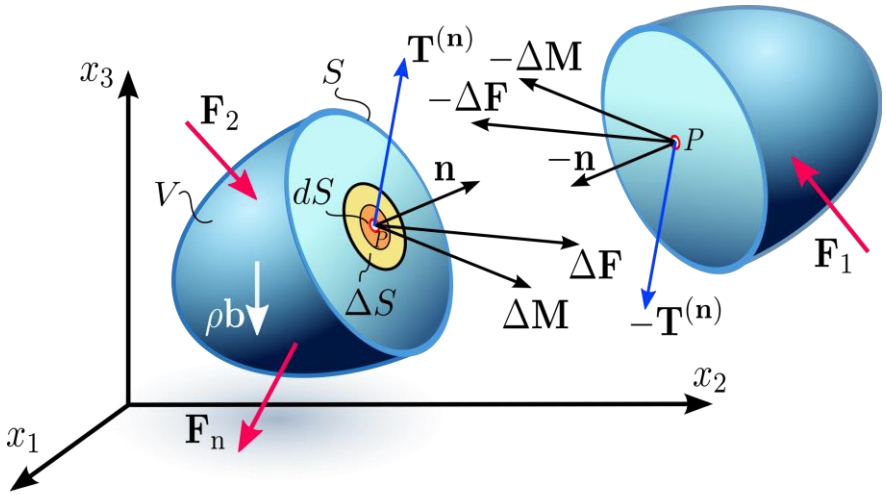


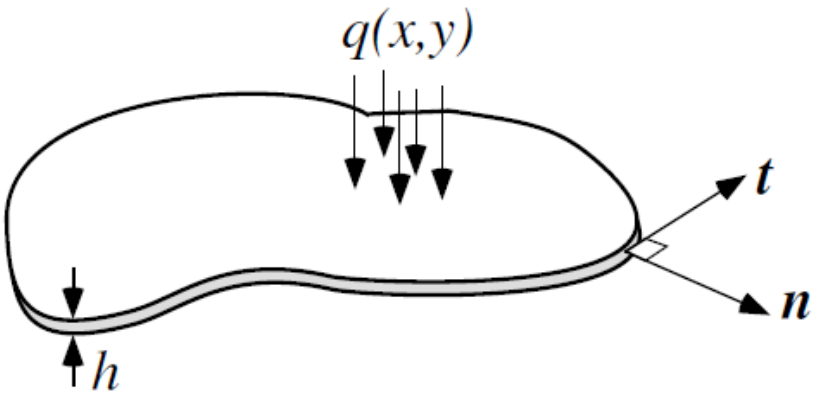


- Concepts of stability of equilibrium states.
- Stability of columns with various boundary conditions and loads.
- Determination of critical loads for structural systems with analytical and approximate methods.
- Inelastic buckling of columns and lateral buckling of beams.

SEM Courses

CESG 507-2: Elasticity *(Wiebe)*



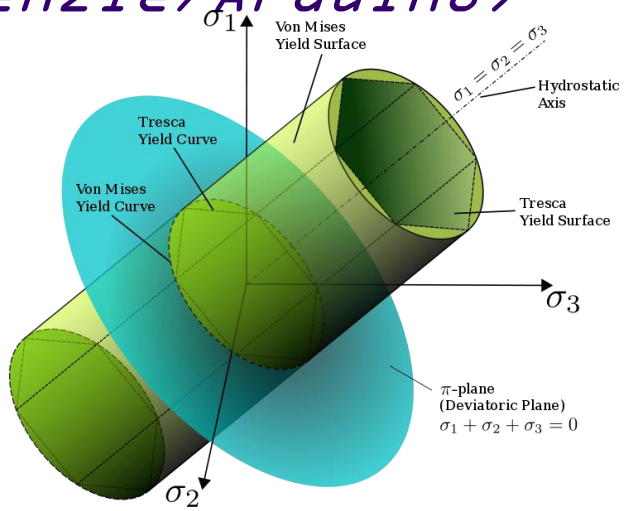


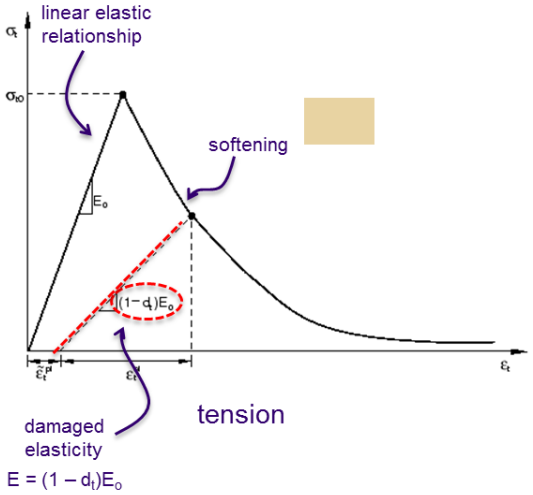
- Fundamentals of 3D structural mechanics – Equilibrium, Compatibility/Kinematics, Constitutive/Material Laws
- Focus on linear, elastic regime, which allows for some closed form analysis.
- Classical solutions of torsion, beams, and subsurface loads.
- Dovetails into FEM.

SEM Courses

CESG 508: Materials Modeling

(Mackenzie/Arduino)

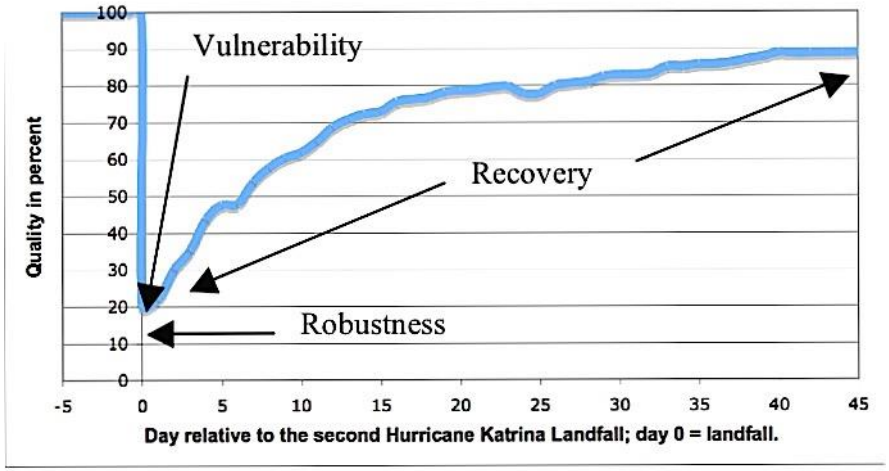


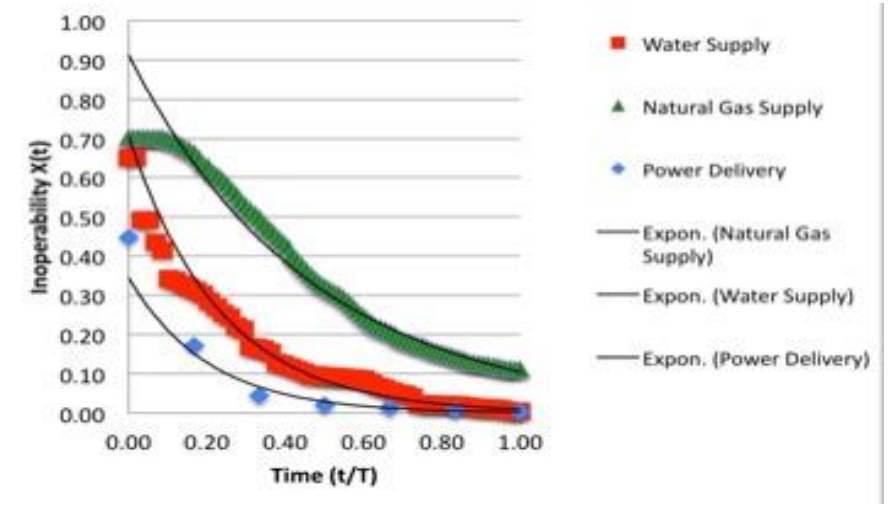


- Inelastic behavior of materials
- Creep, stress relaxation, elastic-plastic behavior.
- Effect of cyclic and other non-proportional loading.
- Damping and friction (Dissipation).
- Numeric algorithms and implementation for 2D and 3D models.
- Intro to anisotropic and composite materials.

SEM Courses

CESG 509: Reliability and Design *(Reed)*





- Introduction to theory of structural reliability and its application to design procedures in civil engineering, including probability theory
- Assessment of uncertainties
- Code specification and the related concept of risk and the influence of socioeconomic factors
- Loads, load combinations, and probabilities of damage.

SEM Courses

Structural Analysis

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Structural Design

- **CESG 521: Advanced Reinforced Concrete (Autumn)**
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- **CESG 599: Advanced Steel II (Summer)**

DESIGN ELECTIVES

SEM Courses

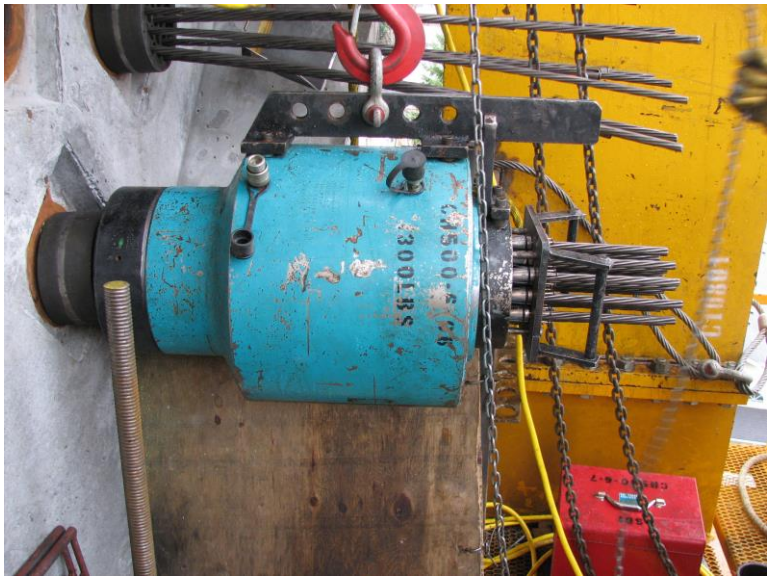
CESG 521: Advanced Reinforced Concrete *(Eberhard)*

- Reinforced concrete behavior, analysis and design.
- Fundamental material behavior including confined concrete and cyclic response of reinforcing steel.
- Development of full nonlinear behavior of flexural components, including moment-curvature response and plastic hinge analysis tools.
- Shear design including strut and tie modeling and bi-directional loading of columns.
- Introductory topics in seismic design including moment frames and columns.

SEM Courses

CESG 522: Prestressed Concrete Design
(Stanton)

- Analysis, design, and construction of prestressed concrete structures.



SEM Courses

CESG 523: Advanced Structural Systems
(Stanton)

- Examines structural design of floor systems for buildings, including one-way and two-way slabs, strip method, yield line theory, prestressed concrete slabs.
- Lateral load resisting systems for buildings.

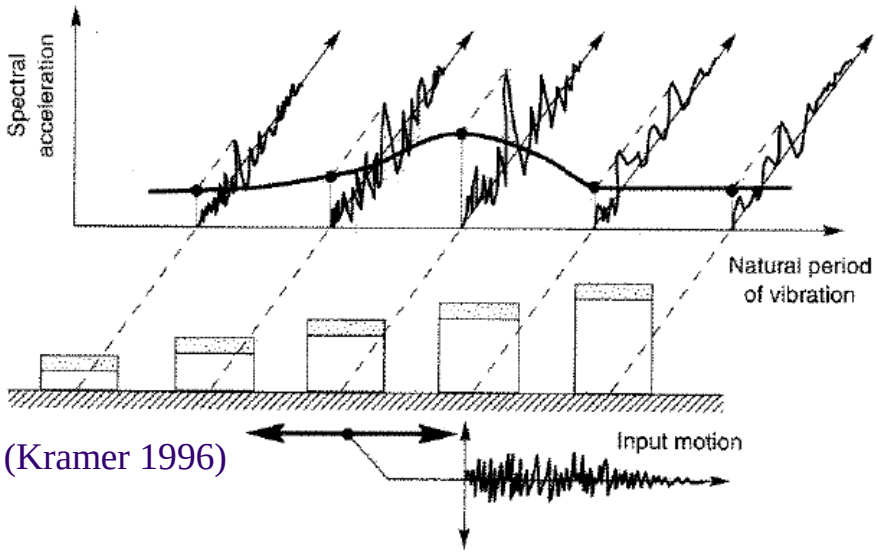
SEM Courses

CESG 524: Advanced Steel Design *(Berman)*

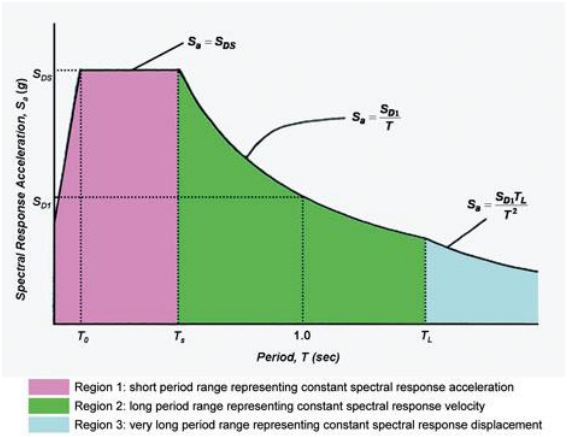
- Factors influencing strength and serviceability of steel structures.
- LRFD limit state design procedures.
- Use of theories of plasticity and stability in development of design methods and specifications.
- Bolted and welded connections, temperature effects, and affect of different fabrication methods on behavior of structure.

SEM Courses

CESG 526: Earthquake Engineering I *(Calvi)*



(Kramer 1996)



- Earthquake mechanism and ground shaking, response spectra, linear elastic methods for prediction of behavior.
- Displacement prediction methods for inelastically behaving structures, modeling and solution schemes, earthquake design philosophy, capacity design.
- Reinforced concrete, steel, and base-isolated structures.

SEM Courses

CESG 526: Earthquake Engineering II
(Berman)

- Performance-based design, development of fragility curves.
- Characteristics and effects of ground-shaking records.
- Passive and active control.
- Dynamic inelastic time history analysis.
- Design of parts, system detailing.
- Soil-structure interaction.
- Repair and retrofit of structures.

SEM Courses

CESG 528: Wind Engineering Design *(Reed)*

- Wind effects on structures, including atmospheric boundary layer flow.
- Bluff body aerodynamics
- Structural dynamics and aeroelasticity
- Development and use of the ASCE Standards
- Estimation of along-wind, across-wind, and torsional response of tall buildings
- Design strategies for avoiding wind-induced discomfort.

SEM Courses

CESG 529: Bridge Engineering

- Design of decks, joints, girders, columns and foundations.
- Gravity loads and seismic loading.

CEE 500: Seminars

There are several seminars options available. Up to three credits may be used toward degree

Department-Wide Seminars

- Great presentations
- Broad civil engineering topics
- Wenk/Evans/Burgess

Structural Engineering Practice

- Local structural engineering firms
- MKA, KPFF, CPL, DCI, etc.
- Buildings and Bridges

Research and Presentation

- Enrolled students research and present a "hot topic" in structural engineering
- Additional presentation on active UW research

SEM Courses

Structural Analysis

- CESG 501: Structural Mechanics, 6 credits, (Autumn)
- CESG 502: Structural Dynamics, 3 credits, (Winter)
- CESG 504: Finite Element Methods in Structural Mechanics, 3 credits, (Spring)
- CESG 505: Engineering Computing (Autumn)
- CESG 506: Nonlinear Analysis of Structural Systems (Spring)
- CESG 507-1: Structural Stability (Winter – Every other year)
- CESG 507-2: Elasticity (Winter – Every other year)
- CESG 508: Materials Modeling, (Winter)
- CESG 509: Reliability and Design (Autumn)

Structural Design

- **CESG 521: Advanced Reinforced Concrete (Autumn)**
- **CESG 522: Prestressed Concrete Design (Winter)**
- **CESG 523: Advanced Structural Systems (Spring)**
- **CESG 524: Advanced Steel (Winter)**
- **CESG 526: Earthquake Engineering I (Spring)**
- **CESG 527: Earthquake Engineering II (Autumn)**
- **CESG 528: Wind Engineering Design (Spring)**
- **CESG 529: Bridge Engineering (Winter)**
- **CESG 599: Advanced Steel II (Summer)**

DESIGN ELECTIVES

SEM Courses

Course offerings for the 2017-2018 academic year

Autumn	Winter	Spring	Summer
CESG 501	CESG 502	CESG 504	TBD
CESG 505	CESG 507	CESG 523	
CESG 509	CESG 508	CESG 526	
CESG 521	CESG 522	CESG 528	
CESG 527	CESG 524		
	CESG 529		

Sample CEE Electives Outside of Structures

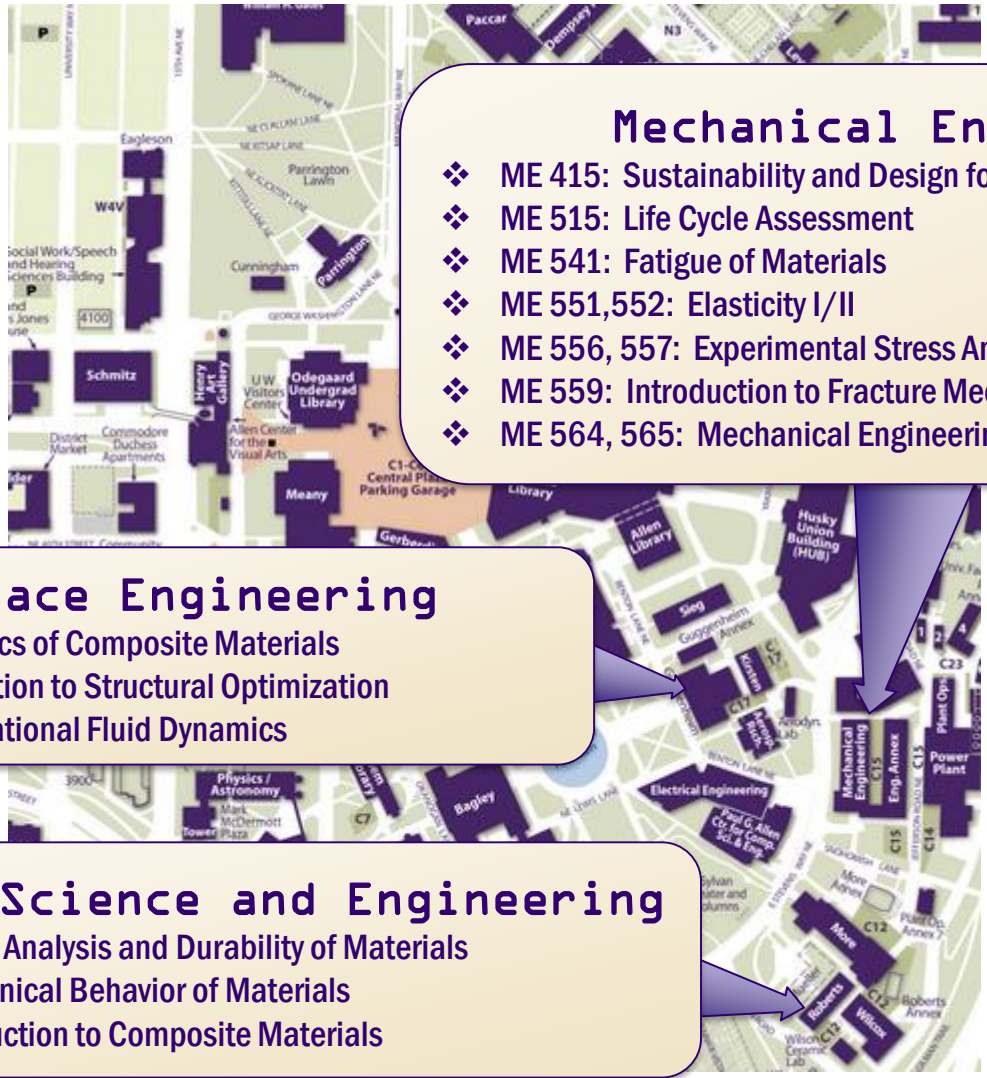
We encourage you to take electives from other disciplines within the department

- Infrastructure Construction
- Reinforced Concrete Construction
- Energy and the Environment
- Geotechnical Earthquake Engineering
- Hydrodynamics
- Introduction to Wind Turbine Design
- Advanced Foundations Engineering
- Geohazards

Sample Courses Outside of CEE

Outside of the department, there are many recommended options, including

College of Engineering



Mechanical Engineering

- ME 415: Sustainability and Design for the Environment
- ME 515: Life Cycle Assessment
- ME 541: Fatigue of Materials
- ME 551,552: Elasticity I/II
- ME 556, 557: Experimental Stress Analysis I/II
- ME 559: Introduction to Fracture Mechanics
- ME 564, 565: Mechanical Engineering Analysis I/II

Aerospace Engineering

- AA 532: Mechanics of Composite Materials
- AA 538: Introduction to Structural Optimization
- AA 543: Computational Fluid Dynamics

Materials Science and Engineering

- MSE 431: Failure Analysis and Durability of Materials
- MSE 462: Mechanical Behavior of Materials
- MSE 475: Introduction to Composite Materials

Sample Courses Outside of CEE

Outside of the department, there are many recommended options, including

College of the Built Environment

Architecture

- ARCH 521: Structural Planning and Design
- ARCH 537: Traditional Building Methods: New Adaptations
- ARCH 538: Building Reuse Seminar
- ARCH 578: Case Studies in Contemporary Architecture

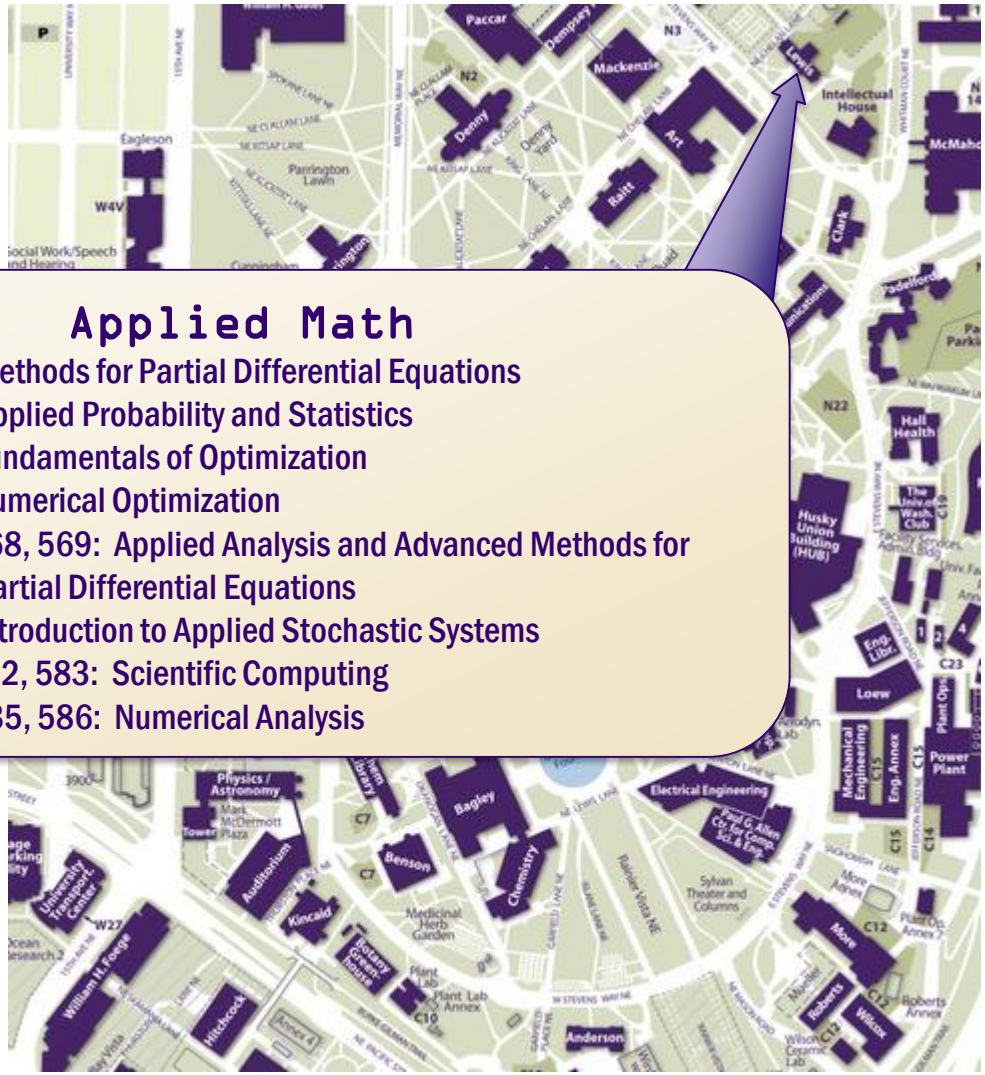
Construction Management

- CM 404: Integrated Design/Build Studio
- CM 450: Construction Project Management
- CM 500: Design and Construction Law
- CM 505: Advanced Integrated Computer Applications
- CM 510: Advanced Construction Technique
- CM 515: Innovative Project Management Concepts
- CM 530: Project Economics and Risk Analysis
- CM 540: Sustainable Construction
- CM 560: Design-Building Project Management
- CM 580: Temporary Structures

Sample Courses Outside of CEE

Outside of the department, there are many recommended options, including

College of Arts and Sciences



Applied Math

- AMATH 503: Methods for Partial Differential Equations
- AMATH 506: Applied Probability and Statistics
- AMATH 515: Fundamentals of Optimization
- AMATH 516: Numerical Optimization
- AMATH 567, 568, 569: Applied Analysis and Advanced Methods for Ordinary and Partial Differential Equations
- AMATH 572: Introduction to Applied Stochastic Systems
- AMATH 581, 582, 583: Scientific Computing
- AMATH 584, 585, 586: Numerical Analysis

TA Opportunities for Incoming Graduate Students

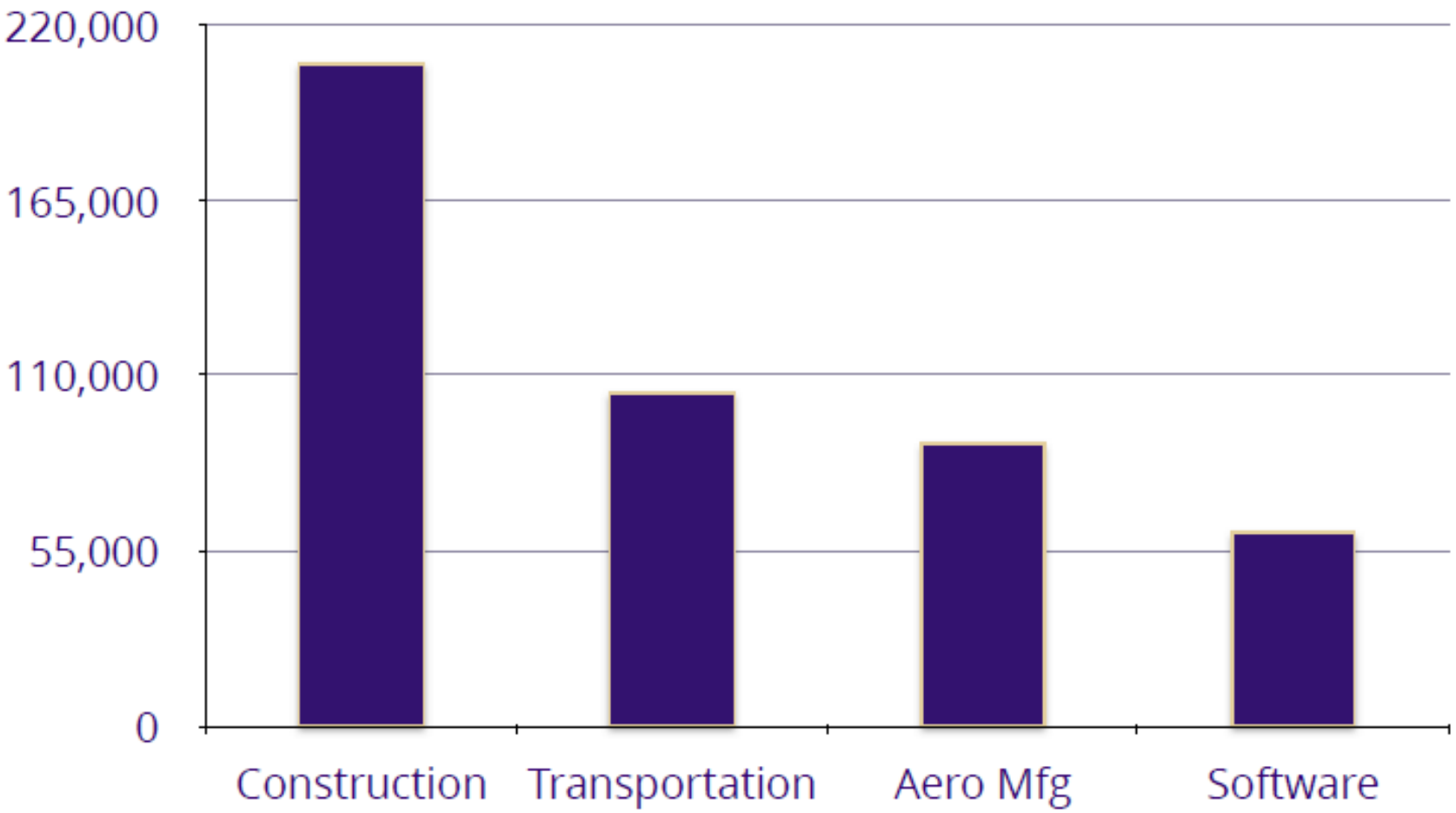
- CEE 220: Mechanics of Materials
- CEE 377: Introduction to Structural Analysis
- CEE 451: Steel Design
- CEE 452: Reinforced Concrete Design
- CEE 456: Structural Analysis I

Why UW?

- Active and diverse research program
  - Local (WSDOT, Sound Transit, M9)
  - National (FHWA, NCHRP, NSF, NHERI, PEER, USAF)
  - International (NCREE)
- Excellent teaching and coursework program
  - Two UW distinguished teaching award winners
- Well-connected with local industry
  - Career fairs, CEE 500 seminars, and more opportunities
- Growth in Seattle provides professional advantages with increasing employment opportunities and of large number of local firm
  - Puget Sound region number 2 in the country in terms of CEEs per thousand employed people across all professions
- Outcomes
  - Our students get competitive positions, and work on exciting projects immediately after graduation.

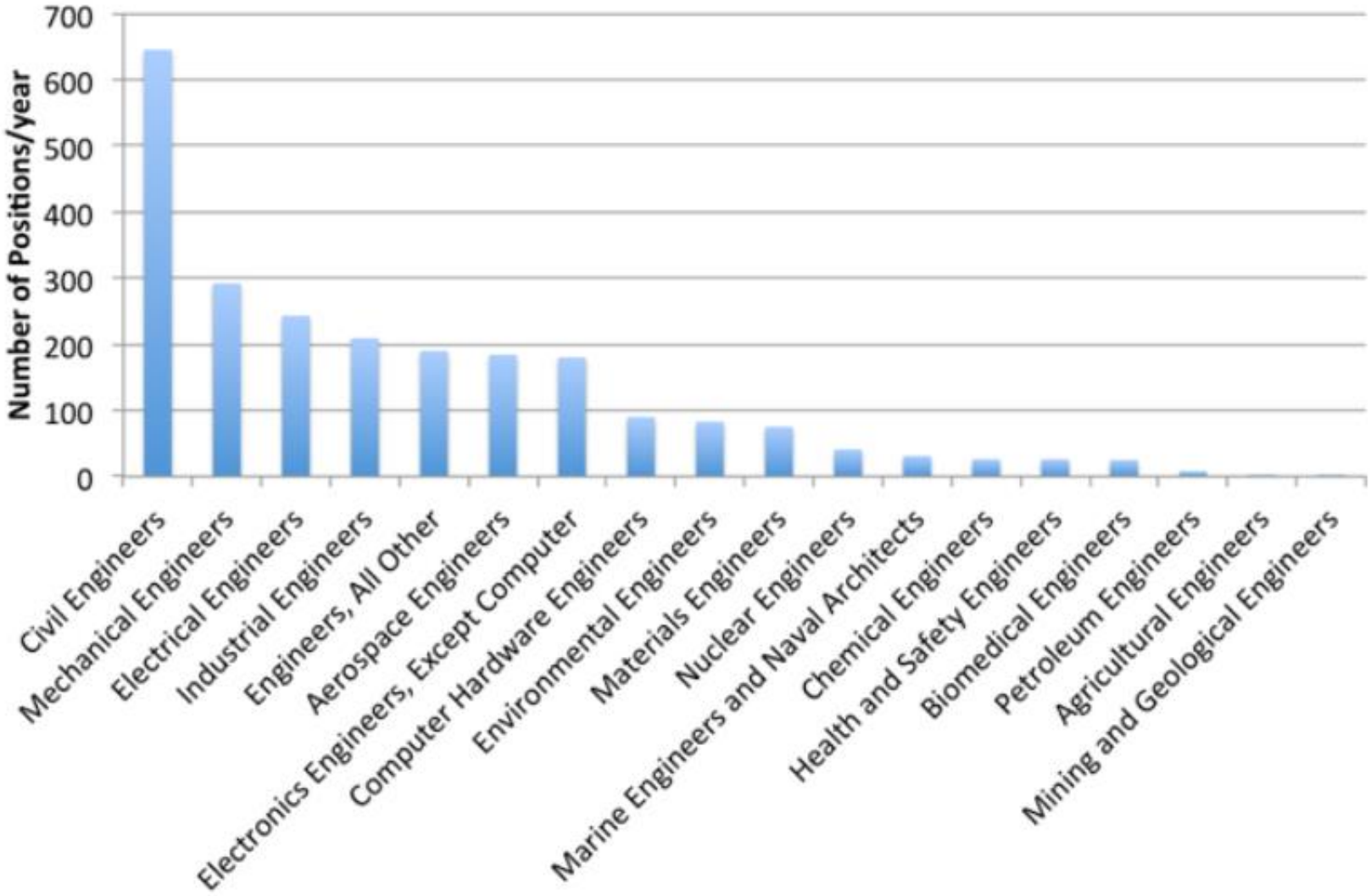
WA State Employment Projections

Selected Economics Sectors, 2020



Source: http://www.ofm.wa.gov/economy/longterm/longterm_forecast_tables.pdf

WA Annual Employment Data, 2015-2020



Why UW?

Seattle is also a great place to forget about work for a while…

Thank You