CE-220: Fundamentals of Civil Engineering

Jacob Sigman

Lecture 1 - 1/25/22

- Course Description
  - Planning, execution, and interpretation of drawings and specifications for Civil Engineering projects.
  - Sample drawings and specifications.
  - Contractual requirements and sample contracts.
  - Permitting, scheduling, and cost estimation.
  - Basic operations of design and construction firms.
  - Interface with other disciplines on Civil Engineering projects.
- Midterm
  - Likely March 8, before Spring Break.
  - Multiple choice questions (might have multiple right answers)
- Final group project/presentation
- Grading
  - Class participation: 20%
  - Quizzes: 15%
  - HW: 20%
  - Midterm: 15%
  - Final Project: 30%
- Office Hours: 4:30 - 5:00, 8:00 - 8:30, by appointment
- 10 points deducted for each week that an assignment is late.
- Recommended readings: ENR, ASCE, any professional journals of interest
- Abbreviated notes will be posted in teams. Take notes like they won't be.
- Civil Engineering Sub-Disciplines
  - Airport Engineering
  - Architectural Engineering
  - Coastal Engineering
  - Construction Engineering
  - Earthquake Engineering
  - Environmental Engineering
  - Forensic Engineering
  - Geotechincal Engineering

  - Highway Engineering
  - Ports and Marine Engineering
  - Materials Engineering
  - Municipal/Urban Engineering
  - Railway Engineering
  - Site Engineering
  - Structural Engineering
  - Transportation Engineering
  - Wastewater/Water Resources Engineering
- Civil Engineers fulfill society's needs, a service profession.
- Introduction
  - **The Process** - from Request for Qualifications and Proposal for initial Planning to Opening Day for the Project.
    * Where it begins
    * A "Need" is identified
      · Owner needs to develop property purchased to lease for income (return on investment)
      · Inspectors note that deck deterioration is advanced and needs repair/replacement.
      · Trafic demands have grown to regularly "jam" the route and no viable alternates are available.
    * Scope developed - usually by owner or owner's representative (program manager for major projects)
    * Request for Qualifications (RFQ) or Request for Proposal (RFP) for Design issued by Owners
      · Lists *qualifications* needed - (Sometimes 2-step process: RFQ first and shortlisted teams get the RFP second).
      · Objectives and Scope of Work are detailed
      · Schedule is defined
      · Criteria
  - **The Players** - Relationships among Owners, Designers, Builders (and sometimes Financers)
    * Owner/Owner's Representative
    * Designer/Engineer - Develops construction (or contract) Documents (CDs). Supports construction (reviews of Contractor's alternatives, RFIs, Means and Methods, relays design intent).
    * Contractor - Bids on work defined in CDs. Lowest qualified bidder (usually) gets awarded the contract.
    * Resident/Construction Inspector - Assures work is performed in accordace with CDs. Processes pay requisitions. Coordinates submissions to/from designer.
    * Quality Control/Quality Assurance/Testing
    * **Design-Bid-Build** Contractual relationships between owner and engineer and owner and contractor. Cooperative support between engineer and contractor.
    * Roles civil engineers play: Designer, Resident/Owner's Representative, Contractor, Owner, Maintenance Engineer, QA/QC.
  - **New Construction** - Case Study - Tacoma Narrows Bridge
    * Timeline for Tacoma Narrows Bridge
      · 1994 - WSDOT Public - Private Initiative Announced
      · 1996 - Major Investment Study

        - 1996/98 - Environmental Impact Studies
        - 1999 - Project Standards and Criteria Development
        - 2000 - Basic Configuration and Initial Design
        - 2001 - Determination of Fixed Price
        - 2002 - Legislation enacted and bonds shortlisted
        - 2002 - Notice to proceed - 9/25/2002
        - 2007 - Opening day - 7/17/2007
    * Financial mechanisms for procuring and paying for projects.
        - Buidlings v. Bridges
        - Procurement Methods
        - Conventional Design-Bid-Build (DBB)
        - Design/Build (DB) and Progressive Design/Build (PDB)
        - Public-Private Partnerships (P3) and Design-Build-Bid-Operate-Maintain (DBOM)
        - Construction Manager/General Contractor (CM/GC)
        - Last three are called alternate delivery (AltD)
        - Conventional Design-Bid-Build: Owner $\rightarrow$ Design $\rightarrow$ contract bid then built
          Engineering Oriented: Owner controlled, low risk, low opportunity.
        - Design-Build and P3: Owner $\rightarrow$ 30-40% Design and RFP $\rightarrow$ Design/Build teams advance design, bid then final designed/built staged. Also adds finance/operate/maintain in P3.
          Construction Oriented: Contractor controlled, managed risk, better opportunity.
        - Progressive Design-Build: Owner $\rightarrow$ 5-10% Design and RFP $\rightarrow$ PDB teams selected on qualifications, advance design with owner and owner's representative.
          Investor Oriented: Investor controlled, high risk, high opportunity.
        - CMGC - Owner "brokers" the marriage
        - Private public Partnerships, Design/Build/Operate/Maintain and other concepts
        - Bonding/Tolling and it's place in financing
        - Federally funded projects - interstate system
        - Real estate and tax implications
    * Contracts for Design
        - General Terms and Conditions: Standard of care, Insurance, Payment terms, other "legalese"
        - Scope of Work
        - Compensation - types of Contracts
        - Schedule for project
        - Special provisions
    * Construction Inspection and Construction Management
    * Contracts for Contractors - General terms and conditions (Division 1). The rest is the construction documents (plans and specifications, usually done by the design engineer)
- **Rehabilitation** - Case Study - Verrazzano Narrows Upper Level Deck Replacement
    * First phase - Study and design brief
        - Notice to proceed - 12/2003
        - Two viable operations: steel orthotropic and concrete filled steel grid.
        - Traffic studies to determine workable staging
        - Utility survey to evaluate relocation
        - Analyses to "global" impact of each alternative
        - Final recommendations
        - Two conceptual (10%) designs
        - Budgetary cost estimates
    * Second Phase - Designer

        - Two main construction contracts (Part A: Utility Relocation and Part B: Deck Replacement)
        - Two prototypes (Trinidad Lake asphalt pavement at throggs neck bridge and orthotropic deck for fabrication "proof of concept" and fatigue tests)
        - Additional Wind Tunnel Testing
        - Value Engineering
        - Constructability review
        - Final Design - VN-90A - December 2008
        - Survey - How Dissimilar might the panels be?
    - **Recent Trends**
        * Sustainability - Going "Green" neeeds to be part of process early if it will be followed through to completion.
        * Integrated Project Delivery/BIM

- Homework 0
    - Do one random act of kindness
    - You cannot personally benefit from this
    - You must not tell anyone what it is
    - If the person you did it for finds out, it doesn't count

Lecture 2 - 2/1/22

- Project documentation
    - Contract/"Boilerplate"
    - Specifications
    - Plans
    - Engineer's estimate
- Bridges vs. Buildings
- Interdisciplinary projects
- Conflicts and Contradictions - minimizing them
- Civil Engineering Sub-Disciplines
    - Airport Engineering
        * JFK Terminal 4
        * LaGuardia Airport re-envisioned
    - Architectural Engineering
        * San Francisco's Salesforce tower
        * Atlanta's Mercedes Benz Stadium
        * Major coordination with architects and other trades
        * Customers demanding more "bells and whistles" and "moving parts"
        * Facade and structural glass specialties are becoming a "thing"
    - Coastal Engineering
        * Waterfront work: Levees and flood protection, bulkheads, seawalls, scour protection
        * Beach erosion mitigation: Jetties, groins, sand replenishment, delta preservation

    - Offshore structures: Oil rigs, wind farms, bridge pier scour protection, wave and tidal generators
- Construction Engineering
    - Means and Methods: Staging, formwork and falsework, concrete curing plans.
    - Traffic control plans
    - Shop drawings
    - Fabrication procedures
    - Erection procedures
    - Sizing cranes for construction: Temporary track driven cranes, tower cranes, gantries
    - Transportation problem solver
    - Procurement
- Earthquake Engineering
    - Seismology
    - Soil effects
        - Soil-structure interaction - coming up with the springs
        - Attenuation/amplification from intervening soil layers
    - Tectonics - movement of plates
    - Monitoring and prediction modeling
    - Stuctural analysis
        - Response spectra
        - Multi-modal response spectra
        - Time history
        - Design elements
    - Research and Development
        - Active/passive damping systems
        - Innovative bearings (isolation, friction/pendulum)
- Environmental Engineering
    - Water treatment
        - Controls for effluent and runoff
        - Groundwater, settlement basins
        - Desalination
        - Waste treatment
        - Cleanup from spills
    - Air
        - Air quality effluent control/scrubbers, etc.
        - Indoor air Quality: Dust control / filtering, Cleaning chemical pollutants
    - Noise control, indoor and out
    - Soil-structure: Erosion controls (planting, hay bales, riprap, etc.)
- Forensic Engineering
- Geotechincal Engineering
    - Soils
        - Geotechnical investigations
        - Classifying
        - Soil improvement: Stone columns, Soilcreting/jet grouting
        - Settlement control/preconsolidation
        - Highway and utility work

    - Foundations
        - Spread footings and mats
        - Pile foundations - many kinds
        - Support of excavation: Tie-backs and sheeting, soil nailing
        - Tunnels, shafts
- Highway Engineering
    - Alignments - plan and profile
    - Cross sections
    - Mass haul optimization
    - Utility plans and relocations
    - Pavement boxes
    - Curbs, sidewalks, paths, driveways
    - Survey coordination
    - Drainage
    - Signalization and lighting
    - Speed and red-light enforcement
    - Traffic control
    - Striping
    - Signing
- Ports and Marine Engineering
- Materials Engineering
    - Metallurgy and alloying
        - High performance steels
        - Other metals
        - Corrosion protection - Coatings, metalizing, cathodic protection, etc.
    - Concrete
        - New mixes and materials: Glassphalt, lightweight aggregates, cements, fly ash, slag, and pozzolans, fiber reinforcement, ultra-high-performance concrete (UHPC)
    - Asphalts and binders
    - Research and Development
        - Plastics and composites, including carbon
        - Fiber reinforced polymers (FRP)
        - Nanotechnology
        - Reuse of waste materials in new work
- Municipal/Urban Engineering
    - Utilities/Infrastructure
        - Communications - phone, broadband, cable, cell cites
        - Electric and power generation/distribution
        - Gas storage and distribution
        - Steam
        - Sewage/sanitary
        - Pump stations
    - Mapping
    - Geographical Information Systems (GIS)
    - Parkland development and maintenance
    - Streetscape

    - Zoning and city Planning
    - Maintenance
- Railway Engineering
    - Railroad design
        - Alignments: Plan, Profile, tolerances get tighter with increased Speed
        - Track work: Rail (continuously welded), frogs and switches, ballast, clamps
        - Signals
        - Platforms and "gaps"
        - Mezzanines and station design
        - Bridge and tunnel design
        - Embankments and retaining walls
- Site Engineering
    - Permitting
    - Site plans
    - Drainage
    - Sanitary sewers
    - Parking lots
    - Survey coordination
    - Curbs, sidewalks, paths, driveways
    - Utility plans and relocations
    - Site and facility lighting
    - Signing and striping
- Structural Engineering
    - Buildings
    - Bridges
    - Retaining walls
    - Tunnels
    - Special structures
        - Guyed towers
        - Blast design
        - Shells and domes
        - Fabric structures
        - Stadiums
        - Oil rigs
        - Wind farms
        - Transfer stations
        - Ports and marine structures
- Transportation Engineering
    - Transportation surveys
    - Planning, modeling, and studies
    - Operations
    - Highway Systems
        - Traffic projections
        - Toll studies and financing
        - Tolling methods
        - Bike lanes and pedestrian paths

        * Mass transit
            · Bus Systems
            · Metro and light rail systems
            · Commuter rail systems
            · High-speed Rail
            · Fare collection systems
        * Carpooling and other alternative transportation
    - Wastewater/Water Resources Engineering
        * Water supply
        * Testing and treatment
        * Storage
        * Distribution
        * Pumping stations
        * Maintenance
        * Fire lines
        * Desalination
        * Wells and Aquifiers
        * Irrigation
        * Hydraulic Studies
            · Dams
            · River backwater studies
            · Flooding studies

- Sub-Disciplines: Wrap-up
    - Lots to choose from
    - Many overlap
    - None are stagnant - continuous developments keep things interesting
    - Plenty of long-term opportunities

- Planning and permitting - Subject overview
    - *Private v. Public*: Who's in charge?
        * Architects tend to take lead on private work/buildings
            · Contract with the owners
            · Subcontract to structural, mechanical, electical, and plumbing designers
            · Make decisions on overall configuration
            · Tend to be the "LEEDers" for Sustainability decisions
        * Civil Engineers tend to take the lead on public works/bridges
            · Many major bridges do not have architectural involvement
            · Geotech, Architects, MEP subs to structural or civil
    - *Planning*: Site selection, preliminary bedgeting, feasibility studies
        * Site selection
            · Owner purchases property, often in consultation with designers
            · Owner objectives = "program"
            · Proximity to utilities/transportation
            · LEED of ENV SP criteria
        * Preliminary Budgeting

            - Does it make economic sense?
            - Cost/benefit analysis
            - Financing - bonds or loans needed?
        * Feasibility studies
            - Any fatal flaws in the plan?
            - Work arounds possible?
    - *Environmental* Assessment - Impacts to consider
        * Water Quality
            - Additional runoff created?
            - Settlement ponds or permeable areas
        * Air Quality
        * Dust and noise control during construction
        * Additional traffic generated?
        * Wildlife affected?
        * Parkland
        * Open Spaces
        * Cultural Resources
        * Historical Resources
        * Natural Resources
        * Quality of Life
    - Major investment studies
        * Will it pay off?
        * Depends on: Cost/benefit analysis, Life cycle costs, return on investment
        * Financing options

Lecture 3 - 2/8/22

- Procurement Mechanisms for Civil projects
    - "Conventional" - "Design-Bid-Build"
        * Designer selected by qualifications and often cost, workload and/or politics.
        * Design developed to 100% complete
        * Usually several submissions (40%, 70%, 95%)
        * Each submission consists of several steps
            - Design development and submission
            - Owner comments
            - Comment resolution
        * 100% contract documents get released to bid
        * Bid phase includes
            - Pre-bid meeting/walkthrough
            - Q&A/RFIs from Contractors
            - Issue Addenda/Clarifications/Amplifications if needed
            - Bid
            - Bid review: Verify qualifications for each bidder, watch for irregularities and unbalanced bids.
            - Contract awarded (signed and executed)
        * Generally contract goes to "Lowest qualified bidder".

    * Takes longer to implement
    * Owner controls each step
    * Owner procures 10-30% design bid package: Package has criteria, rules established, package typically also has indicative plans.
    * Package released to design/build teams to bid
    * Design/Build teams
        · Value engineer/Innovate
        · Advance design - only enough to bid
        · Sometimes "qualifications package" first
        · Always bid
        · Usually low bid wins, but not always
        · Quality points often count
        · Award made
        · Construction starts as final design proceeds
        · Owner reviews work packages along the way
        · Task force meetings for all stakeholders
    * Now "Standard operating procedure" for MTA agencies for projects ¿ $25M
- Work packages
    * WPB1: Suspension system
    * WPB2: Suspended superstructure
    * WPB3: Towers
    * WPB4: Anchorages
    * WPB5: Miscellaneous Appurtenances
    * WPB8: Deck Finishes
    * Project Specs: 100% Project specifications
    * CES-003: Temporary Grout Tube Supports
    * Construction Photographs
    * Design
- Private Public partnerships, Design/Bid/Build/Operate/Maintain and other concepts
    * Like design build, and then some!
    * Rules all vary greatly
    * Not always low bid!
        · Qualifications
        · Financial terms, solvency, and serviceability and handoff
        · "Value" to the ultimate owner
- Bonding/Tolling/Rent
    * Financing - government bonds
    * Toll Levels/Rent established to pay them back
    * Tolls/rent collections also need to pay for maintenance, capital improvements
- Federally Funded Projects - Interstate System and Mega Projects
    * Major public works "Helped make us a great nation"
    * Keeps jobs, helps the economy get/keep going during construction
    * Keeps transportation lines efficient
    * Bipartisan infrastructure law passed
    * Some becoming toll roads, make money
- Real estate market

        - Fluctuations in price are natural
        - 3WTC history lesson
    - Tax implications
        - Incentives - Amazon's HQ2
        - Then it fell apart.

- Insurance and Bonding capacity can limit project size
    - Contractor's Insurance Required
        - Comprehensive general liability and property damage insurance
        - Worker's compensation
        - Marine liability
        - Other insurance for special risk cases
    - Owner's protective liability
    - Wrap-up project insurance for mega-projects
        - Covers all parties
        - More efficient
        - Less common lately
    - Payment and performance bond
        - Surety company
        - Ratings
        - Bonding capacity

- Homework 1
    - Pick a recent project that you want to learn more about. Research the following items and present as a short essay in Five numbered outline/paragraphs corresponding to the list below, citing sources along the way and **bulletizing** as much as possible.
        1. The players: A) Owner, B) Designer(s), and C) Contractor
        2. Initial idea: A) Whose idea, B) when, C) why, D) what need filled, etc.
        3. Timeline: Studies, permits, etc., through completion
        4. Funding Sources/Mechanisms to pay for the facility
        5. Procurement mechanism for the owner to get it done (DBB, DBBOM, etc.)
    - Along the way, explain why you believe these guiding decisions were made the way they were.

- A Bit on Calculations
    - You will be well-prepared by the cooper union
    - Calculations form the basis of our designs
    - They must conform to the design criteria
    - The results must be reflected in the design details
    - Computers are stupid, much calculation (units units units)

- A bit on drafting
    - A bit of AutoCAD
    - Scale is important!
    - Cutting sections and showing details

- A bit on technical writing

  - Each form of writing has its own style
  - Larger firms sometimes have their own style guide
  - Your bosses will want you to emulate them
- Drawing preparation and organization
  - Title sheet
  - List of drawings
  - General plan and elevation
  - Scope of work
  - General notes
  - Material notes
  - Notes along the way: References to pay items, perscriptive instructions on means/method, don't repeat anything in specs.
  - Abbreviations
  - Existing conditions/demolition
  - Make sure pay items in specifications are clear and fully coordinated.
- Plan preparation and organization
  - Plans show arrangement, include a North arrow and jump to: Sections, elevations, part plans, details
  - Use cross-references to other drawings, specifications
  - Sections, elevations
  - Everything must be set out to "tell a story" and build towards an understanding of the "whole"
  - Scales - don't over-mix!
  - Tie it all together, make usre everything is consistent and coordinated.
  - Most clients want electronic delivery from PDF to CADD native files
  - Plan prep for public vs. private sector
- Horizontal Alignments - Horizontal Curves an Stationing
  - Roads and rails aren't straight
  - Stationing is how distance is measured
  - 1 Station is 100'
  - Rails and highways gradually change from tangent to curve

Lecture 4 - 2/15/22

- Sample Structural drawings
- Legend

Lecture 5 - 2/22/22

- HW 2 and HW 3 are going to happen concurrently.
- March 8 is the midterm
  - Part 1: Multiple choice (multiple right answers)
  - Part 2: Short essay
- San Francisco - Oakland Bay Bridge
  - Sequence
  - Format
  - Linework
  - Font Sizes
  - Scales
  - Plan views with north arrows
- What is BIM? (2D, 3D Laser Scanning, GIS, Digital Terrain Models, Geometric Controls, Project Schedule, Database Attributes)
  - 4D: Time
  - 5D: Scheduling
  - Intelligent Labeling: Auditorium plan view, automatic labeling from a database
  - BIM replicates our 3D thinking digitally
  - Allows for more braod Interdisciplinary collaboration
  - BIM produces drawings as needed - the 3D, 4D, or 5D design is the deliverable.
  - Purpose
    - Rich models of design
    - Reduce errors
  - Benefits
    - Better visualization
    - Improved productivity
- Specifications Preparation Outline
  - Bridges vs. Buildings
  - Standard Specification with Supplementary Specifications
  - CSI/MasterSpec
  - Secttions
    - "Boilerplate" / "Division 1" - Laying down the "Law"
    - Technical specifications: Sometimes handling pay items within, Sometimes separate section for handling pay items - unit prices, lump sum, etc.
    - Coordination with the drawings, specs, and estimate
- MasterSpec/CSI Format
  - Five digit number 1995
  - Six digit number 2004 version when new sections added
  - first two digits are "Division" number in 2004
  - Each technical section has a similar outline

- Typical CS Format - 1995 version
  - Division 1 usually comes from the owner in public sector work
  - Other sections do as well - coatings, health and safety, and other agency-wide specs too
- Get your PE right away!

Lecture 6 - 3/1/22

- WMATA Background: WMATA was created in 1967 by a tri-state compact between CA, MD, and DC, ratified by congress.
- At start: Many unknowns
  - Earn public trust that bus/rail travel is safe.
  - Effectively communicate changing service/fare plans.
  - Protect employees and customers.
  - Serve essential workers/industries.
  - Organizational and financial survival.
  - Help to prevent the collapse of civilization.
- Ridership
  - Historic losses in ridership.
  - Challenging revenue losses (fares, non-fares, Federal Stimulus).
  - Significant unplanned expenses.
- Protecting Employees and customers
  - January 2020: Implemented Pandemic Plan/Pandemic Task Force
  - Mid-March 2020
    - To reduce employee exposure and cross-contact, implemented A/B split schedules. Service reduced to 30-40% of normal.
    - To reduce the use of cleaning supplies, 19 low-use stations were closed to customers.
- Expand Reconstruction Work During Low ridership
  - High-Level concept
    - During low-ridership period, use surges for maintenance, larger shutdowns for previously planned work.
    - Catch up from early covid delays, and get ahead if possible.
- Opportunities
  - Monitor crowding to adjust service. Implement real-time crowding information.
  - Coordinate with the jurisdictions on new temporary or permanent dedicated bus lanes.
  - Customer communication advertising campaign.
  - Advance mobile payment apps.
- Anticipating Rider Behavior Post-Pandemic
  - Customer research conducted throughout to inform plan.
  - Rider focus groups to learn about concerns, preferences, and information sources.

  - It's easy to shut stuff down, but it's not easy to bring service back.
- Budget Challenges
  - Rail fare revenue was major contributor to budget.
  - Largely driven by peak hour, long-distance commuters, federal commuters.
  - Rail costs are largely fixed.
  - Fewer riders means lower revenue.
- COVID-19 Related Challenges
  - Continues workforce availabilty.
  - Unclear future demand and service goals.
- Equity Customers, Essential Trips
  - Half of customers were still riding.
  - High percentage of riders in lower-income neighborhoods.
- Engineering Ethics
  - Remain objective and professional.
  - Code of Ethics for Engineers
  - ASCE Code of Ethics
- Homework 2
  - Lookup the rest of NSPE's Code of Ethics and ASCE's Code of Ethics and read them both.
  - Find one common thread and think about how it applies to a similar situation you faced in your life.
  - Write about it.
  - One page, single-sided.
  - Last_First_CE220_HW2.docx or pdf
- MasterSpec / CSI Format
  - Each section has a similar outline
  - Header has section number and title
- Supplementary specifications
  - Uses a prevailing standard specification as a starting point.
  - Typically general amongst states.

Lecture 8 - 3/22/22

- Construction phases
  - Owners "representation" Part 1a:
    - Owner hires and engineer for construction support services
      - Usually design engineer - most familiar with the design intent
      - Sometimes independent if conflict of interest may be percieved

        - Scope generally entails review of contractor's submissions: Baseline schedule, LS breakdown, Safety plan, Traffic control plan, Quality control / quality assurance plan, Fabrication plan, Shop drawings, mill certifications, test results, Whatever is defined by contract / specs to ensure the design intent is met.

- Owners "representation" Part 1b:
    - Owner hires an engineer for construction support services
        - Construction support also entails providing: clarifications for ambiguity and interpretation for conflicts, supplementary informatoin, additional design, change order preparations, review of payment requests, final walk through.

- Owners "representation" Part 2
    - Owner hires resident engineer to see that the work is installed in accordance with the plans ans specs.
        - Sometimes design engineer's company serves this role - in which case different staff
        - Sometimes designer hires and supervises subconsultant to be resident
        - Sometimes resident is independent