

# CE-220: Fundamentals of Civil Engineering

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## 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
  - Geotechnical 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.
      - Traffic 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 accordance 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.
  - Buildings 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 → Design → contract bid then built  
**Engineering Oriented:** Owner controlled, low risk, low opportunity.
  - Design-Build and P3: Owner → 30-40% Design and RFP → 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 → 5-10% Design and RFP → 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 its 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” needs 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
  - \* Structural 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
- Geotechnical 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 Aquifers
  - \* 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, electrical, 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 budgeting, feasibility studies
    - \* Site selection
      - Owner purchases property, often in consultation with designers
      - Owner objectives = “program”
      - Proximity to utilities/transportation
      - LEED or 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  $\geq$  \$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, prescriptive 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 sure 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 and Stationing
  - Roads and rails aren't straight
  - Stationing is how distance is measured
  - 1 Station is 100'
  - Roads 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