

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
 - 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
- 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 broad 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
 - Sections
 - * “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!