Fall 2023

CE 702-103: ST:Structural Engineering in Construction

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Structural Engineering in Construction (Fall Semester 2023)

Course Outline

1. **Brief introduction (week 1)**
    a. Contractor's responsibilities:
        - Provide a safe workplace (site safety)
        - Maintain structural stability during construction
        - Means and Method of construction
        - Deliver structures that meet EoR's design intent
    b. Main objective of this course:
        - Application of structural engineering principles and knowledge to design temporary structures that help to provide a safe workplace during construction
        - Introduce methods of safeguarding the stability of structures under construction.
        - Study the commonly used erection/construction procedures to
            - Deliver the structure per EOR's specification and design intent
            - Minimize the impact to the general public at large
            - Improve sustainability of construction activities
        - Brief introduction of the current advancements in construction technology
    c. Introduction of most commonly adopted codes and regulations
        - Relevant government regulations -
            - OSHA 1926 https://www.osha.gov/laws-regs/regulations/standardnumber/1926
            - NYC Building code (chapter 33) https://codelibrary.amlegal.com/codes/newyorkcity/latest/NYCadmin/0-0-0-86713
            - NY State Safety & Health Code Rules https://dol.ny.gov/safety-health-code-rules
            - Marine Operations - DNV, OSHA
            - Other codes covering construction operations: AASHTO, ANSI
    d. Sample construction projects:
        - Safe access - works platforms, scaffold, stairs
            - Cable suspended platforms and some of analysis theory (Verrazano Bridge)
            - Scaffold (Goethals bridge)
            - Works platform temporary tie strut for main pylons (Goethals bridge)
        - Construction means and methods
            - Middletown Bridges (SPMT Roll-in and Roll-out) (videos)
            - K-bridge main span removal (videos)
            - Willis Ave Bridge float-in (video)
            - Erection of curved girders (videos)
        - Other References
            - Manual on use of Self-propelled modular transporters to remove and replace bridges https://www.fhwa.dot.gov/bridge/pubs/07022/chap00.cfm
            - Engineering for Structural Stability in Bridge Construction https://www.fhwa.dot.gov/bridge/pubs/nhi15044.pdf

2. **Course project and Review of prerequisite courses (1) (Week 2)**
    a. Brief introduction of course project – erection of curve girder bridge
        - Project locations and structural type (review of design drawings)

        - Standards and References
        - Required submittals
        - Groups
    b. Linear Algebra
        - Linear system and linear equations
        - Matrixes and basic operations
        - Eigen value and Eigen Vectors

3. **Review of prerequisite courses (2) (Week 3)**
    a. Statics
        - Free-body diagrams
    b. Strength of material / Structural analysis
        - Moment and shear diagrams
        - Trusses
        - Frames
    c. FE analysis - introduction

4. **Support of Excavation (SOE) (Week 4)**
    a. Active soil pressure, passive Soil pressure
    b. Surcharge
    c. Type of SOE:
        - Design of cantilever system
        - Design of braces system
    d. Design Codes
    e. Commercial analysis programs
    f. Underpinning
    g. Dewatering
    h. Design examples
        - Highway Bridge projects
        - Excavation next to railroad tracks
        - Excavation in urban setting (NYC building code requirement)

    i. Ref:
        - STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION TRENCHING AND SHORING MANUAL: https://dot.ca.gov/-/media/dot-media/programs/engineering/documents/structureconstruction/201906-sc-trenchingshoring-a11y.pdf
        - SUPPORT OF EXCAVATION & UNDERPINNING - NYC.gov https://www1.nyc.gov/assets/buildings/pdf/presentations/underpinning_soe.pdf
        - Heavy construction operation and equipment https://www.youtube.com/channel/UCBkkjuVOaW57MquK_XPIeTA/video

5. **Design of work platforms and scaffolding system (Week 5)**
    a. Type of rigid work platforms
        - Manufactured systems :
            - Scaffold - modular systems
            - Suspended (sky climbers, swing stages)
            - Aluminum work platforms

        - OSHA Planks
        - Self launching work platforms (Quickdeck, https://www.youtube.com/watch?v=64uBmIZLaVs)
    - Custom designed work platforms OSHA requirements
b. Flexible systems
    - SafeSpan system
    - Total containment system
c. Design calculations
    - Cable system - General introduction, span, sag, tension..
    - Analysis of flexible and inextensible cable structures
        - Uniform load
        - Point loads
    - Design of cable structures
        - Under point load
        - Elastic, flexible cable structures under distributed loads
            a. Approximate procedures and solutions
            b. Exact solutions (Cable structures by Max Irine, https://www.abebooks.com/Cable-Structures-Max-Irvine-Dover-Pubns/31079436453/bd?cm_mmc=ggl-_-US_Shopp_Trade-_-product_id=COM9780486671277USED-_-keyword=&gclid=Cj0KCQiAlMCOBhCZARIsANLid6a0v_eqadXV5LMNw2D6cH-abo4lyrr6QYhX8pUmmIrfGR9Yfv-9GysaAp96EALw_wcB)
        - Design of multi-span cable suspend work platform
            a. Hand calculation (closed form calculation)
            b. FE analysis
                i. Geometry of cable
                ii. Boundary conditions
                iii. Design loads
                iv. Understand the results
            c. Design items:
                i. Hangers, check bridge stringers/girders for local stresses
                ii. Anchors
                iii. Check of bridge components, abutments, steel members…
            d. Design drawings, examples

6. Analysis of structures during construction (Weeks 6 and 7)

a. Code and specifications
    - AASHTO Standard Specifications for Highway Bridges (Construction)
    - AREMA
    - ASCE37
b. Methods
    - Per design code formulas
    - FE analysis
        - Modeling
        - Boundary condition

        - Staged Construction analysis using Larsa or CIS Bridge
    c. Theory of Structural Stability (Wei's previous lecture notes)
        - Column buckling
            - Bracing for stability
            - AISC approach
            - Nonlinear analysis - FE analysis approach
        - Beam torsional buckling and required braces (AISC provision)
            - Simplified approach, classical approach (Classical AASHTO approach)
            - Timoshenko's energy method
    d. Erection stability of curved girders
        - Center of gravity
        - Rigging design
        - Temporary support of partially erected girder bridges
    e. FE Analysis of rebar cages: https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/f0016574-2010-11-task-1098-geotech-and-structures.pdf

    f. FE analysis - geometric nonlinearity
        - Modeling consideration
        - Loading consideration
        - Determine equivalent K factors
        - Examples (K-bridge)
    g. Ref: **Engineering for Structural Stability in Bridge Construction** https://www.fhwa.dot.gov/bridge/pubs/nhi15044.pdf

7. **Accelerated Bridge Construction, ABC (roll-in and Roll-out with SPMT) (Week 8)**
    a. Concept
    b. Equipment (Self-Propelled Modular Transporters)
    c. Stability of SPMT
        - Three-point configuration
        - Four point configuration
    d. Design considerations
    e. Structural analysis of SPMT-Bridge structures
        - FE analysis modeling
    f. Design of falsework
    g. Lateral load and Accelerations
    h. Ref:
        - https://www.fhwa.dot.gov/bridge/abc/spmts.cfm
        - AASHTO LRFD Guide Specifications for Accelerated Bridge Construction, 1st Edition : https://store.transportation.org/Common/DownloadContentFiles?id=1788
        - Manual on Use of Self-Propelled Modular Transporters to Remove and Replace Bridges: https://www.fhwa.dot.gov/bridge/pubs/07022/hif07022.pdf

8. **Case Study (Middletown, Goethals Bridge) (Week 9)**
    a. Middletown
        - Original proposed construction sequences proposed by the EOR and its impact:
            - To railroad's operation
            - To local traffic

        - Schedule
        - Financial implications - TARP funding deadline
    - Kiewit-UrbanTech's approach (ABC)
        - Understand EOR's design intent and objectives: Foundation and Superstructure
        - Identify risks associated with the construction
            a. Underground utilities
            b. Clearances
            c. Identify preassembly sites
            d. SPMT stability
            e. Railroad schedule risk
        - Coordinate with the general contractors and subcontractors
        - Perform detailed analysis to ensure the safety of structures
        - Execution - detailed work plan and stick to the design. (tie-down, last minute argument)
b. Goethals Bridge (just show a video)

9. Barge stability (Week 10) (Basic knowledge of Naval Architect)

a. Ship stability - terms
b. metacenter
c. Trim and list
d. Dynamic stability
e. Understand barge hydrostatic chart
f. OSHA regulations
g. Introduction of DNV
h. Crane on Barge
    - Analysis
    - Crane chart - capacity reduction
    - OSHA Requirements
    - Coast Guard requirements
i. **Barge structure interaction -**
    - Introduction of barge-structure interaction
    - Design loads, sea conditions, routing services (work with a naval architect!)
    - Analysis method (FE analysis)
    - Introduction of seafastening design per (DNV) using a given value of deck accelerations

10. Final project (Week 11) : Steel Bridge Erection Plan - three span multi-girder curved girder bridge erection plan

a. Understand the project:
    - Understand the structure
    - understand the design intent of the EoR
    - Understand site conditions and access limitations
    - Select your equipment
    - Understand the risk and critical structural conditions
    - Develop preliminary erection procedures

11. Presentation 1 – MPT and site logistics (Week12)

12. Steel Girders (Week 13)

- Straight girders
  - Initial imperfection
  - Rigging - stability during lifting (NYSDOT formula)
  - Seating stability
    a. Design of temporary bearing (Allow rotation, longitudinal movement)
    b. Longitudinal and lateral restraint, design of tie-downs
- Curved girder
  - CG of girder
  - Design of rigging
  - Design of shoring
  - Design of end restraint
  - Check girder deflection and stresses, what is the acceptable range?
  - Installation of lateral braces and diaphragms. (Erection method and detailing approach - fully assembled, or dead load fit)
  - Design examples (LGA curved girder erection- Engineer. Amos)
- References
  - AASHTO/AISC Steel Bridge Erection Guide Specification
  - UT-Lift (http://fsel.engr.utexas.edu/facilities/software/software)
  - Some useful engineering software from Texas DOT: https://www.txdot.gov/inside-txdot/division/information-technology/engineering-software.html

13. Structural Analysis and design (week 14)

a. Structural Analysis
   - Basics of structural stability
   - AISC direct analysis method and its implementation
   - Model the structure (FE Model)
   - Perform nonlinear analysis
b. Erection Engineering
   - Design rigging, structural analysis of girders under rigging load
   - Define stages, boundary conditions based on preliminary erection procedures
   - Design necessary shoring plans, bracing details
   - Prepare erection plans
c. Group discussion
d. Ref: Steel Bridge Erection Guide Specification
   https://www.aisc.org/globalassets/nsba/aashto-nsba-collab-docs/s-10.1-2019-steel-bridge-erection-guide-specification.pdf

14. Continuation of Final project - Group presentation (Week 15)

A few more thing to add:

1. Objectives of each learning unit
2. Homework assignments
3. Videos to help students to visualize the construction operation

Grading

- Attendance - 20%
- Group discussion and projects - 25%
- Final projects - 35%
- Presentation - 20%

Fall 2023 Academic Calendar

Sept	4	Labor Day. University Closed
Sept	5	First Day of Classes
Sept	11	Last Day to Add/Drop a Class
Sept	11	Last Day for 100% Refund, Full or Partial Withdrawal
Sept	12	W Grades Posted for Course Withdrawals
Sept	18	Last Day for 90% Refund, Full or Partial Withdrawal - No Refund for Partial Withdrawal after this date
Oct	2	Last Day for 50% Refund, Full Withdrawal
Oct	23	Last Day for 25% Refund, Full Withdrawal
Nov	13	Last Day to Withdraw from Classes
Nov	21	Thursday Classes Meet
Nov	22	Friday Classes Meet
Nov	23	Thanksgiving Recess Begins. No Classes
Nov	26	Thanksgiving Recess Ends
Dec	13	Last Day of Classes
Dec	14	Reading Day 1
Dec	15	Reading Day 2
Dec	16	Saturday Classes Meet
Dec	17	Final Exams Begin
Dec	23	Final Exams End
Dec	25	Final Grades Due