STRUCTURAL ENGINEERING FOR PLANT ENGINEERS

Presented by ADF Engineering

Dayton, OH

Omaha, NE

Presenters

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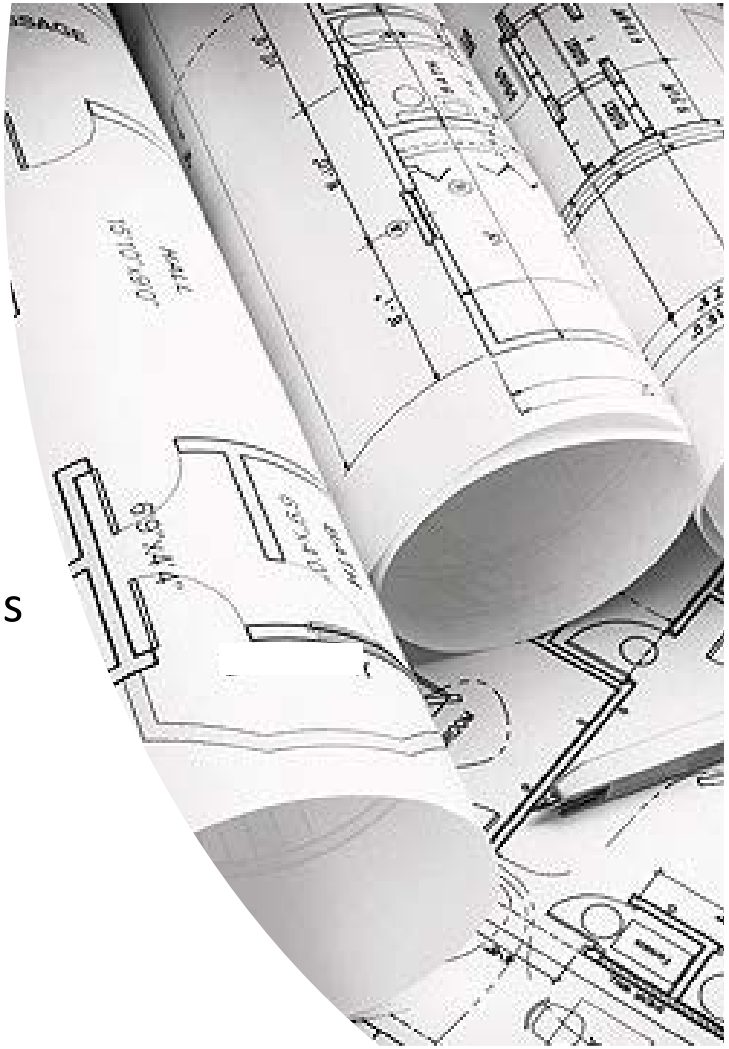
Learning Objectives

- Understanding Str drawings
- Structural project considerations
- Structural Engineering basics & materials
- Preparing for construction
- Construction phase Engineering and support



About ADF

We are Process and Facility Engineers!!!

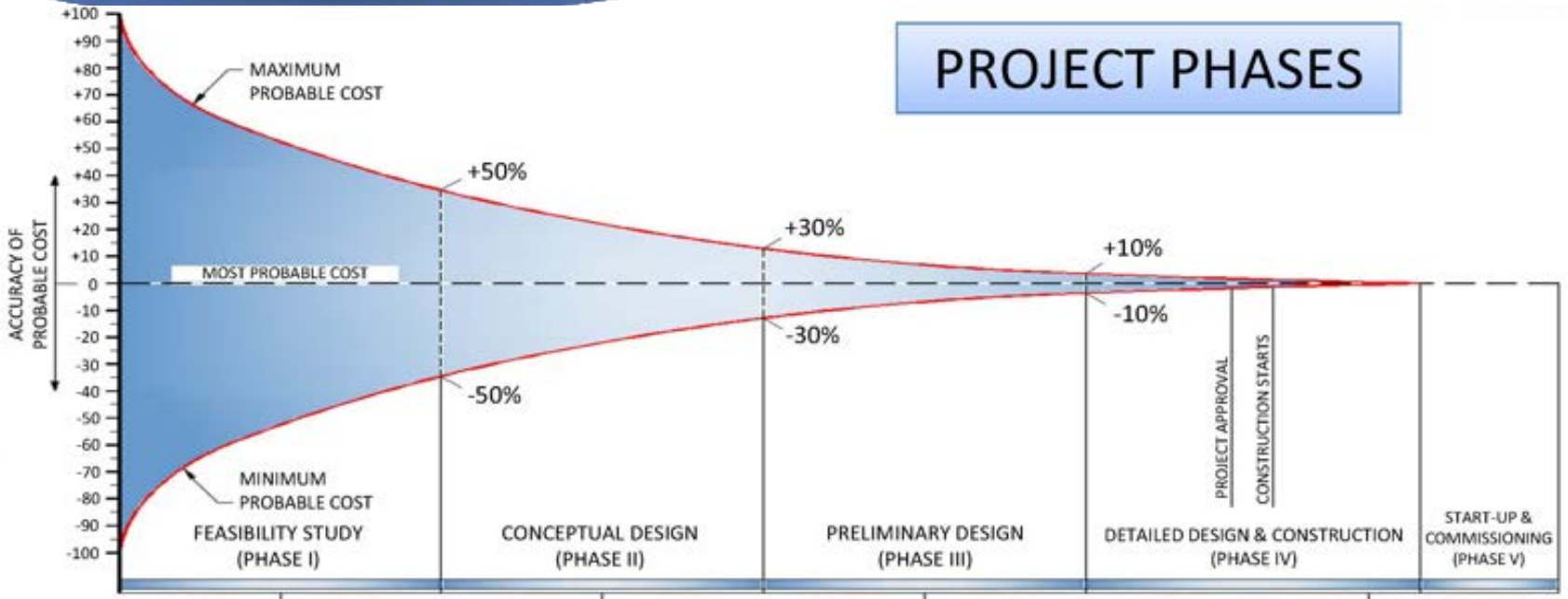
- Process design
- Mechanical, piping and HVAC design
- Civil and Structural design
- Electrical design
- Controls and Instrumentation design
- Project management
- Construction administration
- Audits: Energy, Structural, food safety, etc.

Cargill
Partner since 2003

1000+
Projects for Cargill

CSS, CASC, GEOs, CAN and PreMix, Salt , USA, China, Brazil

PROJECT PHASES



BASIS OF ESTIMATE:

- ASSUME PRODUCTION OUTPUT.
- STUDY PROJECT LOCATIONS.
- STUDY AVAILABLE UTILITIES.
- STATE PROJECT SCOPE ASSUMPTIONS.
- PROVIDE A NARRATIVE OF THE PROCESS.
- DEFINE A MILESTONE SCHEDULE.
- DEFINE A ROUGH ORDER OF MAGNITUDE COST WITH A 50% +/- ACCURACY.

FEASIBILITY STUDY

BASIS OF ESTIMATE:

- DEFINE PRODUCTION OUTPUTS.
- SELECT PROJECT LOCATION.
- DEFINE UTILITY REQUIREMENTS.
- DEFINE PROCESS FLOWS AND LIST MAJOR EQUIPMENT.
- PRELIMINARY 3-D MODEL CREATED.
- DESIGN DISCIPLINES PROVIDE CONCEPTUAL DESIGNS.
- MILESTONE SCHEDULE UPDATED TO INCLUDE DESIGN, PROCUREMENT AND CONSTRUCTION.
- BUDGETARY ESTIMATE CREATED WITH A 30% +/- ACCURACY.

CONCEPTURAL DESIGN

BASIS OF ESTIMATE:

- PROCESS AND INSTRUMENTATION DIAGRAMS FINALIZED.
- 3-D MODEL UPDATED WITH QUOTED EQUIPMENT.
- GENERAL ARRANGMENT DRAWINGS CREATED.
- DESIGN DISCIPLINES UPDATE DESIGNS TO PRELIMINARY LEVEL.
- DETAILED ENGINEERING, PROCUREMENT AND CONSTRUCTION SCHEDULE CREATED.
- DEFINED COST ESTIMATE CREATED (INCLUDE ALL DISCIPLINES) WITH A 10% +/- ACCURACY.

PRELIMINARY DESIGN

DESIGN:

- EQUIPMENT PURCHASED.
- 3-D MODEL FINALIZED.
- MECHANICAL LAY-OUTS FINALIZED.
- DESIGN DISCIPLINES COMPLETED AND ISSUED FOR CONSTRUCTION.
- FINALIZE SCHEDULE WITH START-UP AND COMMISSIONING PLANS.
- CONTRACTORS SELECTED.

DETAILED DESIGN

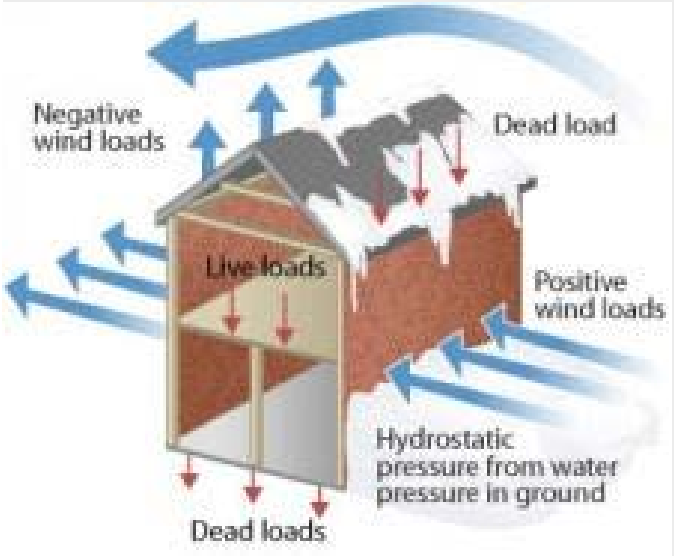
ADF Engineering

Structural Engineer Role

- Structural Engineers are responsible for the design of steel, concrete, or timber framed structures such as:
  - Buildings, towers, and bridges
  - Equipment support
  - Equipment access platforms
  - Retaining walls, & foundations
  - Tanks, Stacks & Ducts
  - Pipe Stress Analysis and supports
  - Fall arrest systems and anchor points

Structural Design Flow

Loads	Determine types & magnitudes of loads
Code	Determine structural context • Building Code: IBC with State Amendments • Site Survey and Geological information • Cost / Schedule / Height/ Etc. limitations
Concept	Generate preliminary structural design for larger projects to get construction estimates.
Details	Receive final equipment information & layout approval
IFC	Complete Detailed Design & Issue for Construction
Verify	Construction Support



Types of Loads

- Dead loads: self-weight of structure and equipment
- Live loads: weight of people, material storage, product weight inside bins/tanks
- Dynamic loads: vibrating or moving equipment
- Wind loads: high wind events
- Seismic loads: earthquake forces
- Thermal loads: expansion between fixed points

Quiz Time

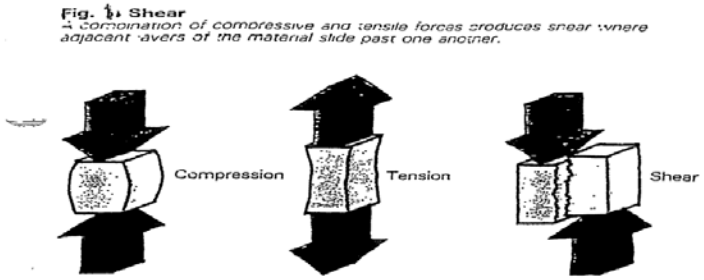
- An operator standing on an elevated platform would be considered as what kind of loading?
  A. Dead
  B. Live
  C. Seismic
  D. Dynamic

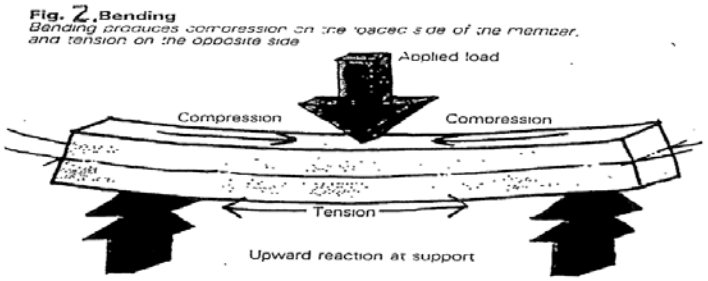
Quiz Time

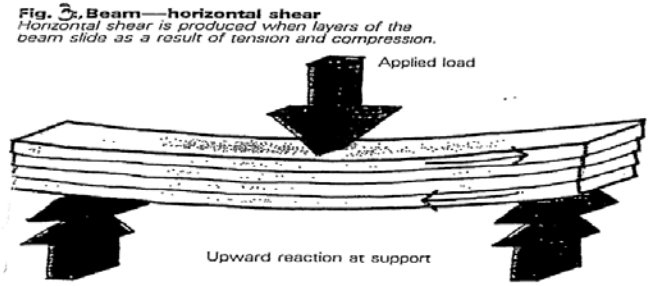
- An operator standing on an elevated platform would be considered as what kind of loading?
  A. Dead
  B. Live
  C. Seismic
  D. Dynamic

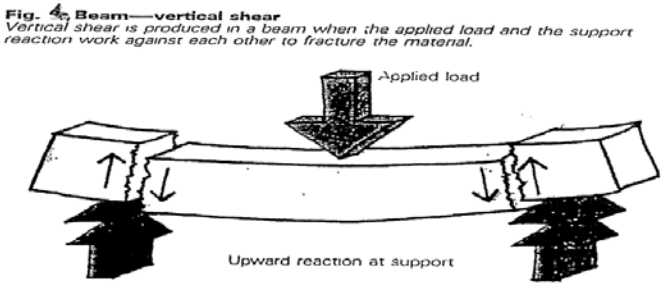
Answer: Live Load

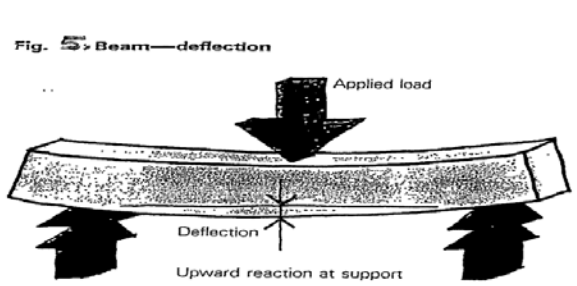
Structural Terminology: Types of Forces

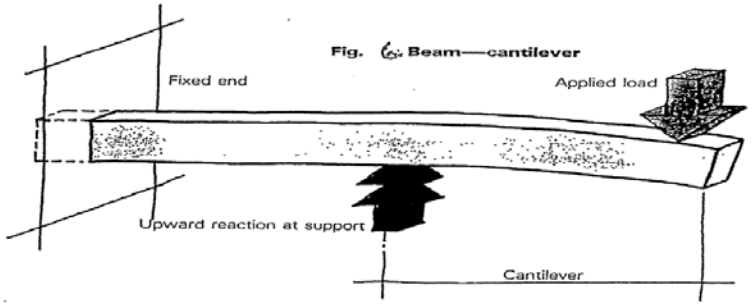






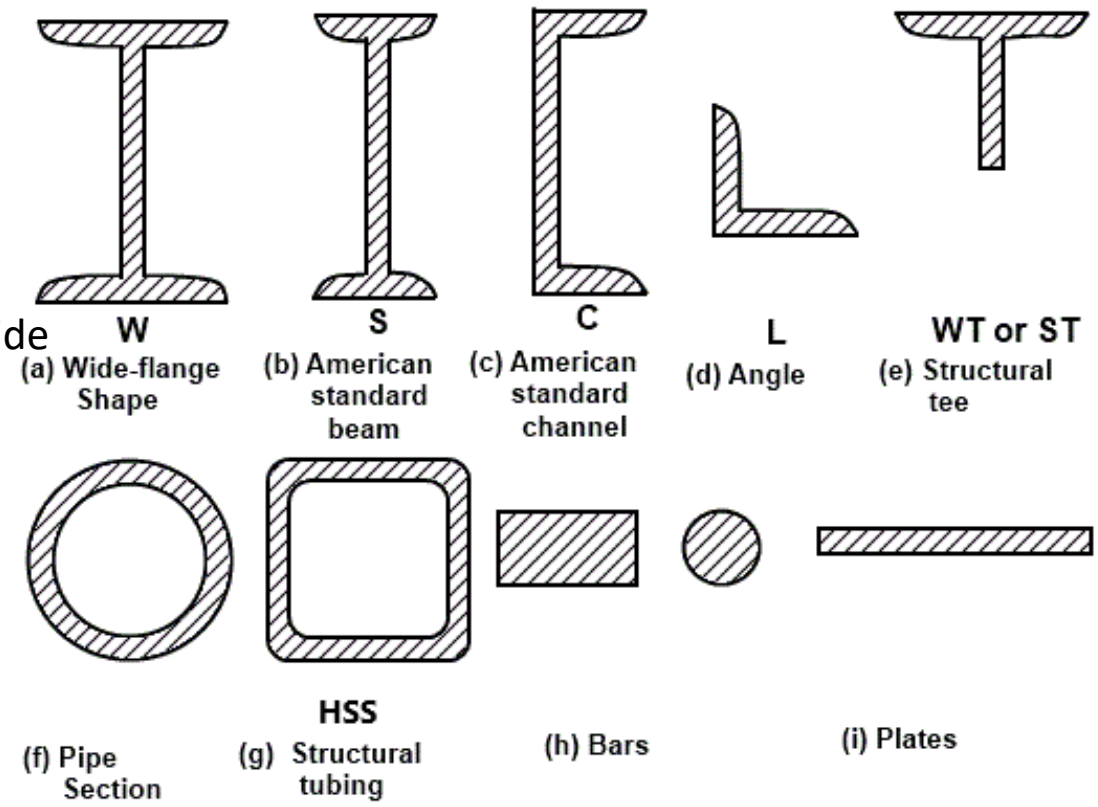






Structural Terminology: Steel Shapes

- W, S, C, WT Shapes: W8x13
  - 8” Deep & 13 lb/ft
- HSS & L Shapes: HSS 10x3x1/4
  - 10” Deep, 3” Wide, ¼” Thick Walls
- Plates: PL 3/8 x 4 x 0’-8”
  - 3/8” Thick, 4” Short Side, 8” Long Side
- Good in both tension & compression
- Ductile behavior (slow, yielding deformation instead of sudden brittle collapse)
- High strength to weight ratio
- Specified by yield strength **Fy**: Typically 50,000 or 36,000 psi

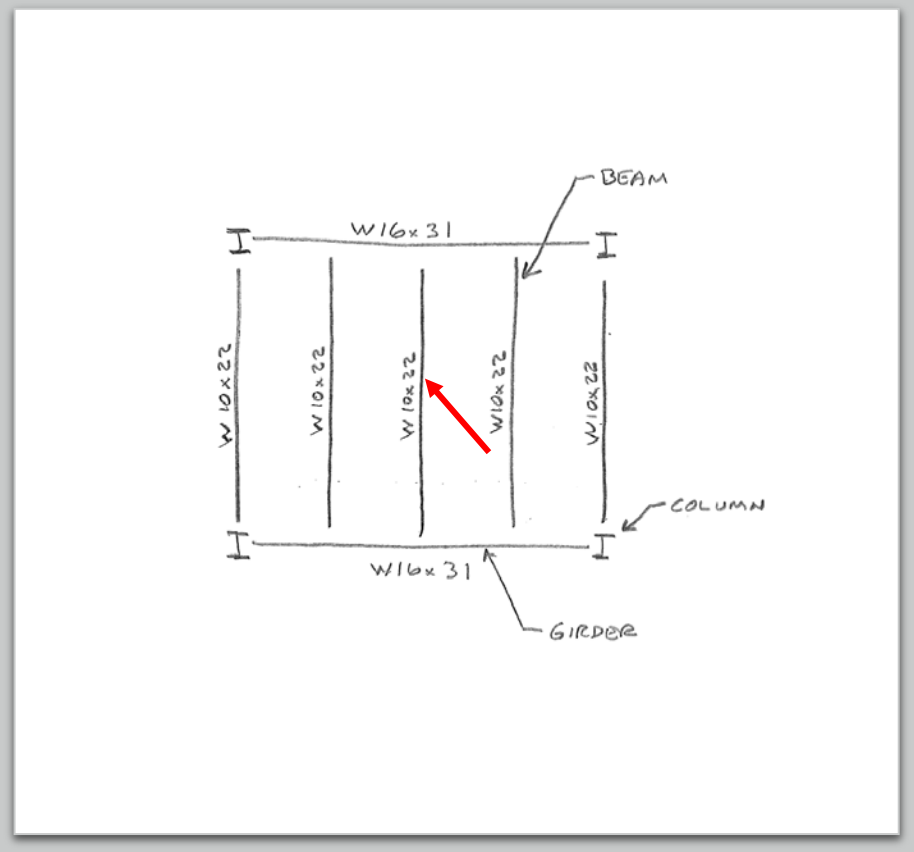


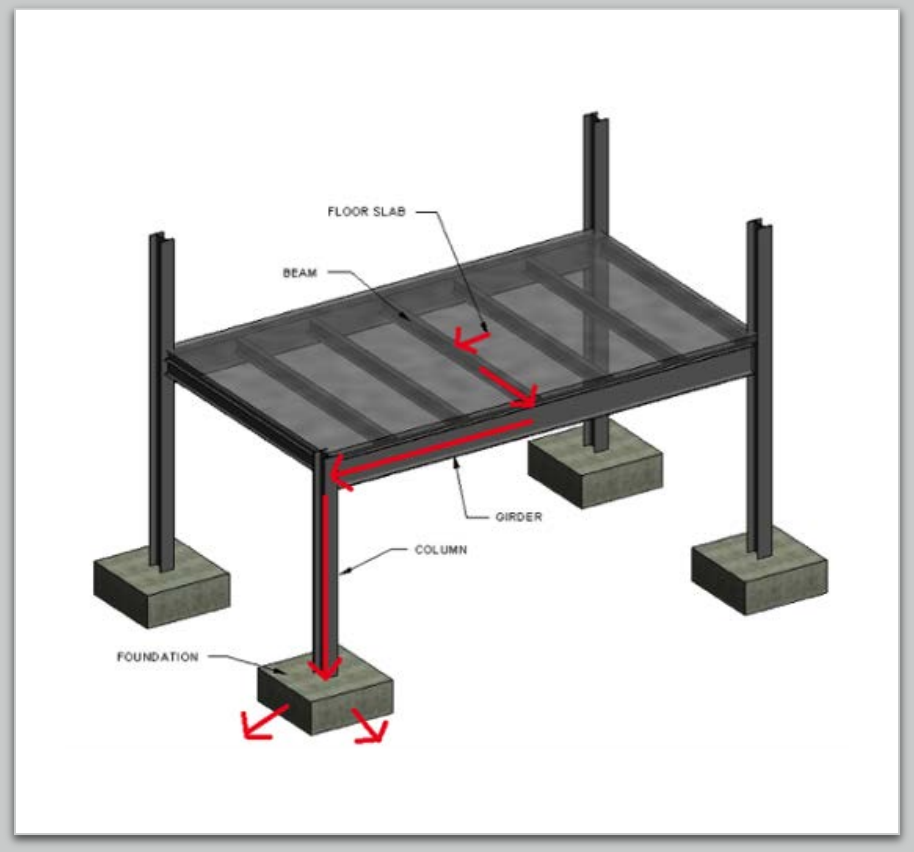
Structural Terminology: Concrete

- Very strong in compression
- Very weak in tension
  - Introduce Rebar to take tensile forces
  - Specified by "**f'c**" refers to the ultimate stress of the concrete. Generally 2,500 – 5,000 psi
- Special Inspections
  - Reinforcing Steel Install
  - Cast-in Anchors
  - Fresh Concrete Sampling
    - Slump Test
    - Air Content
    - Temp
  - Strength Testing
    - Compression Test per ASTM C39
    - One set for each days pour (min)
    - One specimen tested at 7 days, two at 28 days, and one reserve

Structural Terminology: Vertical Load Path

- 1 Kip = 1,000 lbs

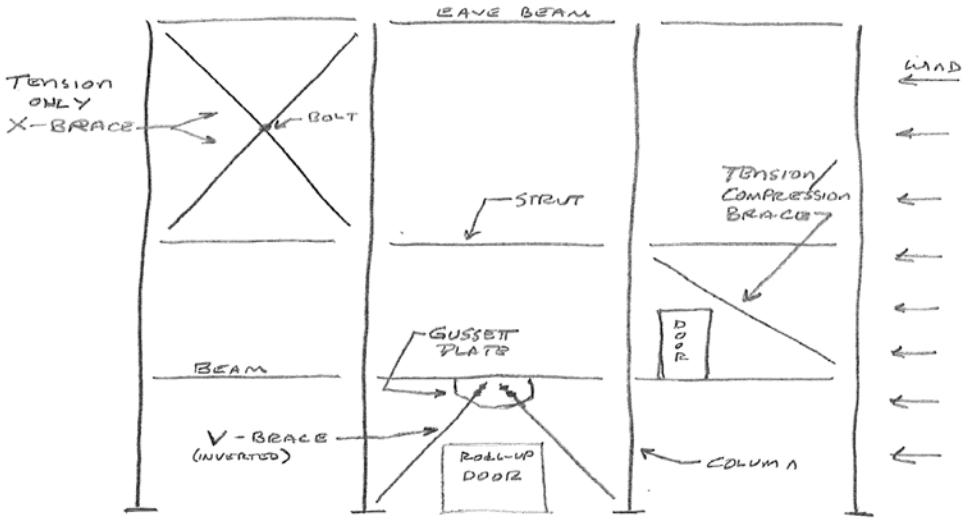




Structural Terminology: Lateral Load Path

Bracing provides Stability against Lateral Loads

- Limit story drift & possible collapse
- Transfer lateral loads to the foundation
- Other options
  - Infilled Frame (Shear Wall)
  - Rigid Joints (Moment Connections)
- Prevent Racking Failure due to eccentricity



ELEVATION w/ BRACING

Wind Damage to Bucket Elevator support tower

Quiz Time

- It is ok to remove/cut one side of a “X” brace configuration if the other side is left in place.
  A. True
  B. False

Quiz Time

- It is ok to remove/cut one side of a “X” brace configuration if the other side is left in place.
  A. True
  B. False

Answer: False

Each member is only designed to resist tension loads. The length of the brace is likely too long for the given section to resist buckling in compression. (e.g. cables)

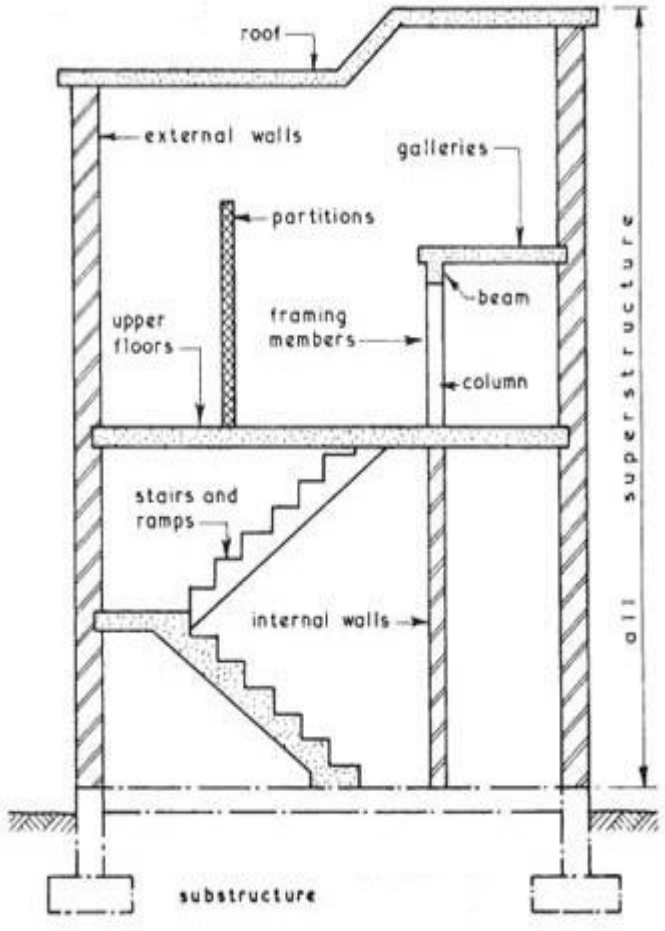
Structural Terminology: Substructure & Superstructure

Superstructure – The portion of the structure above a Ground Level baseline generally serving the purpose of the structures intended use.

- Building
- Platforms
- Tower
- Support structures
- Bridgers

Substructure (Includes Foundation) – The underlying portion of the structure supporting the superstructure by transmitting loads to the soil beneath.

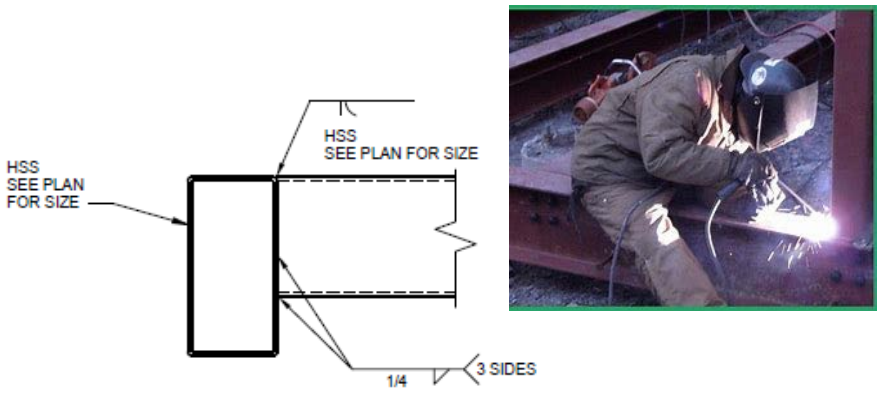
- Shallow
  - Spread Footings
  - Mat Foundations
- Deep
  - Piles
  - Caissons



Welded or Bolted Connections

Welds

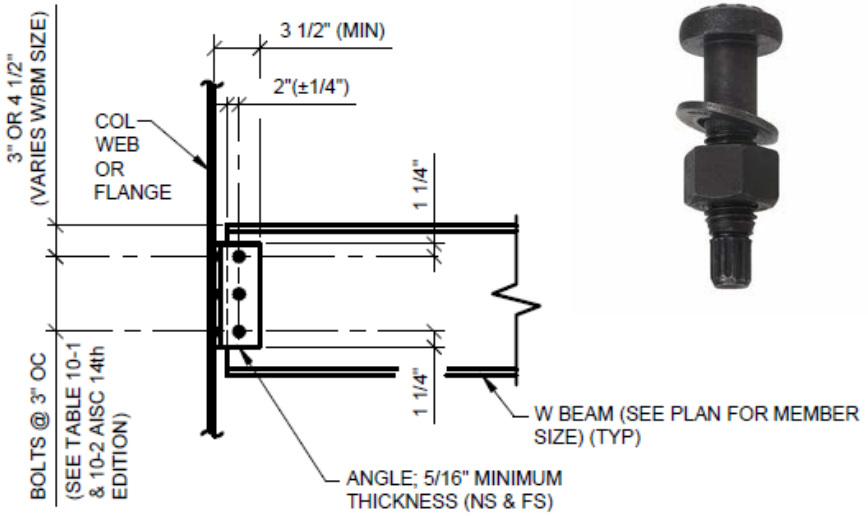
- Good for connecting new to existing
- Less fabrication
- More field time
- Needs special considerations:
  - Galvanizing
  - Fire Protection



TYP MOMENT CONNECTION DETAIL

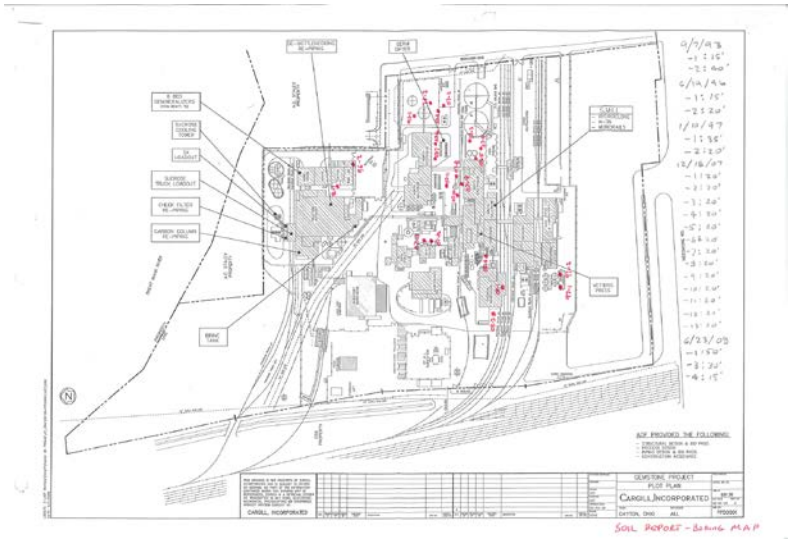
Bolts

- Typical new to new connections
- More complicated fabrication
- Quicker erection
- Requires field drilling when connecting to existing members

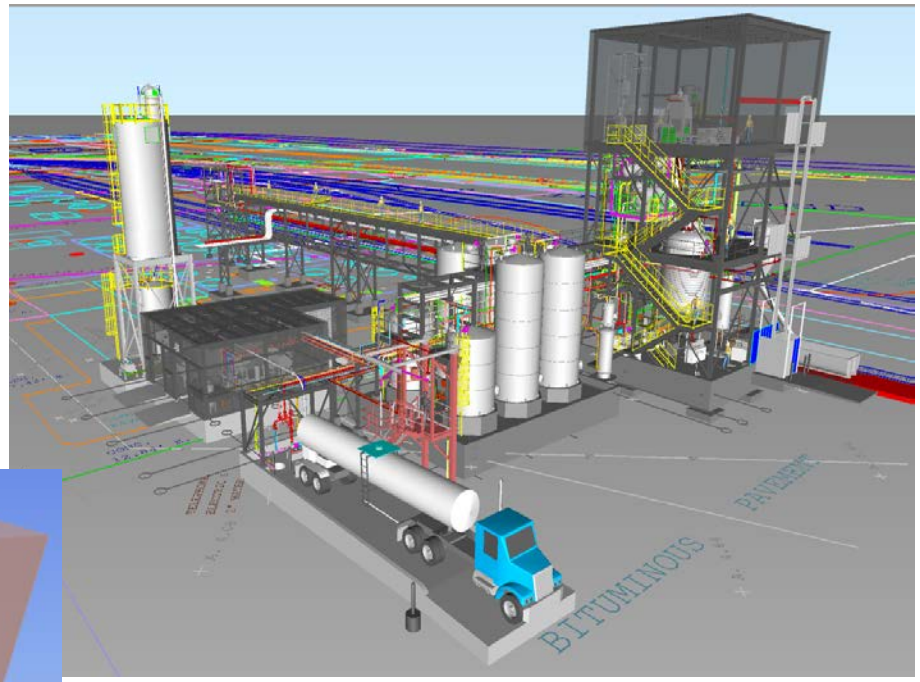


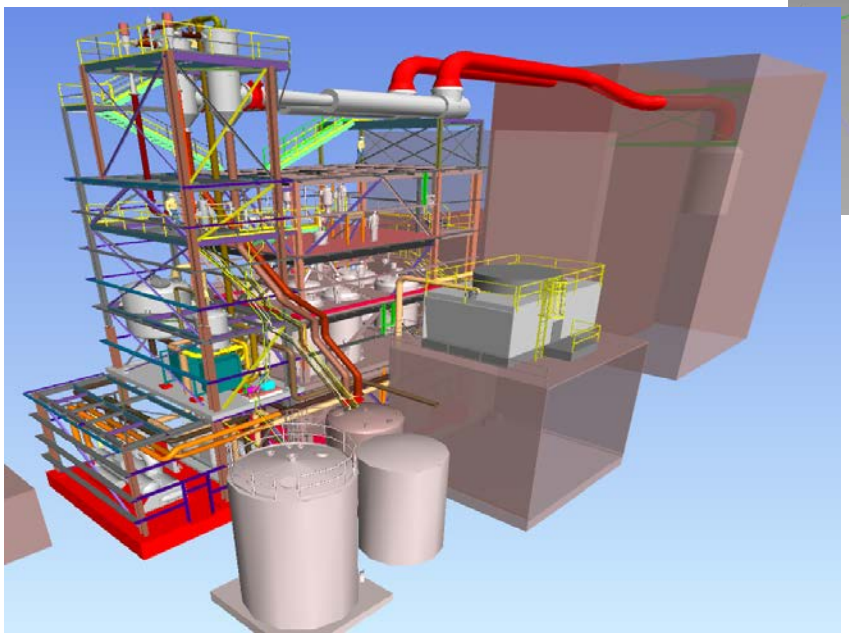
Soil Borings & Reports

- Soil Reports provide geotechnical data to evaluate existing or design new foundations.

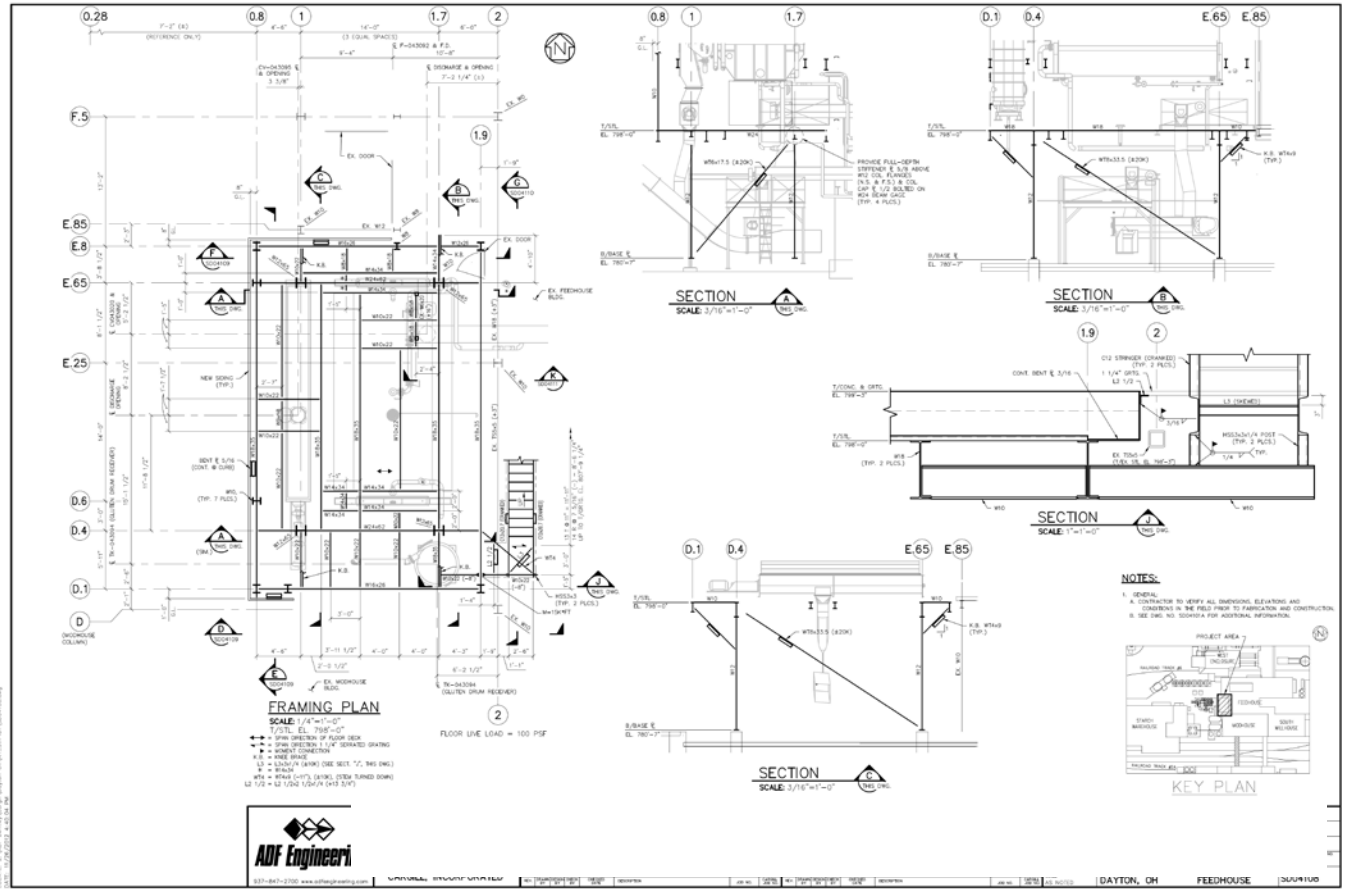


3D Model Creation





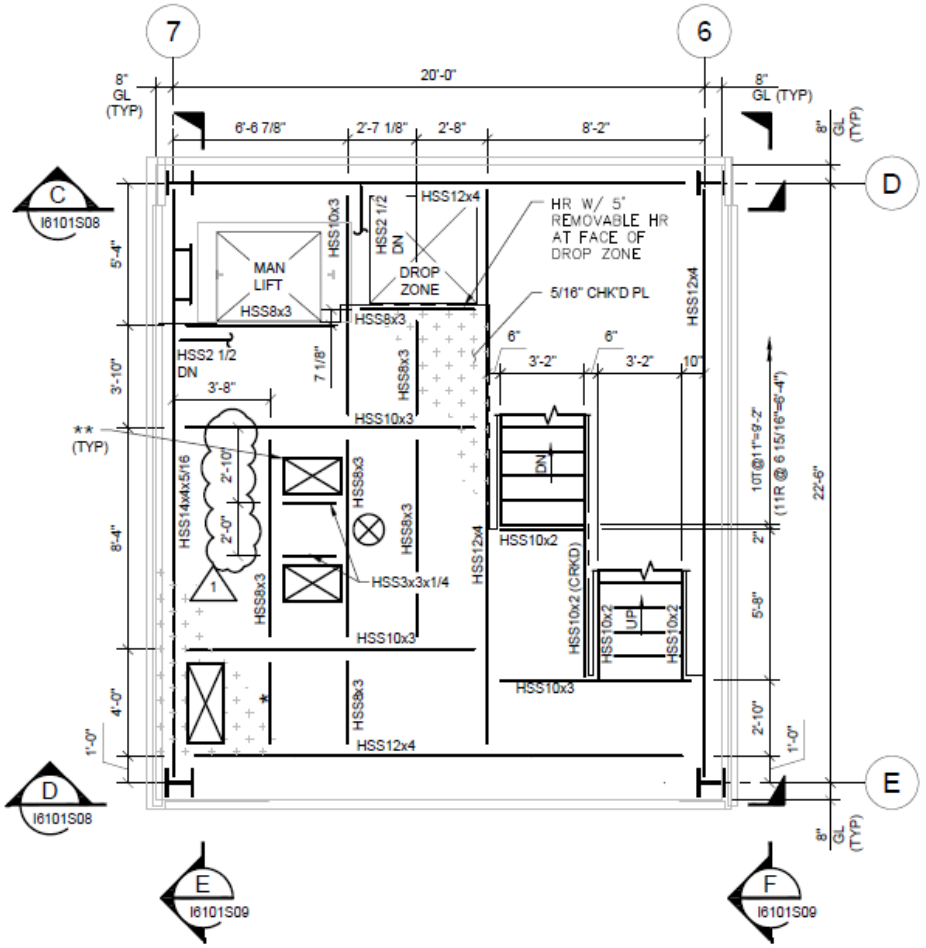
Design Drawings



- Design Phase – Show design intent of the engineer.
- Includes specifications for materials, testing, and inspection.
- Issued to begin Construction Phase
- Not for erection

Design Drawings

- Plan Views
  - Top Down view showing horizontal beams and girders

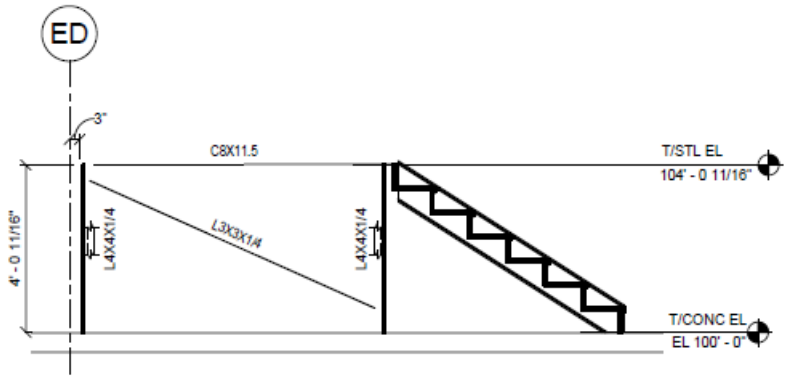


15TH FLOOR FRAMING PLAN (GALLERY ACCESS LEVEL)

SCALE: 1/4"=1'-0"
T/STL EL 250'-0"

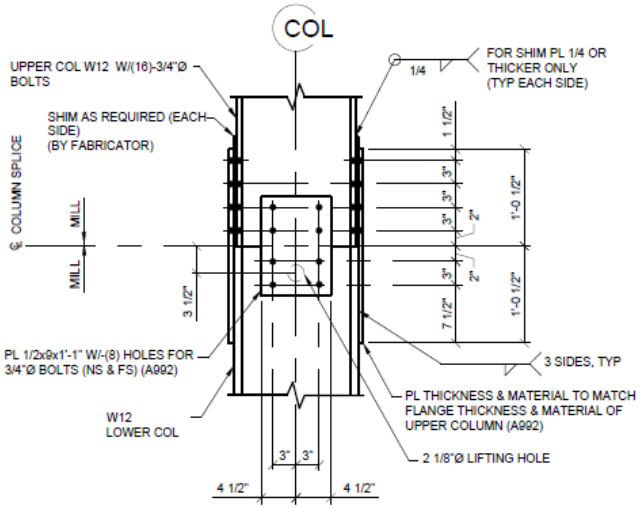
Design Drawings

- Section Views
  - Side view showing columns and vertical braces



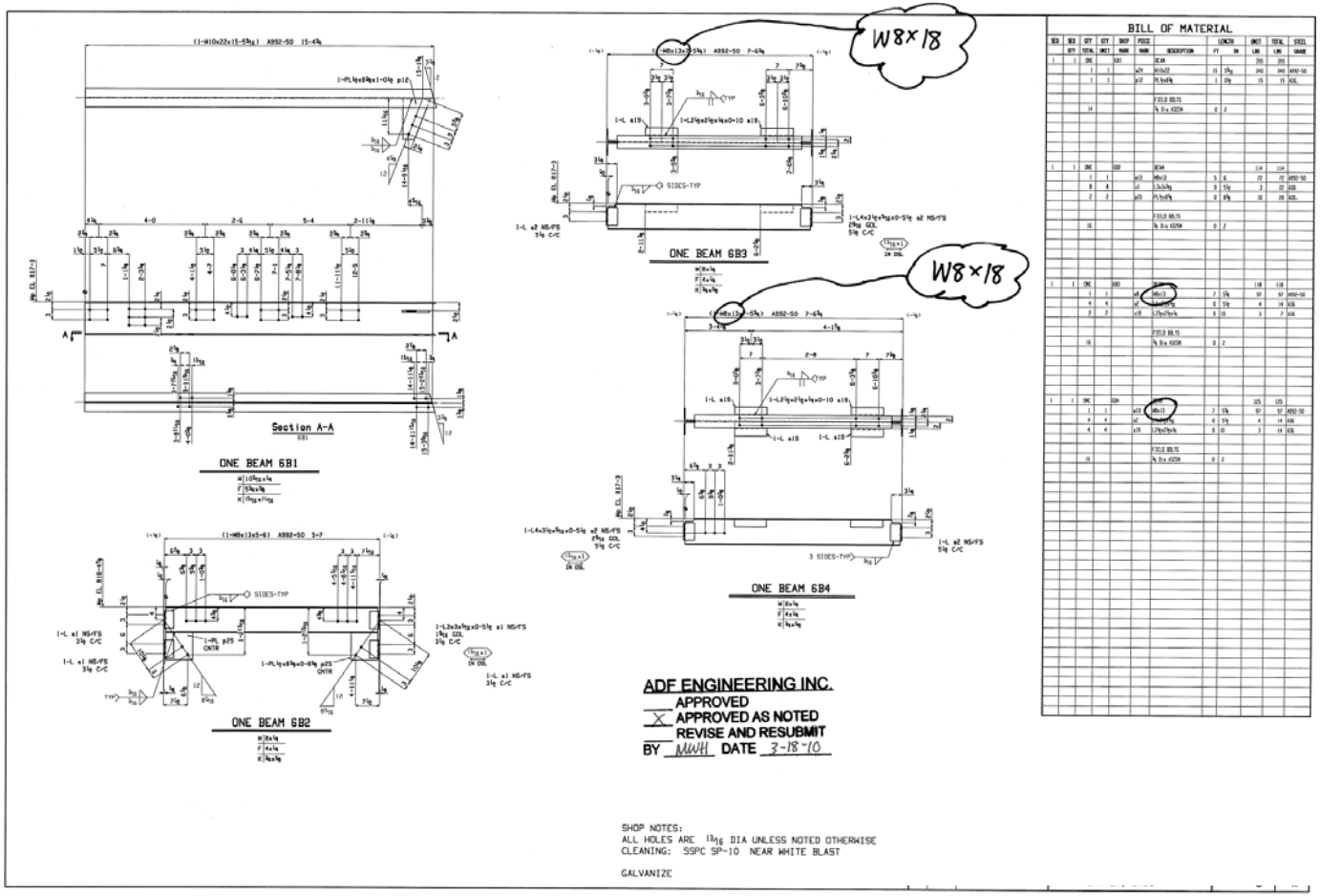
SECTION B
SCALE: 3/8" = 1'-0"
ST-06-215

- Detail Views
  - Large scale images showing specific requirements for contractor or fabricator use.



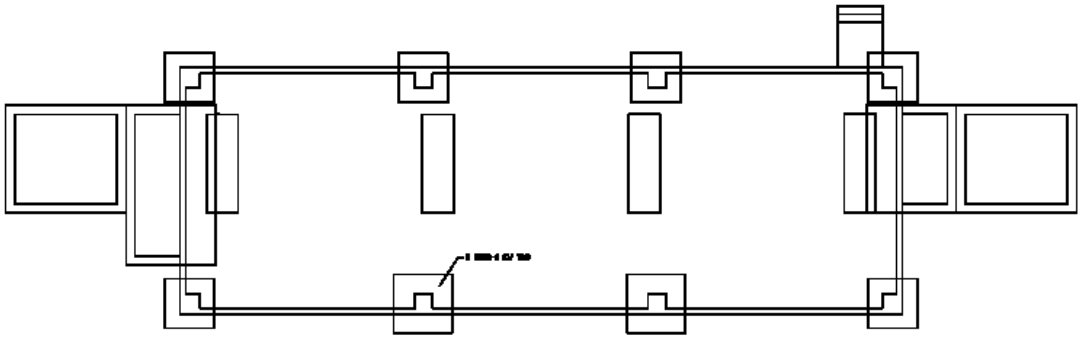
TYP COL SPLICE DETAIL
SCALE: NONE

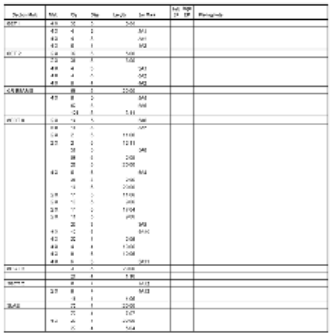
Steel Shop (Fabrication) Drawings

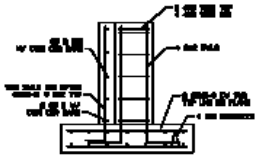


- Between Design & Const Phase
- Done by detailer following engineer's design dwgs
- Assembly dwgs: Issued to begin fabrication of individual members
- Erection dwgs: Issued for installing contractor

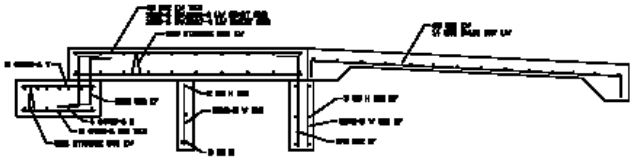
Rebar Shop Drawings



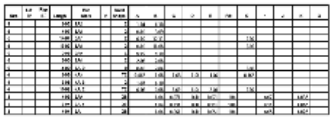




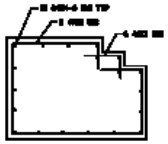
TYPICAL PIER DETAIL



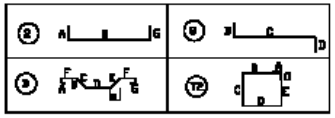
SECTION A

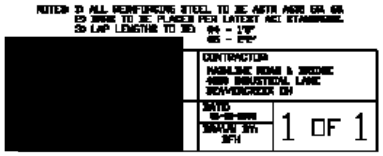


SECTION B



SECTION C





Engineering Support During Construction Phase

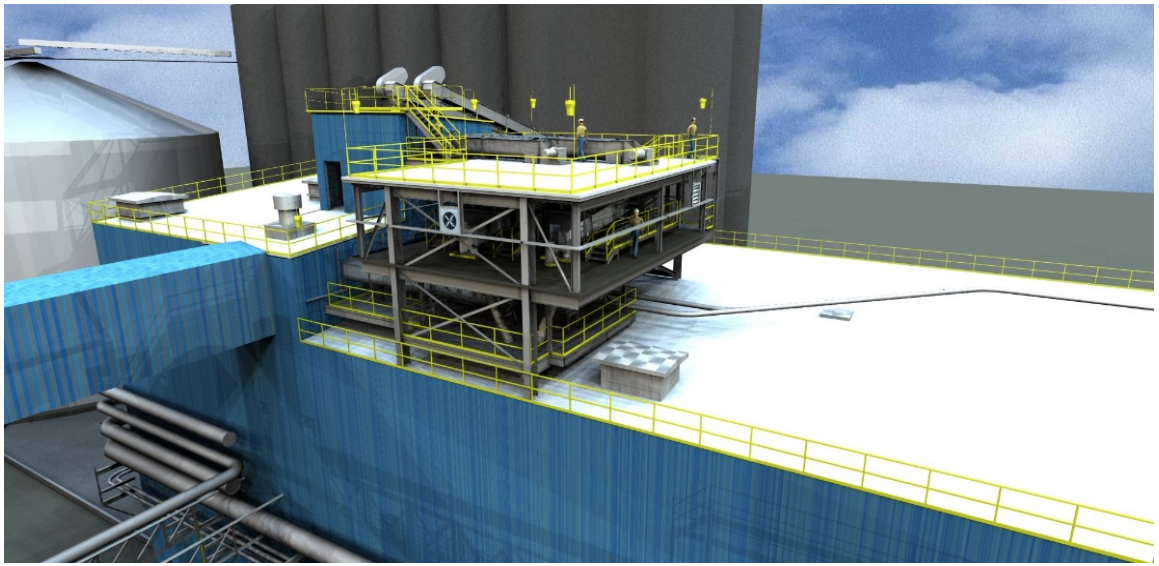
- Owners rely on design engineers to plan construction, specify equipment, and select contractors, but then assume huge risk for the project and themselves by not engaging design engineers in the construction phase of the project.
- EOR can recognize construction issues, provide valuable insight to help mitigate the risk of misinterpretation of the design intent, respond to RFI's, as well as review and document changes.

Engineering Support During Construction Phase

- Provide confidence that work is proceeding in accordance with the Construction Design Documents
  - Approval of contractor provided concrete mix design as well as site and lab testing data.
  - Inspection of steel placement, bolts, welds, rebar setting, etc…
- Determine the acceptability of substitutes proposed by contractor that vary from the construction & material specifications or design intent
- Provide recommendations to the owner regarding whether the contractor should correct any defective work or should remove and replace it instead
- Conduct a final visit to determine if work is complete and acceptable

Dealing with Existing Structures

For most industrial clients, new projects focus on expanding or renovating their existing facilities for new or upgraded processes. These are considered “Brownfield” projects. Brownfield projects offer their own unique challenges that require consideration during the design process.



- The plant must remain in operation or only has a limited shutdown window.
- Flammable chemicals eliminate the use of all non-intrinsically safe equipment.
- High potential for interferences with existing structures, equipment, and utilities.
- Constructability a major factor.

Collecting Field Info

Before

- Measuring Tape
- Surveying Transits
- Cameras
- Eyeball

Now

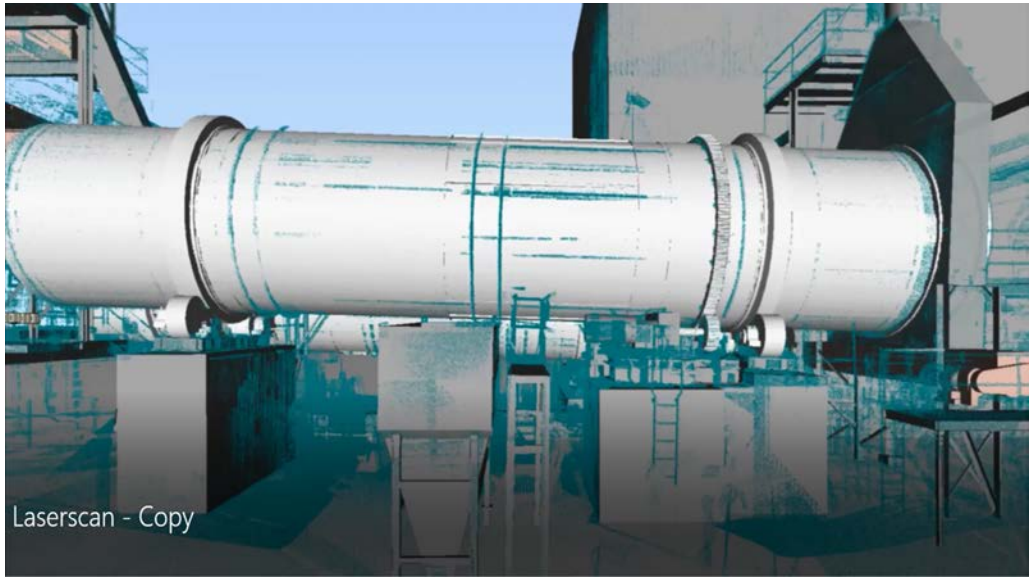
ADF offers

- Laser scanning
- Classified/Explosion proof scanning
- Photogrammetry
- UAS/Drones

Laserscan Case Study

Steam Tube Dryer

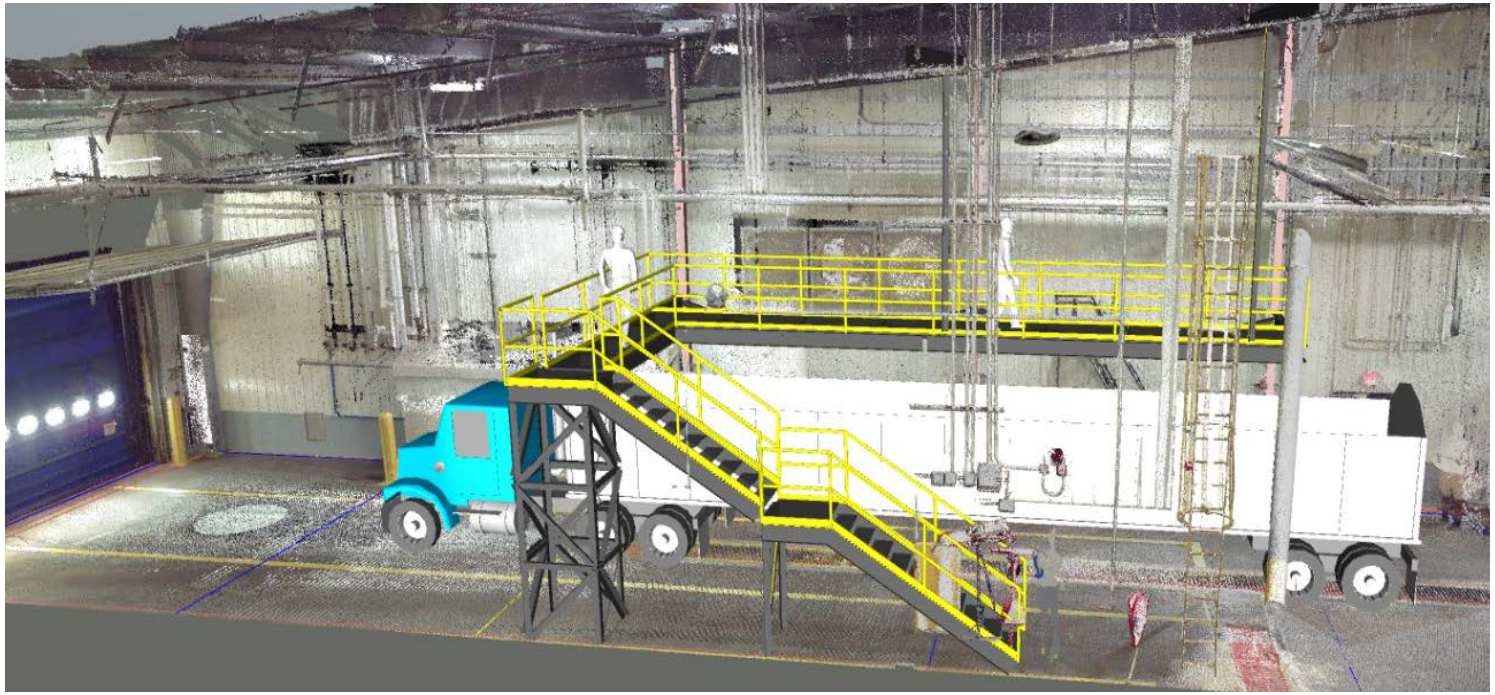
Replacement: Dayton Plant



Design Challenges:

- Foundation Alignment Of New Dryer
- No Down Time Available During Design Phase
- Critical Path Schedule To Meet Production Needs

Combining Laser Scan & 3D Modeling

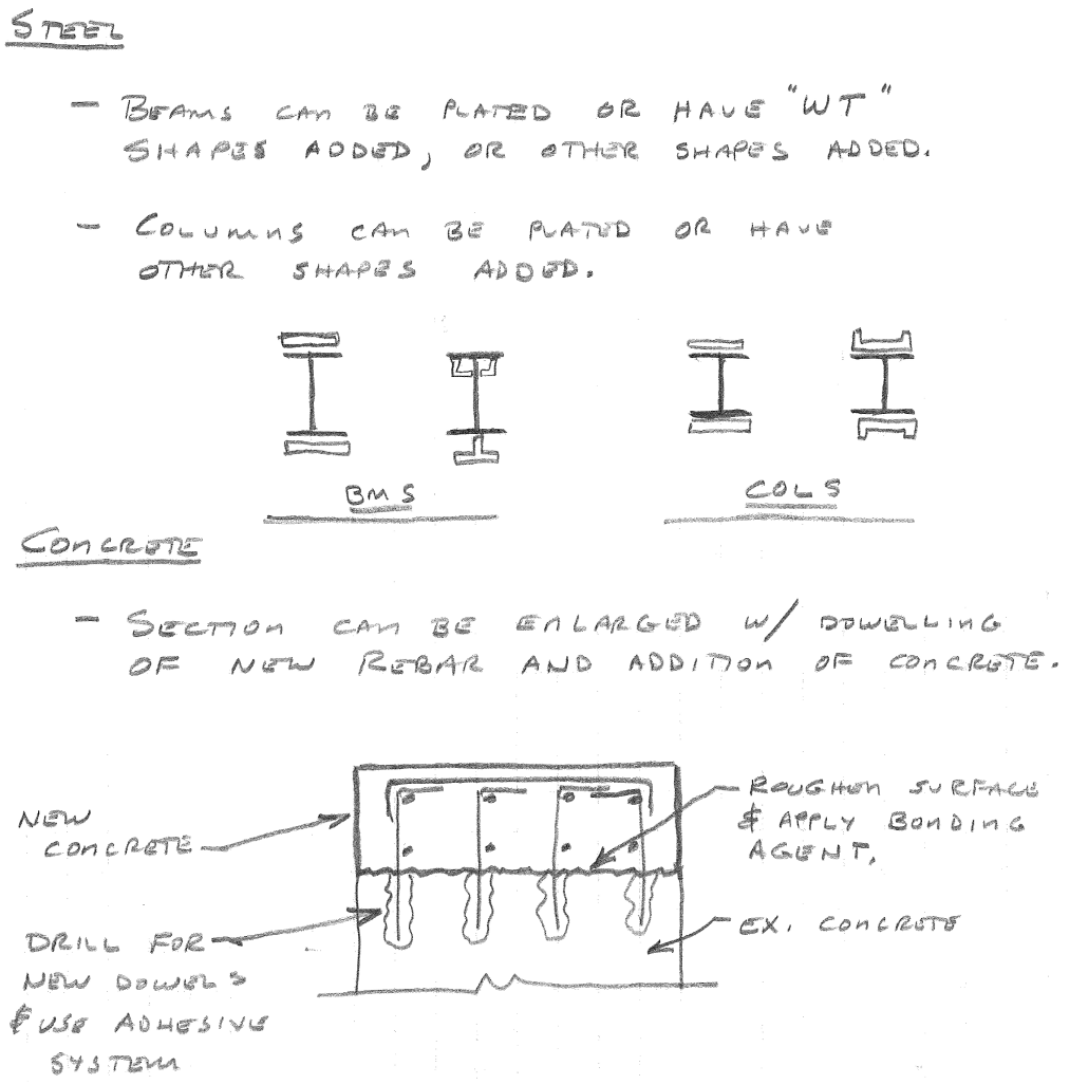


Walkthrough Files created including:

- Point cloud representation of laser scanned site condition
- Conceptual structural additions
- New equipment models
- Employee or Vehicle models

Structural Reinforcement

- When existing members are subjected to different loads from the original design.
- Increase capacity of existing members instead of replacing them.
- Labor costs higher per Ton of steel than new members but potentially more economical overall with:
  - Less down time
  - Easier constructability



When do we need a Structural Condition Survey?

Have you ever seen anything like this?

Structural Condition Survey

- Visit an area and mark-up an existing dwg (or hand sketch if dwg is unavailable) with any issues or concerns. This includes looking at the handrail, grating, ladders, stairs, roofing, and of structural framing.
- Photograph and physically tag each item to help document any noted issues of concern.
- Any items of immediate concern for personnel safety with regards to handrail, grating, ladders, stairs, or structural steel is provided to Client daily for their consideration.
- Items requiring additional effort by ADF are noted and a remediation plan is developed with the associated Client Department Manager.

Quiz Time

- It is alright for the contractor or fabricator to make changes to the structural design…
  A. only if they are little changes.
  B. as long as they are a “good” contractor.
  C. only if they have been submitted to and approved by the Engineer.
  D. never.

Quiz Time

- It is alright for the contractor or fabricator to make changes to the structural design…
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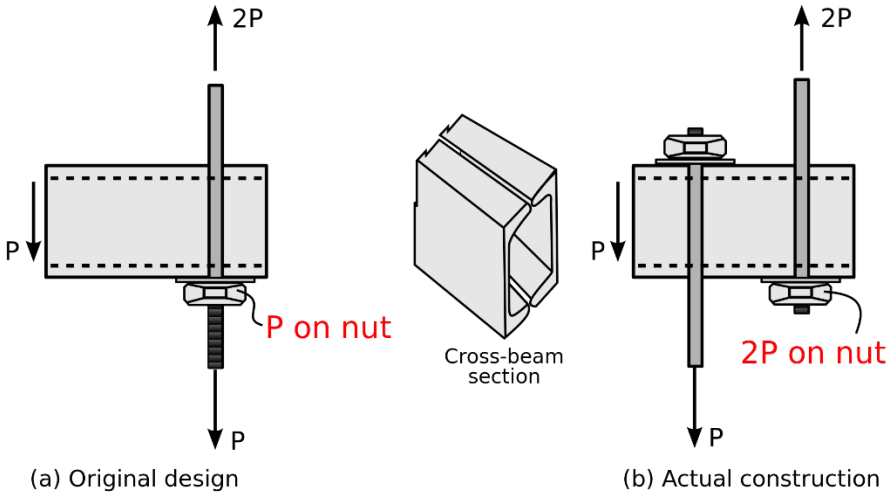
  C. only if they have been submitted to and approved by the Engineer.
  D. never.

Answer: C

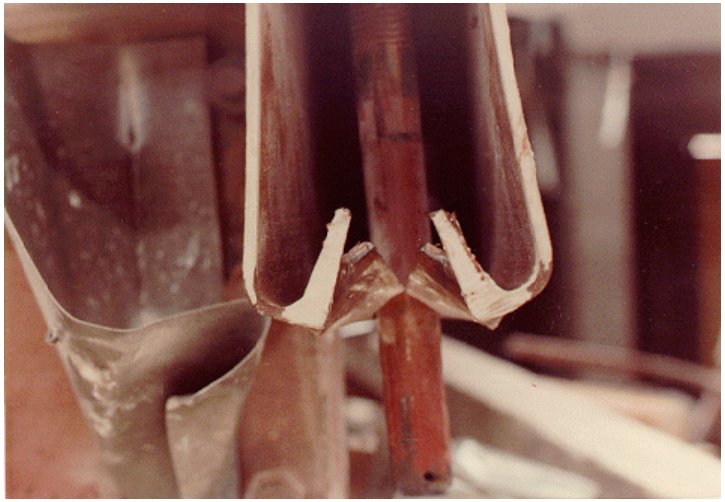
Case Study: Hyatt Walkway Collapse

- Built in 1978
- Failed on July 17, 1981
- Two 120’ bridges collapsed into a dance being held below.
  - 114 Dead
  - 216 Injured
  - 9 Hours to rescue last survivor
- Deadliest non-deliberate structural failure in American History
- Required several years of Engineering investigation

Case Study: Hyatt Walkway Collapse



- Fabricator wanted to alter original connection design to simplify constructability. Continuous threaded rod would be subject to damage.
- Proposed two separate offset rods, unintentionally doubling the force on the connection.



- Investigators found that the underlying problem was lack of communication between engineer and fabricator. Dispute over design revision approval.
- Provides vivid example of the importance of accuracy and detail in engineering design and shop drawing review (particularly regarding revisions)

Case Study: Salt Plant Roof Collapse

- Constructed in 1965
- Current owner 1983
- Large segment of roof and wall collapsed during major storm event. Contributing factors likely:
  - Block wall was cracked an unreinforced
  - Roof joists were corroded.
  - Additional loads
    - Ponding
    - New roofing

Summary

- How can Structural Engineers make your projects successful?
  - Design structures to provide safe and economical load paths.
  - Review contractor submittals to ensure they follow the original design intent.
  - Inspect the construction site to verify the work meets quality and safety standards.
  - Act as your advocate when discussing contractor change requests or test results.

References available for Downloads:

- Webinar PDF
- Structural Abbreviations
- PDP phases
- OSHA walkdowns checklist

Questions?

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