State of Practice for Spillway and Gate Inspections and Analyses

Innovative Water Technologies for California Workshop

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PETERSON . BRUSTAD . INC
ENGINEERING . CONSULTING

Outline

- Spillways Inspections
  - Oroville Spillway
  - Planning
  - Visual
  - NDT
  - Drains
- Gate Inspections
  - Visual
  - NDT
- Trunnion Friction Testing
- Radial Gate Finite Element Analysis (FEA)

Oroville Spillway, February 2017

- Emergency Response
  - Scour hole
  - Slab thickness measurements
  - Gate inspections
- Independent Forensic Investigation
  - Joint Details
  - Drain Details
  - Cracking/Spalling
  - Foundation Preparation
  - Designer/Contractor Communication
  - As-built Design Review

California Legislation

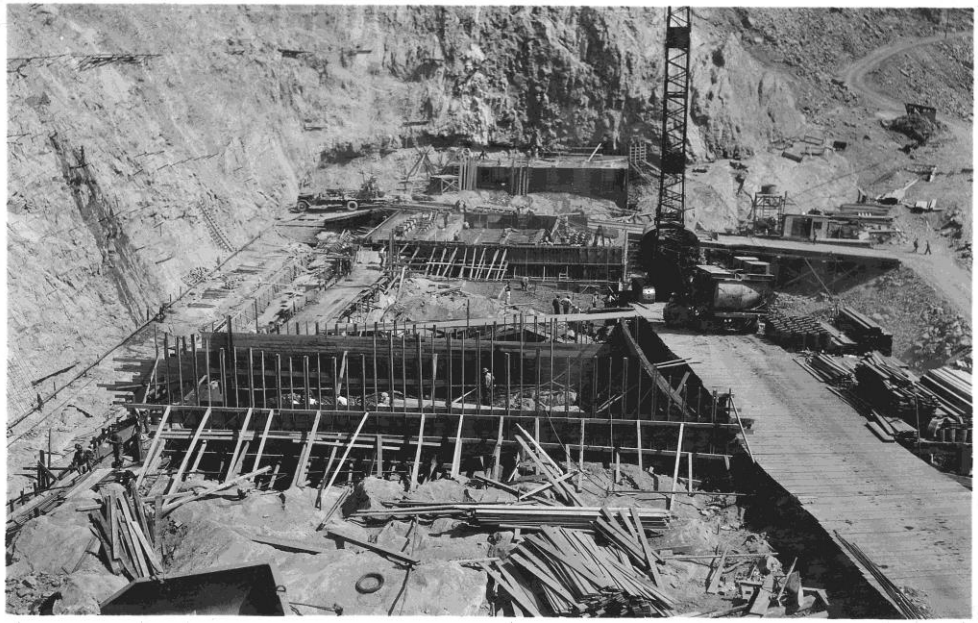
- Assembly Bill No. 1270
  - Approved on 2/26/18
  - Water Code
    - Repeal and replace 6102
    - Add 6102.5 and 6103
  - Required Inspections
    - Significant, high, or extremely high hazard classifications
      - Once per fiscal year
    - Low hazard classification
      - Once every two fiscal years
  - Operate critical outlets and spillways annually
  - DSOD to update inspection and evaluation protocols before 1/1/19 and every 10 years thereafter

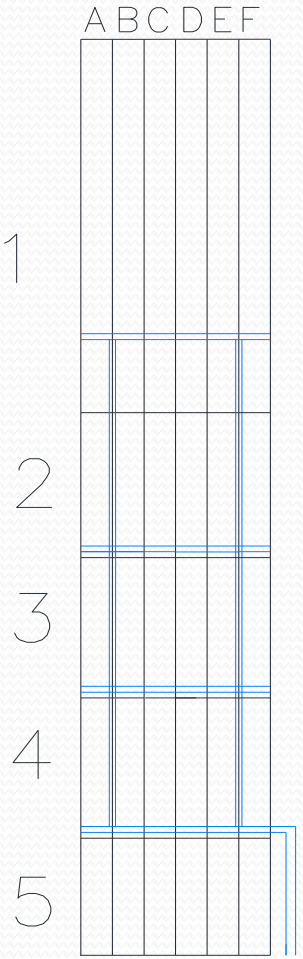
Spillway Inspection - Planning

- Spillway Configuration
  - Grade
  - Geometry
  - Access
    - Equipment
    - Rope Access
- Determine what NDT if any is part of the scope
  - If impact echo and/or GPR is to be performed:
    - The slab must be reasonably dry
      - Weather
      - Leakage
    - Five-foot lanes may be marked with spray paint

Spillway Inspection – Planning

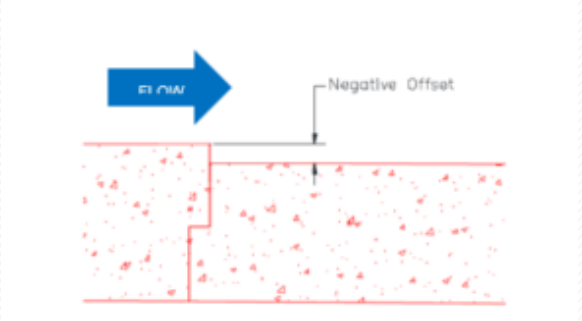
- As-Built Details
- Spillway Inspection, Repair and Retrofit History
- Drain Layout

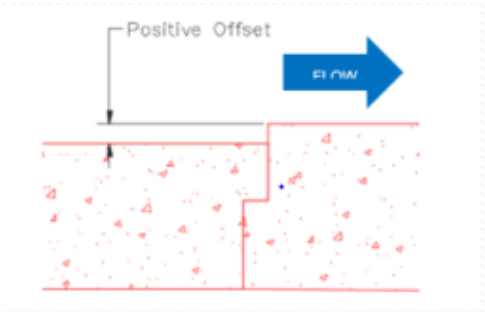




Spillway Inspection - Visual

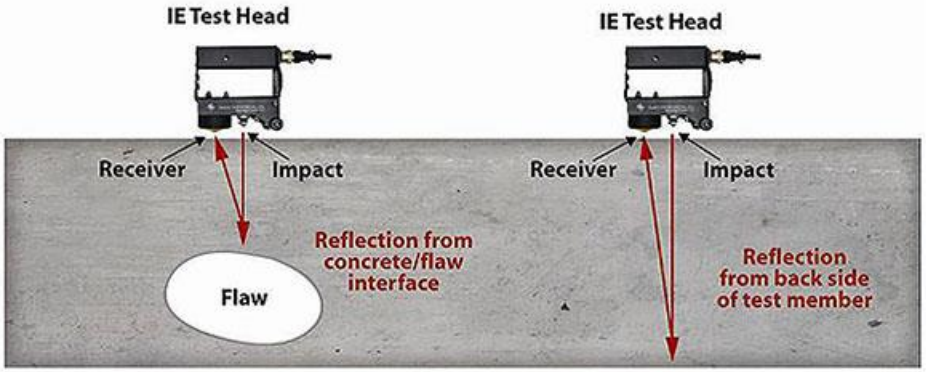
- Indicating Deficiencies
  - Different color spray paint for cracks, spalls, and delaminations
  - Typically identify cracks that are 1/8" or larger
- Hammer Sounding
  - Used to find surface delaminations
- Offset Measurements
  - Slab and wall joint offsets and identify as negative or positive offsets
  - Negative = DS lower than US, Positive = DS higher than US





Spillway Inspection - NDT

- Impact-Echo
  - Slab thickness
  - Potential delaminations
- Ground Penetrating Radar
  - Voids under slab
- Slab coring
  - Core at points of interest identified from Visual or NDT methods
  - DWR starting this phase on many of their spillways, so it will be a good way to validate the above NDT methods

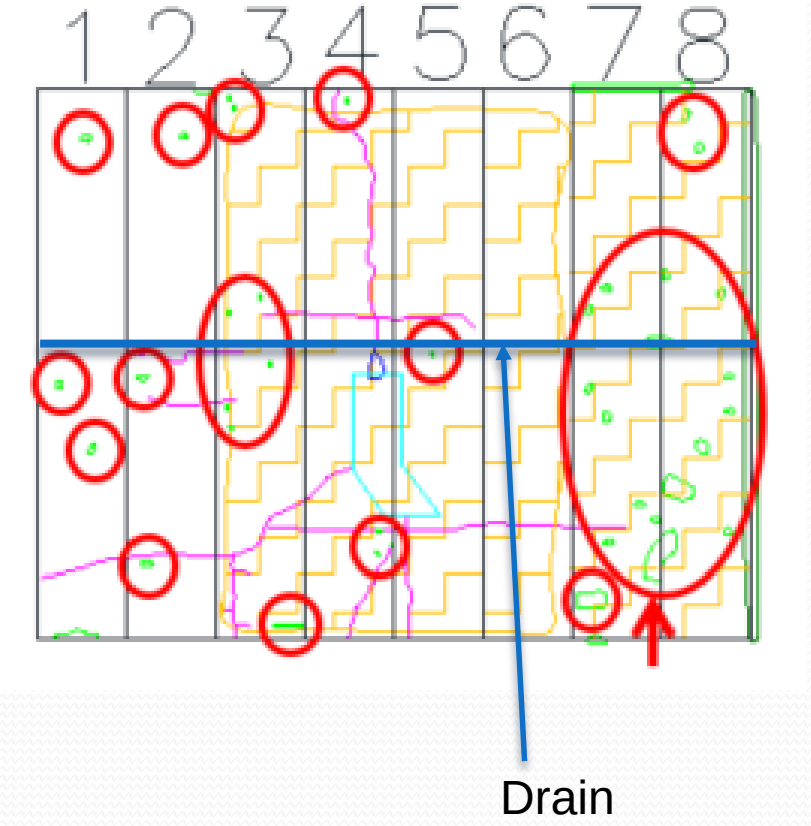


Spillway Inspections - Drains

- Subconsultant Snake Camera and Prodding
  - Clogs
  - Broken Pipe

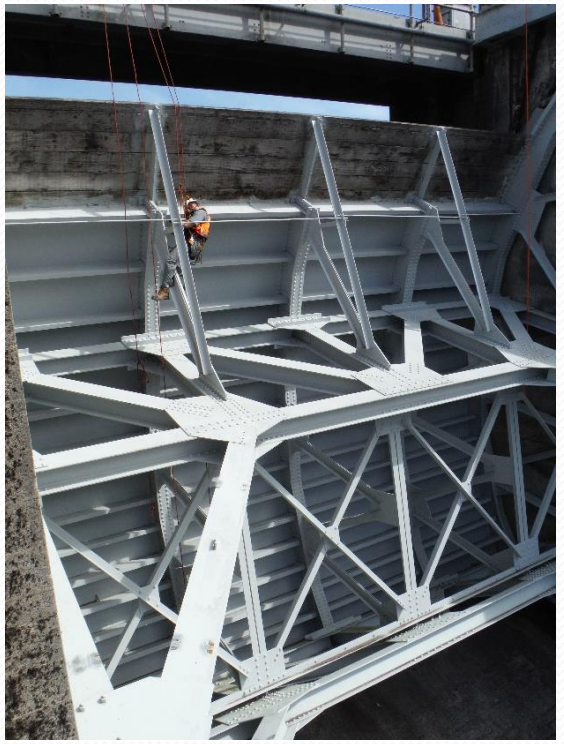
Spillway Inspection – Post Processing

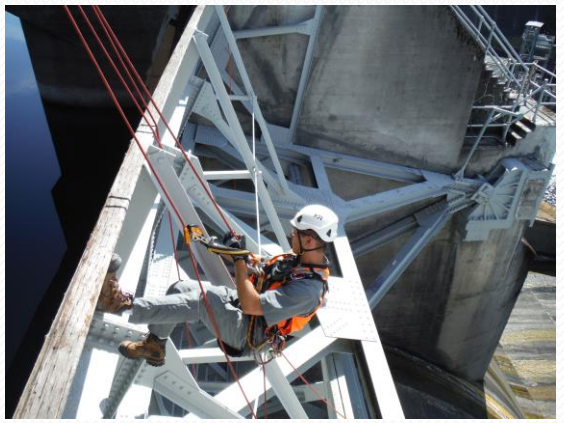
- Comparing Visual Inspection, NDE, and Drain Inspection Results
- Form Conclusions
- Develop a Plan of Action



Gate Inspections

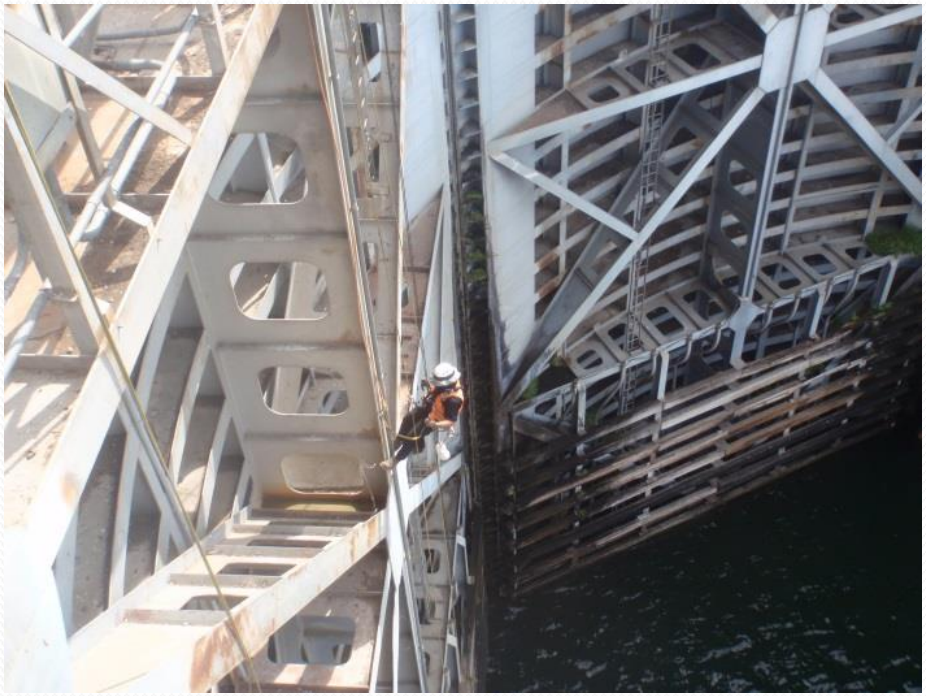
- Visual inspections
  - Welds
  - Bolts/Rivets
  - Deformations
    - Impact vs Stress Related
  - Coating/Corrosion
- NDT
  - UT thickness
  - Mag Particle
  - Subcontractor
    - Weld UT
    - Weld Phased Array

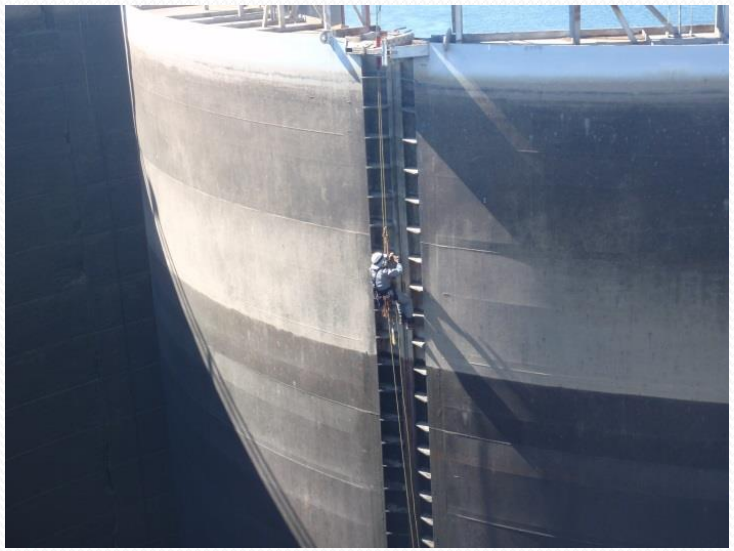




Gate Inspections – McNary Lock

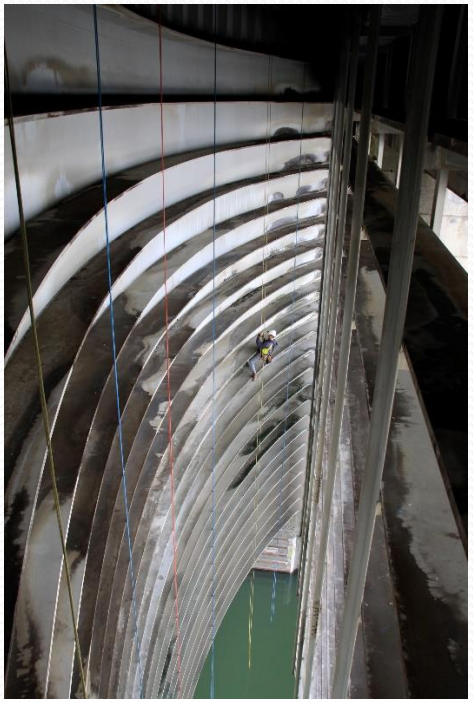
- Miter Gate Leaf
  - 106’ Tall
  - 53.5’ Wide

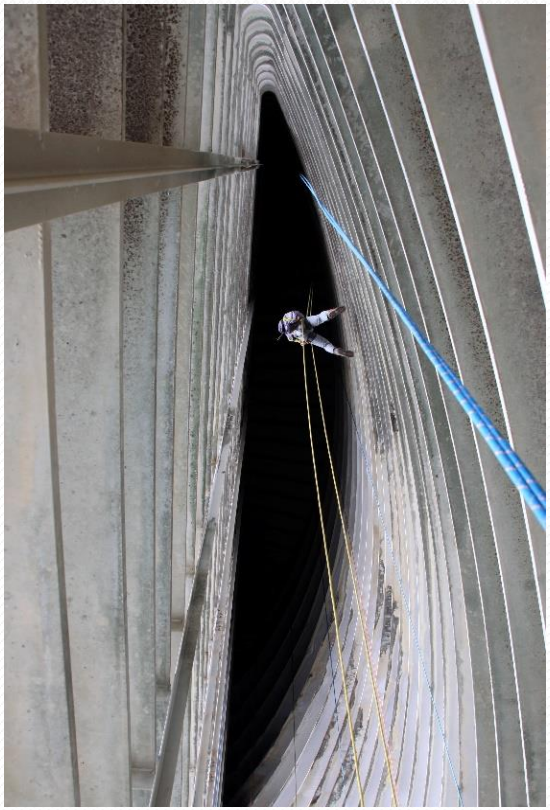


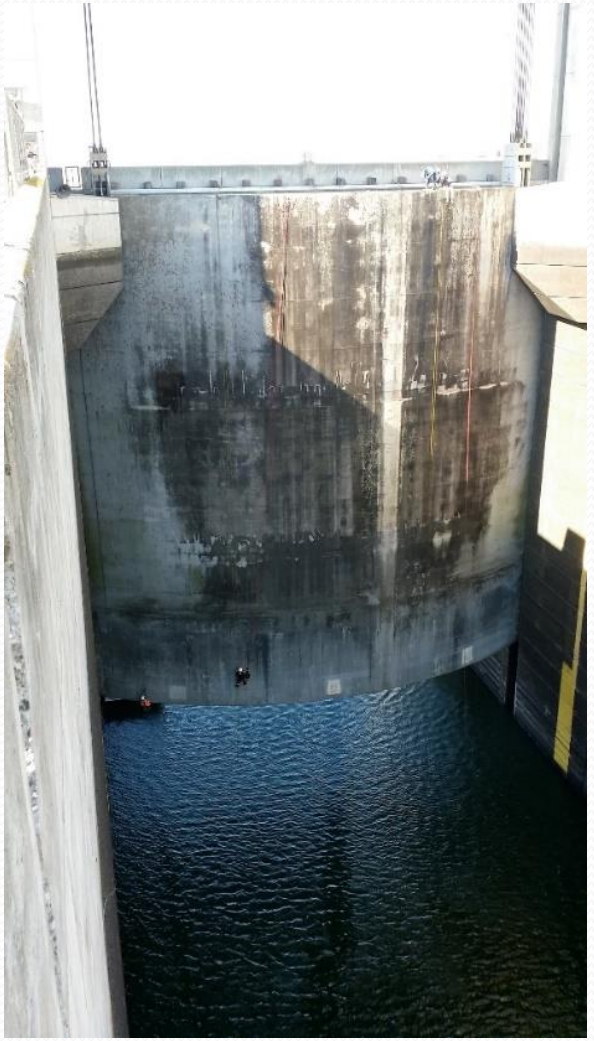


Gate Inspections – Ice Harbor Lock

- Vertical Lift Gate
  - 90’ Tall
  - 87.5’ Wide
  - Arch Design





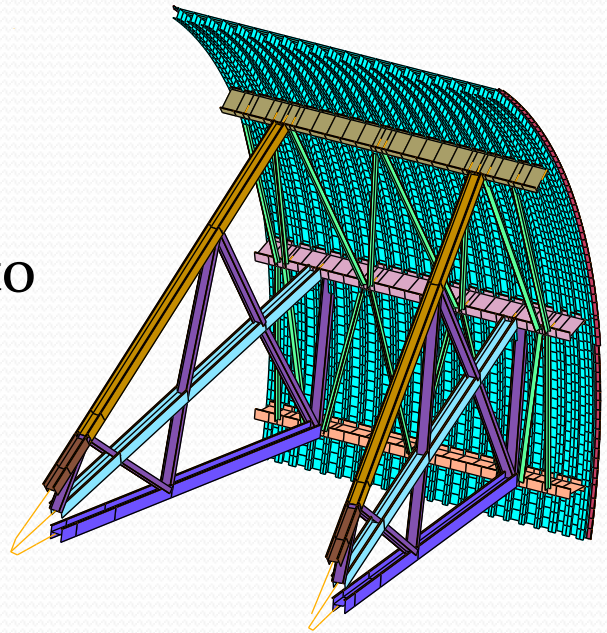


Trunnion Friction Testing

- Performed by Subconsultant (BDI)
- Purpose
  - Estimate Actual Trunnion Friction Coefficient in Field
  - Replace 0.3 Value Recommended by USACE and FERC
- Procedure
  - Install strain gages
  - Cycle gates up and down
  - Back-calculate axial, shear, and moments
  - Sum forces at pin to estimate friction moment
  - Use known thrust load to back-calculate the friction coefficient

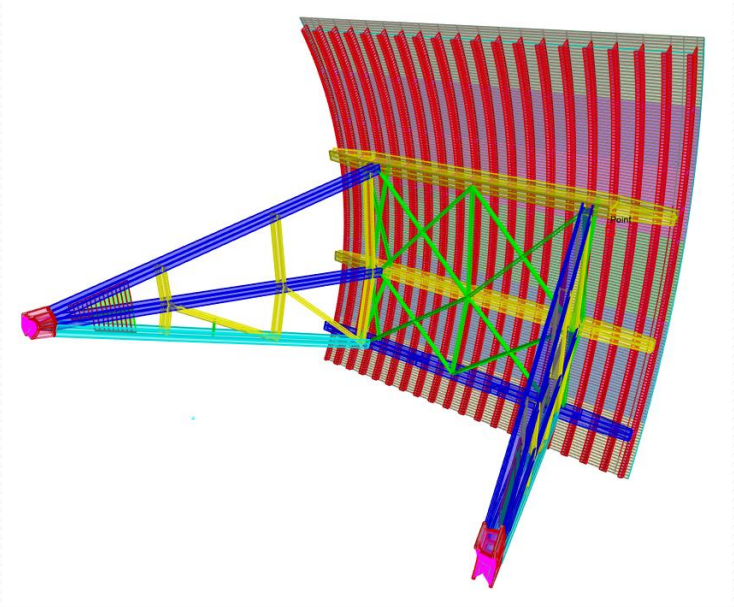
Trunnion Friction Testing

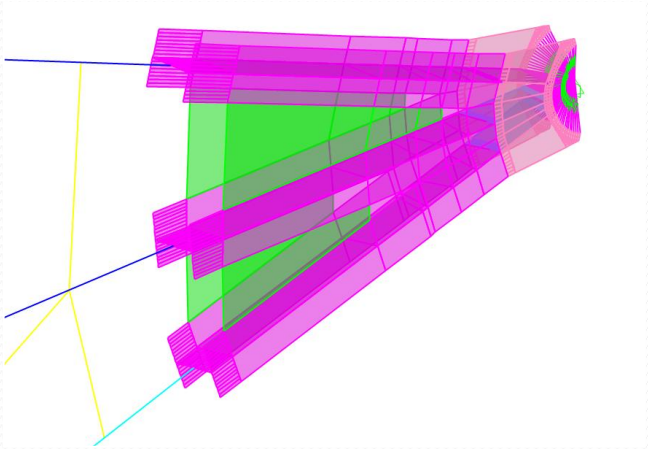
- Structural engineer performing gate analysis may do the following:
  - Review testing report
  - Use field measurements and SAP2000 model to validate one another
  - Once validation is complete use field measured trunnion friction to run operating load cases rather than 0.3.



Radial Gate FEA

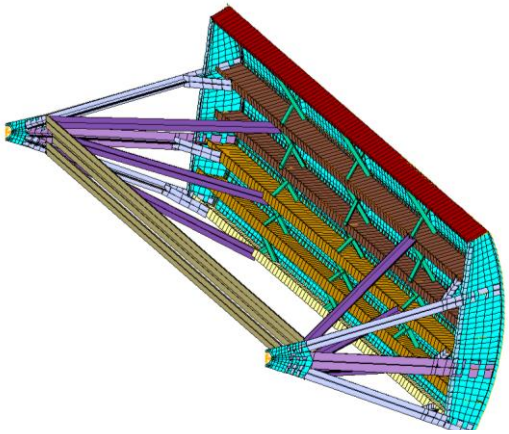
- Standard Practice
  - 3-D FEA model
  - Gate closed cases
  - Gate operating cases
- Typical Element Types
  - Shells
    - Skin Plate
    - Ribs
    - Trunnion Transition Plates
  - Frames
    - All other members

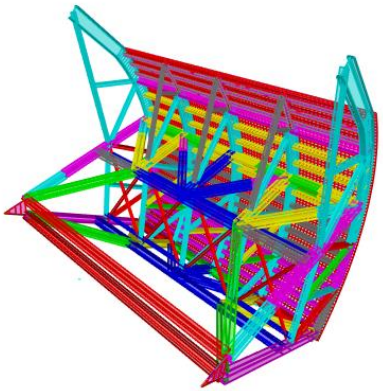


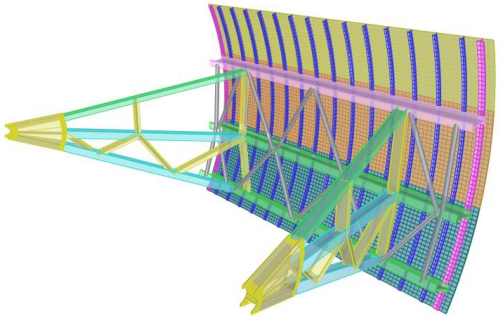


Radial Gate FEA

- Potential reasons to update analyses
  - PMF WSE changes
  - Seismic demand changes
  - Include or update trunnion friction
  - Meet current code
    - USACE ETL 1110-2-584 is most relevant code
      - Not all load cases typically required by FERC

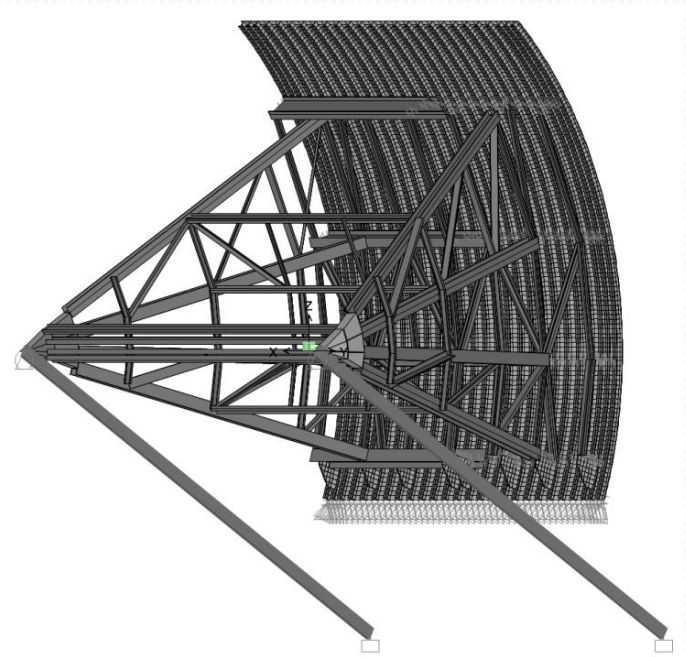


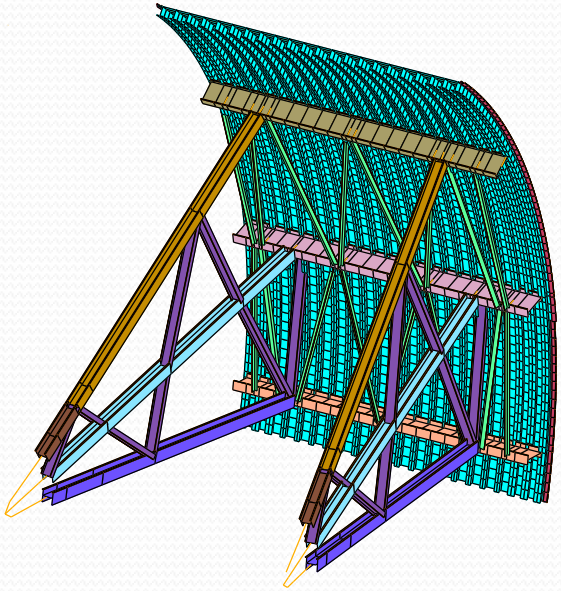


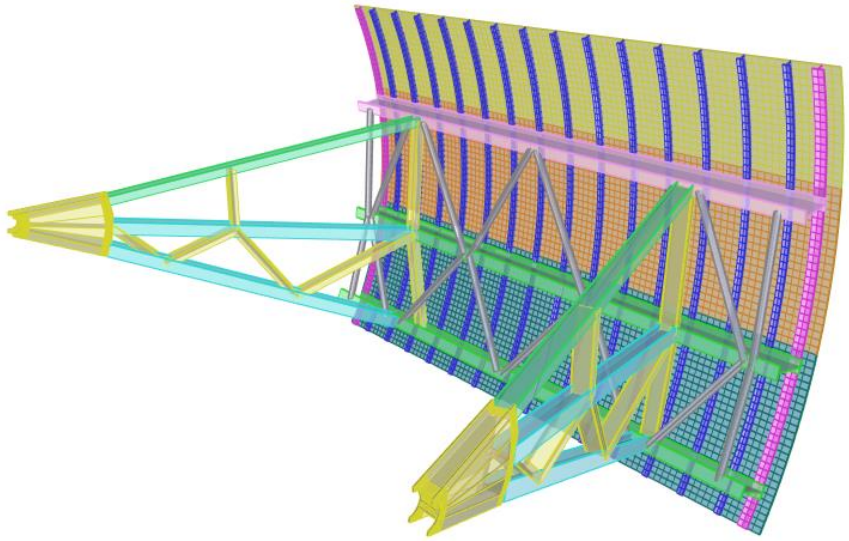


Radial Gate FEA

- Modeling near trunnion
  - ASDSO paper abstract
  - Rigid link/frames vs 2-D shells vs 3-D shells







Questions, Comments, Discussion