Structural Analysis on Hanford Single Shell Waste Tanks

EM Waste Processing Technical Exchange

Waste Storage and Tank Inspection

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Pacific Northwest National Laboratory

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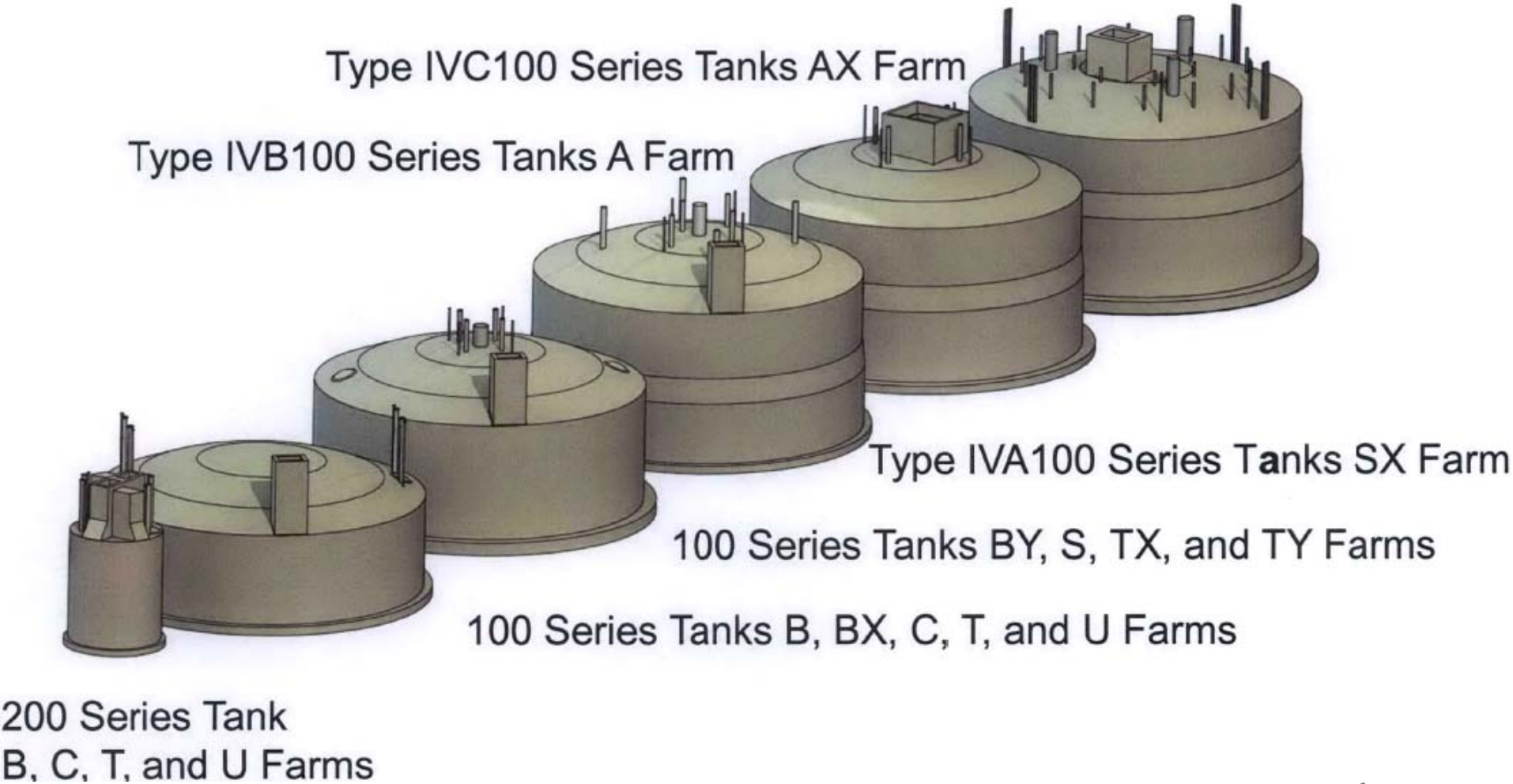
Introduction

- Motivation for Single Shell Tank Structural Integrity
- Description of the Single Shell Tanks (SSTs)
- Evaluation Criteria for SSTs
- Loads that Generate Structural Demands
- Thermal and Operating Loads Analysis
- Seismic Analysis
- Challenges
- Results to Date

Motivation for Single Shell Tank Structural Integrity

- Single-Shell Tank (SST) Analysis of Record (AOR) was recommended by the SST Integrity Panel
  - Perform a modern structural analysis of SSTs
- All the SSTs are well beyond their estimated design life (25 years)
- Structural analysis should include
  - Determine the current load demand and carrying capacities
  - Estimate any structural damage from past operations
  - Thermal degradation of concrete structural properties
  - Concrete creep
  - Seismic loads
- Provide a technical basis for the allowable structural loads that govern day-to-day operations of the SSTs
- Ensure adequate margin remains against dome limit loads through period of waste retrieval and closure
- Analysis performed to NQA-1 requirements

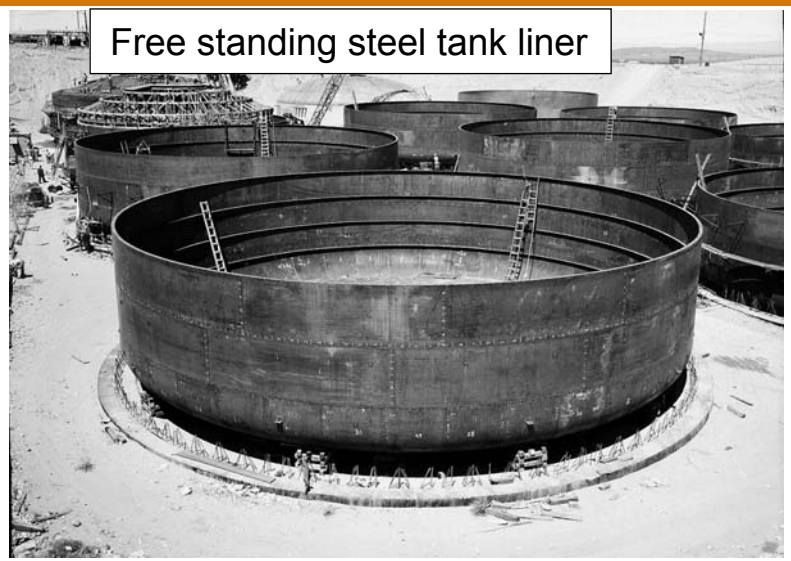
Description of the Single Shell Tanks (SSTS)



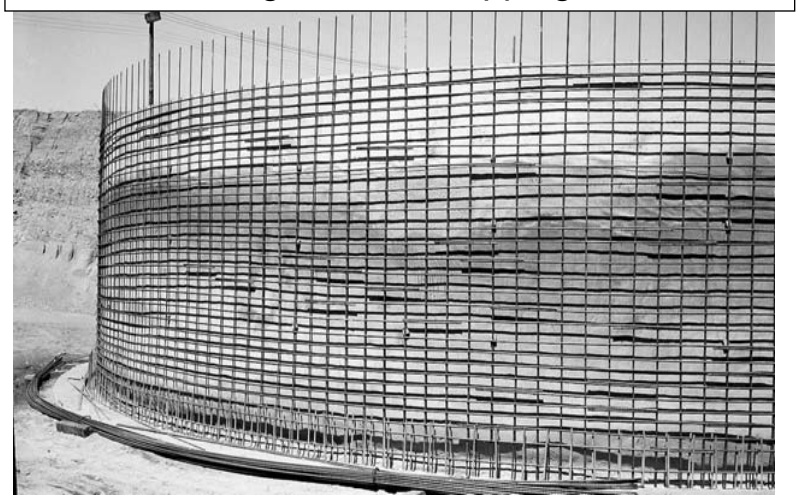
Description of the Single Shell Tanks

Basemat with dowel steel connecting to wall footing

Free standing steel tank liner



Wall reinforcing steel overlapping dowel steel



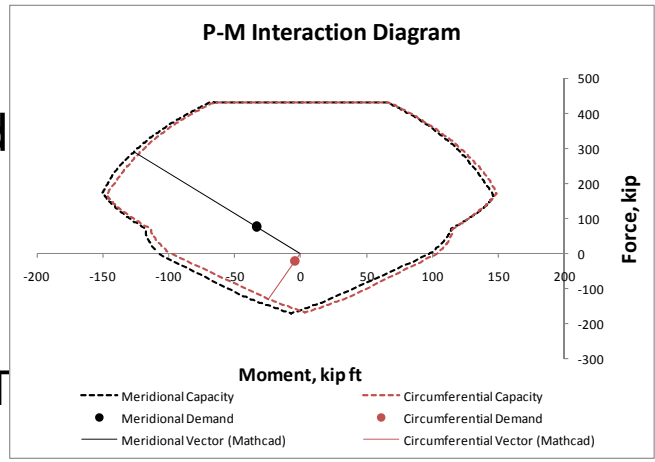
Dome reinforcing steel

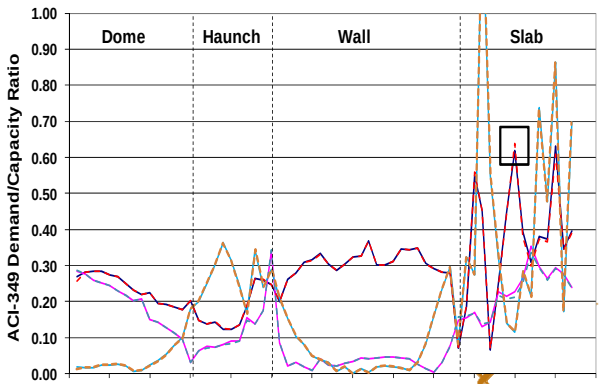
Description of the Single Shell Tanks (Cont.)

- SSTs are steel-lined, reinforced concrete cylindrical tanks with elliptical concrete domes (except 200-series)
- 12 tank farms equally divided between 200-East and 200-West areas with149 tanks
- Constructed between 1943 and1964 for high level waste
- First leak detected in 1956 and about 6 leaking tanks by 1960 led to the initiation of reduced storage amounts
- Out of 149 SSTs, 67 are known or are suspected to have leaked
- All the SSTs are out of service and no process wastes have been added since Nov-1980
- Currently all the SSTs have been Interim Stabilized

Evaluation Criteria for SSTs – Reinforced Concrete – ACI-349 (2006)

- Structural Demand Calculations
  - Ultimate strength analysis using factored load combinations
    - 1. U = l.4D + 1.4F + 1.7L + 1.7H
    - 4. U = D + F + L + H + To + Ess
    - 9. U = 1.05D + 1.05F + 1.3L + 1.3H + 1.05T
  - Factored loads are applied to the nonlinear finite element model
- Models include concrete cracking, soil plasticity and interface contact with friction.
- Model results are section Force, Moment, and Shear loads.
- Structural Capacity Calculations
  - Tank section demands are evaluated against ACI-349 section capacities.





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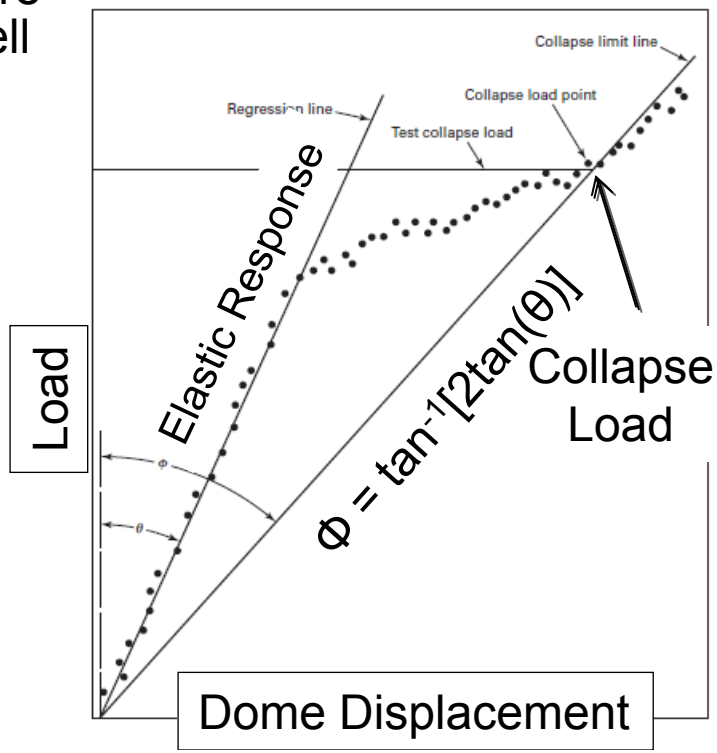
Evaluation Criteria – Buckling and Limit Analysis

- Buckling Analyses
  - Dome buckling => distributed + concentrated loads
  - Cylindrical wall buckling => axial force + external pressure
  - Imperfection buckling load reduction factors are recommended from ACI SP-67, Concrete Shell Buckling

$$P_b^{Allow} = \alpha_1 \alpha_2 \alpha_3 \alpha_4 P_b^{lin} \frac{1}{SF_b}$$

- Limit Analysis
  - Tank Models use nonlinear, large strain finite element analysis with concrete cracking and rebar yielding
  - SST scale model test results available for model validation
  - Ultimate Load - ASME NB-3213.25
  - Ultimate Load Safety Factor = 3 bounds ACI and ASME implicit safety factors

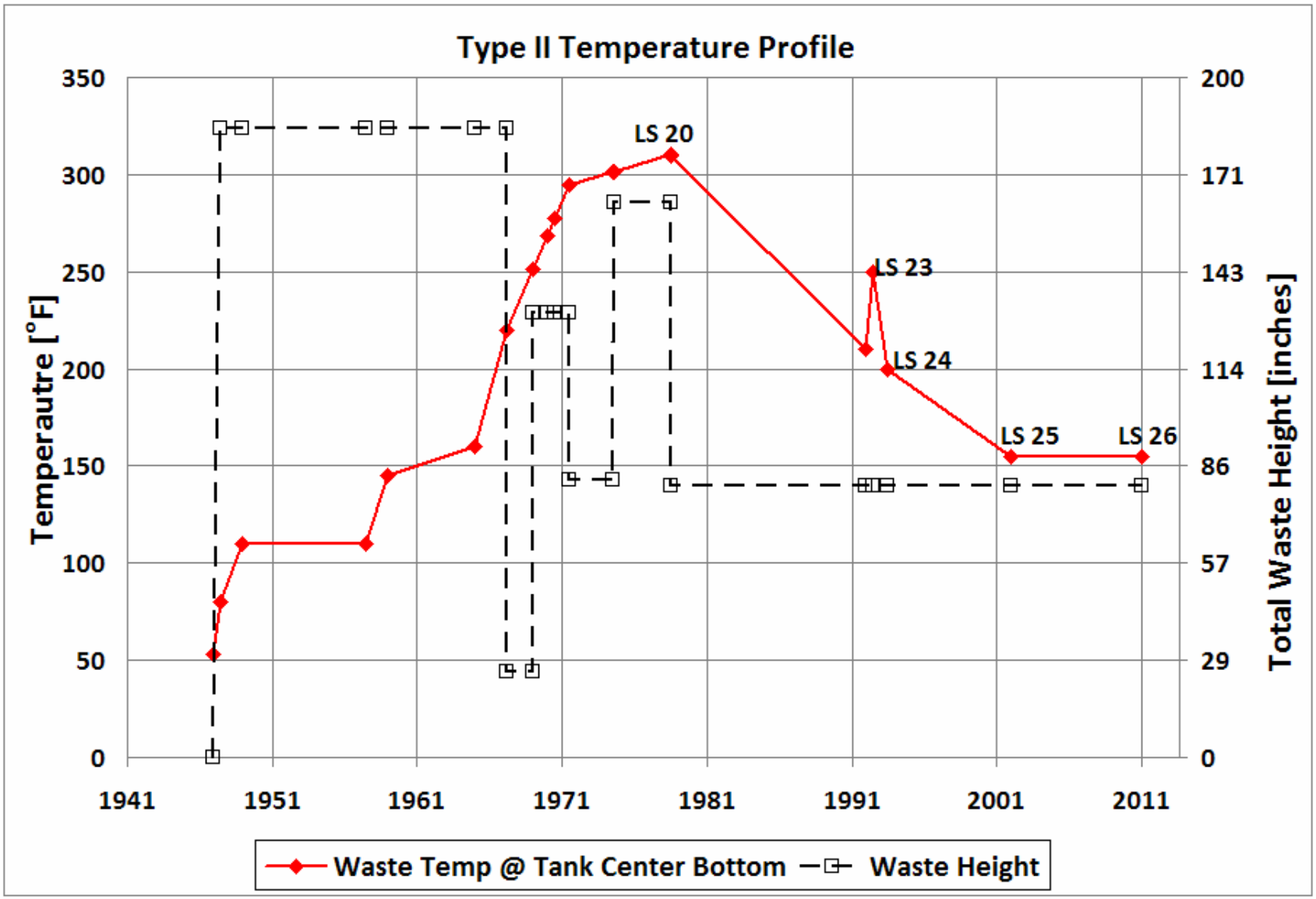
FIG. II-1430-1 CONSTRUCTION FOR II-1430



Loads that Generate Structural Demands

- Pressure (F) – dome space and hydrostatic pressures
- Lateral Earth Pressure (H)
- Dead Load (D) – concrete, steel, backfill + earth cover
- Live Loads (L) – distributed and concentrated over dome
- Thermal (T) – long-term maximum waste temperature and short-term drain and fill transients
- Seismic Loading (Ess) – Geomatrix is completing a PC-2 spectrum and time-histories based upon the DST AOR.
- Equipment Loads – included as Dead and Live loads

Thermal Profile for Type II Tanks



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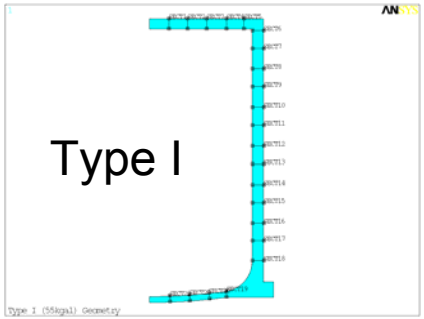
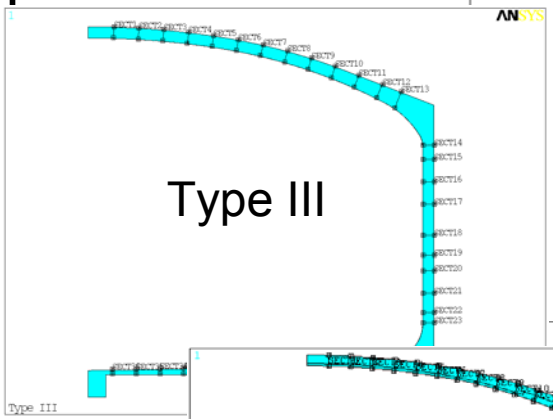
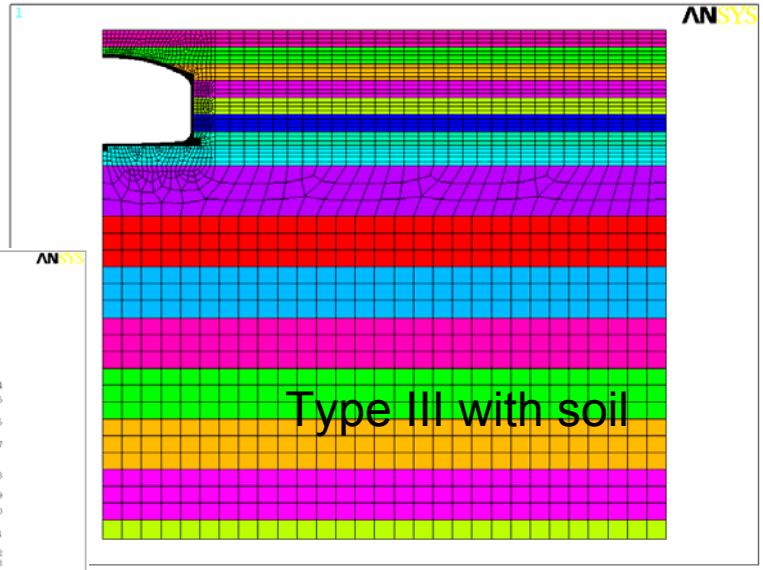
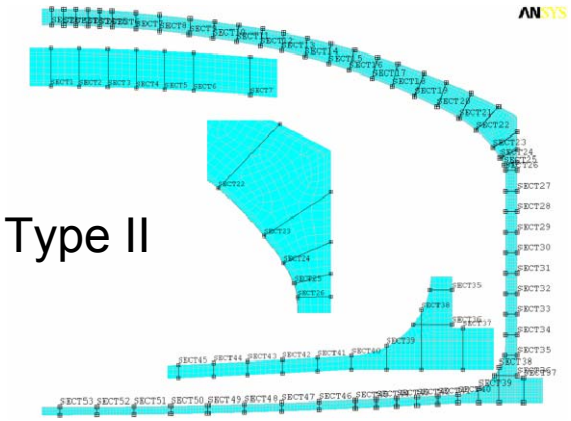
Thermal and Operating Loads Analysis (TOLA)

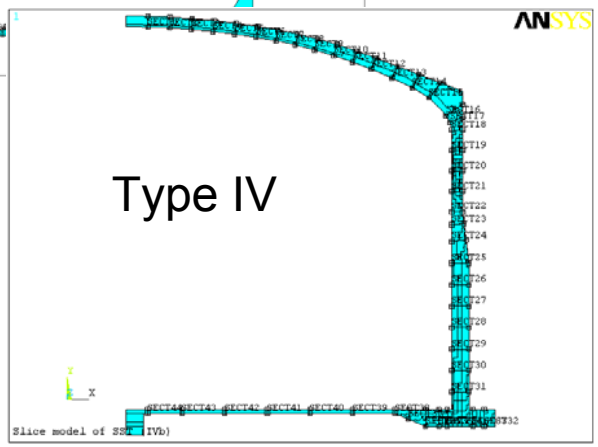
- Finite Element Models have been generated for all four tank types.











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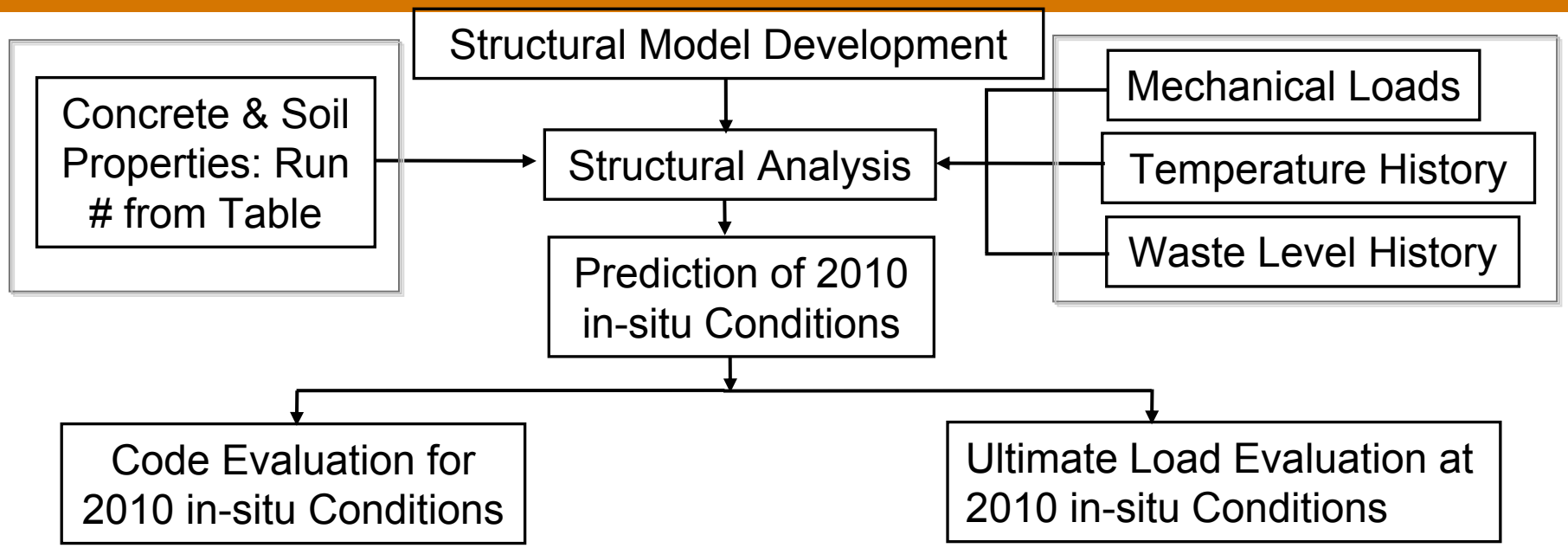
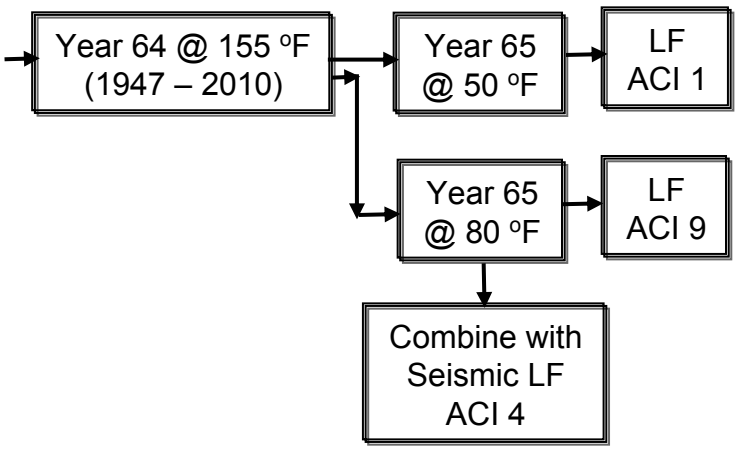
Detailed Analysis Flow – Type II Tank

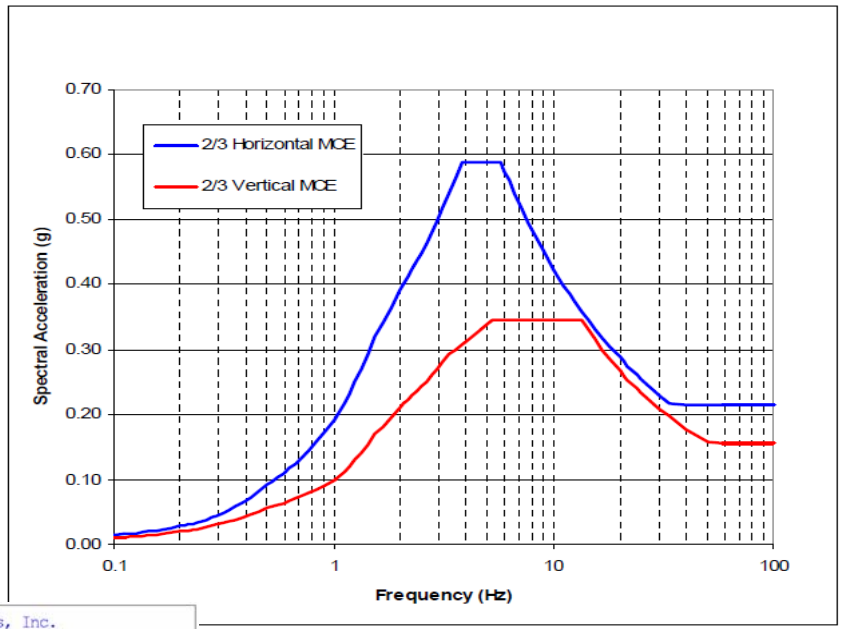


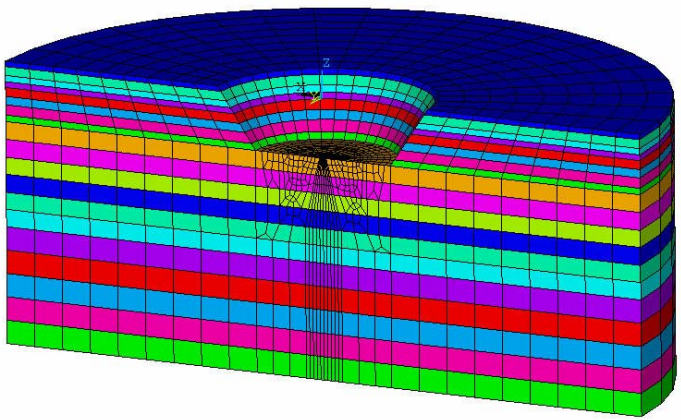


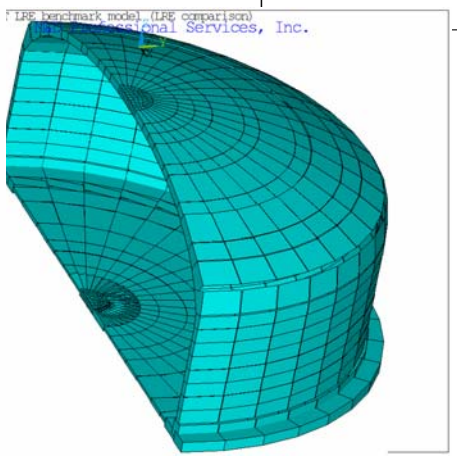
Run #	Soil Modulus	Concrete Modulus	Concrete Tensile Strength	Concrete Creep
1	N	N	Near Zero	Yes
2	N	N	Near Zero	No
3	N	H	Near Zero	No
4	L	H	Near Zero	No
5	L	N	Near Zero	No
6	N	N	N	Yes

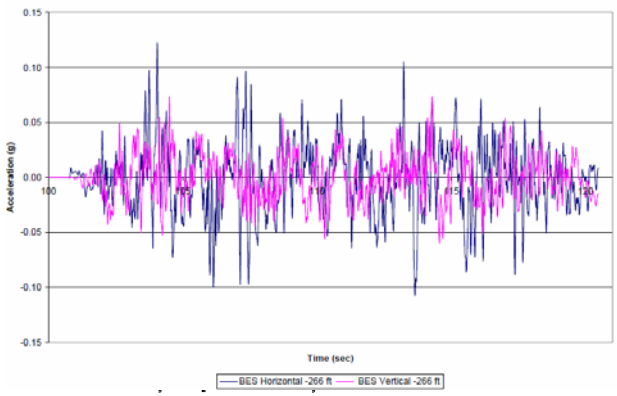
Seismic Analysis

- Seismic Demand
  - Benchmarking against TOLA completed.
  - Type II model development is completed
  - Working on obtaining new SST time histories for seismic input









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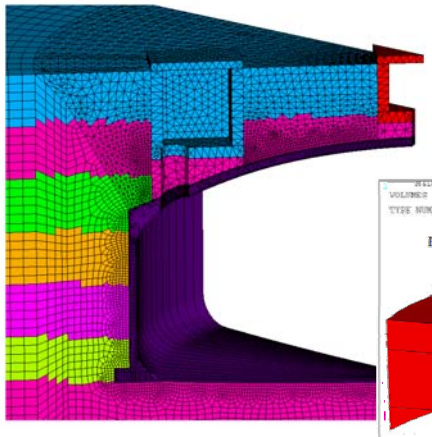
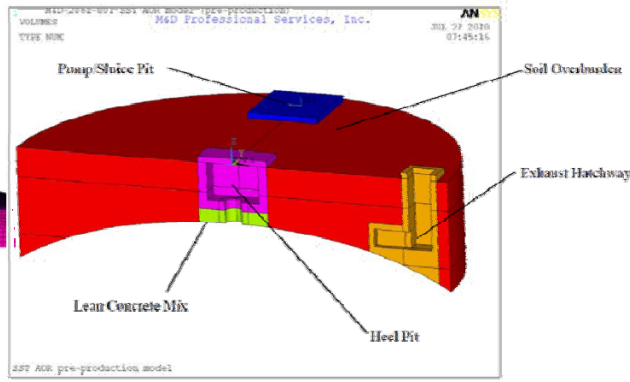
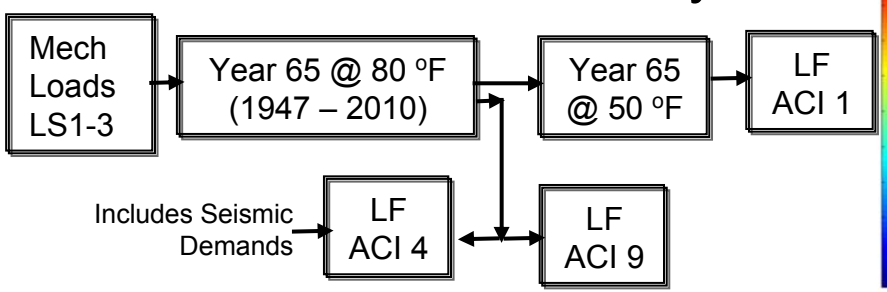
Challenges – Modeling of Appurtenances

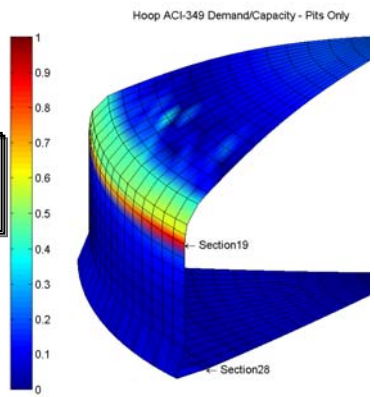
- Determine the impacts of Appurtenances
  - Pump pits and Penetrations
  - Can we neglect them for detailed analysis?
- Check ACI D/C at:
  - After mechanical loads
  - Peak temperature
  - After thermal history

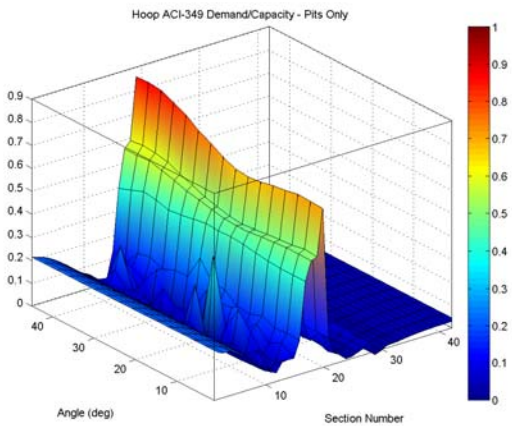


Type II Tank Appurtenances



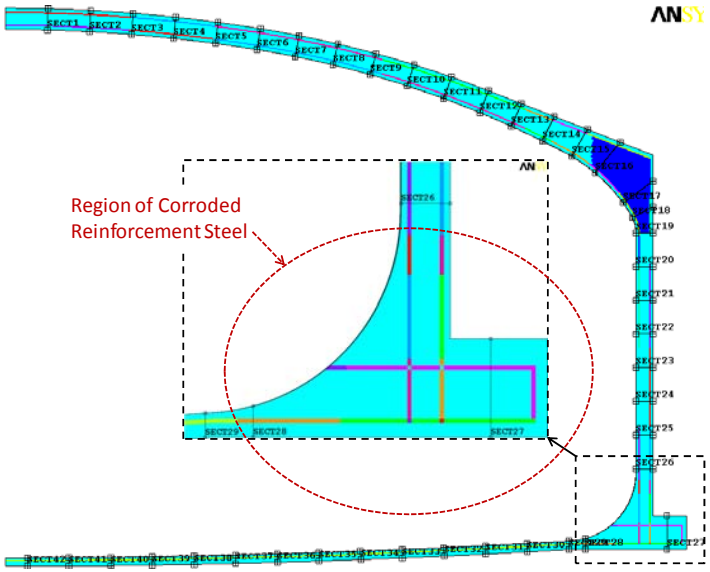


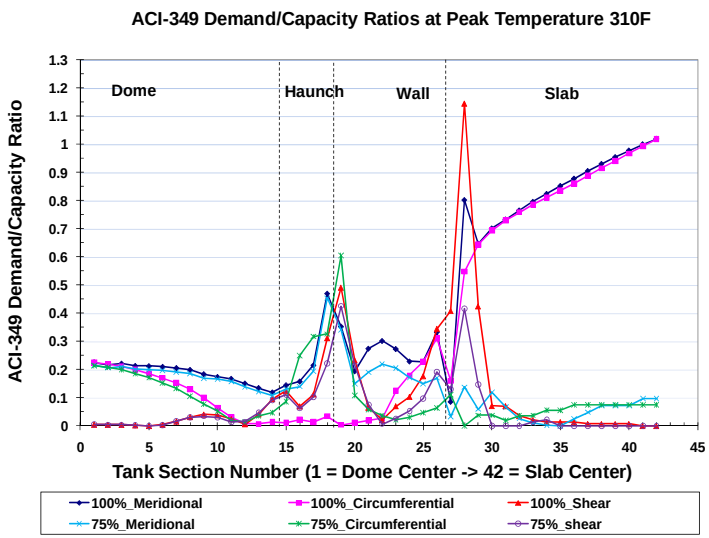




Challenge – Impact of Degraded Reinforcement

- If corrosion has occurred in the lower knuckle, what are the effects of reduced reinforcement.
- Several cases have been run including a reduction of 50%, 75%, and nearly 100%
- Demands are insensitive – capacities are sensitive
- Initial conclusion is that adequate margin exists for significant reduction of the reinforcement



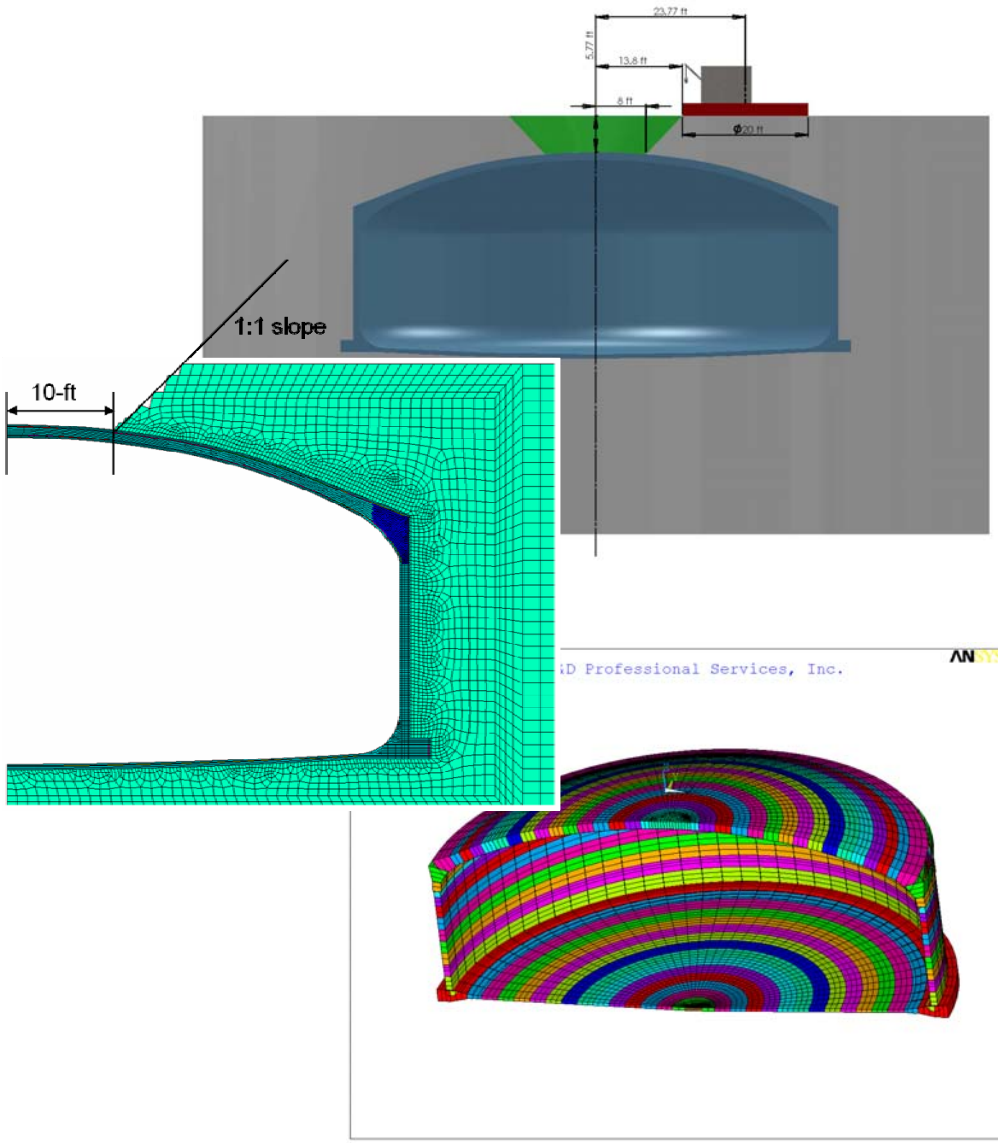


Other Challenges

- Reinforcement overlap of Dowel Steel in construction joints
- Ensure that locations with smooth square reinforcement have the appropriate knockdown factors applied.
- Evaluate the radial extent of soil required for analysis
- Soil (both disturbed and undisturbed) properties used by Seismic and TOLA models are based upon best known values.
- Lateral soil pressures on the tank need to be evaluated to ensure no soil bridging and that the models reflect realistic soil pressures.

Structural Analysis of C-107

- Large Riser Evaluation completed in 2009
  - Comparative analysis based upon simplified existing model
  - Results were a large riser cut into C-107 would have minimal impact on integrity
- Recent study completed to evaluate the removal of soil from C-107 prior to cutting the new riser
  - Could net tension develop in dome when soil is removed?
  - New SST models used
  - Results - Soil can be safely removed with minimal impact on structural integrity.



Results and to date – *Stay Tuned*

- Type II Tank Analysis
  - Type II Thermal and Operating Loads Runs are complete and post-processing is being conducted
  - Limit Analysis modeling will be completed in November
  - Seismic Analysis for Type II waiting for final time history input.
- Type III tank analysis to be started in December
- Type IV tank analysis, the most challenging, will be initiated during the second quarter
- Type I tank analysis will be initiated late in the second quarter.
- Tank C-107 – Not part of Analysis of Record
  - Unique condition analyzed separately

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