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Simulation Study of Cement Isolation in Extreme Temperature Heavy Oil Development

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Outline

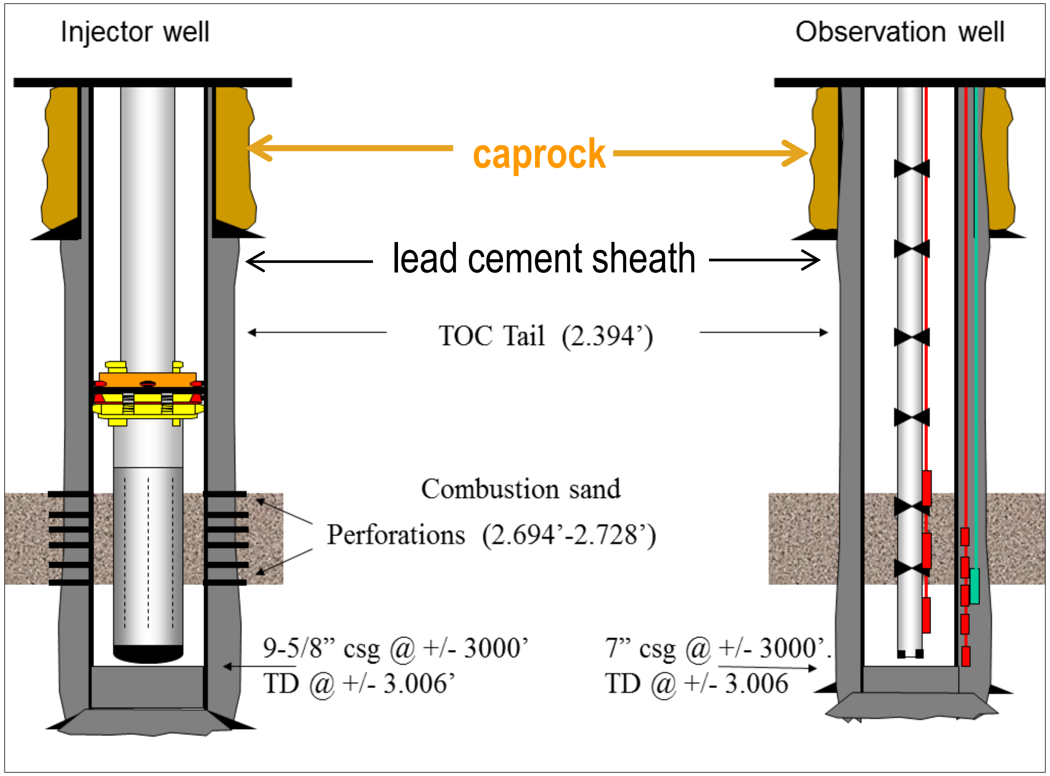
- Challenges & Objective
- Thermal-shock-resistant cement system
- Abaqus Finite Element Analysis (FEA)
- Simulation procedures: Thermal and Geo-mechanics coupling
- Case Histories
- Conclusion

Challenges

- Bare field (Orinoco Oil Belt), Venezuela
- Heavy oil recovery by in-situ combustion
- Lead cement sheath exposed to 392 F
- Tail cement sheath exposed to 1,202 F
- Extreme stresses for the cement sheathes

Objective:

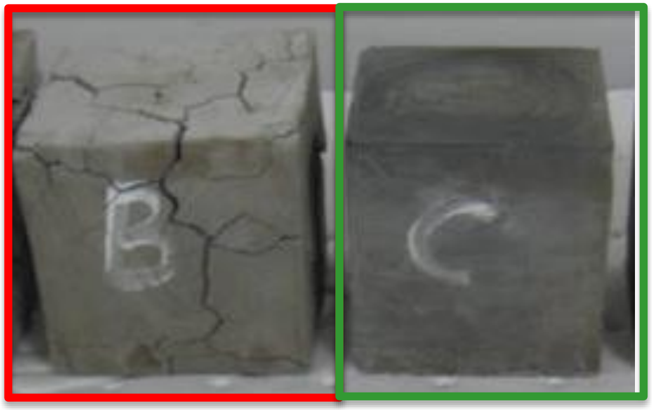
- Zonal isolation at least along the caprock
- with a thermal shock resistant cement



Thermal-shock-resistant cement system

- Improve the *thermal-shock-resistance* by adding 50% high temperature stable minerals (selected alumosilicates)

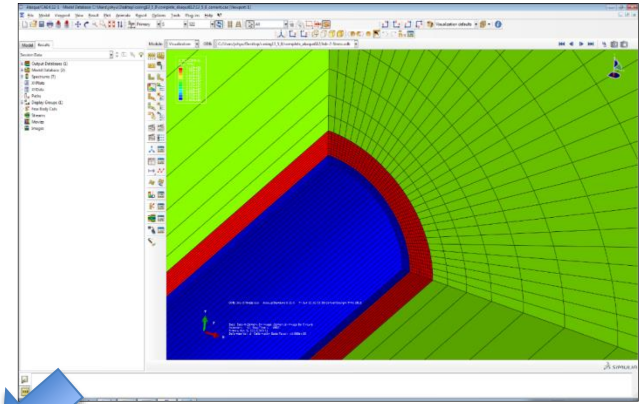
- Enhance the "resilience" by increasing tensile strength & lowering Young's Moduli (with inorganic fibers)

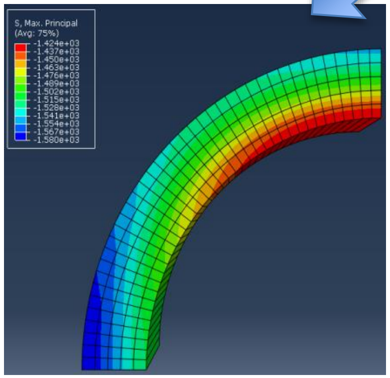


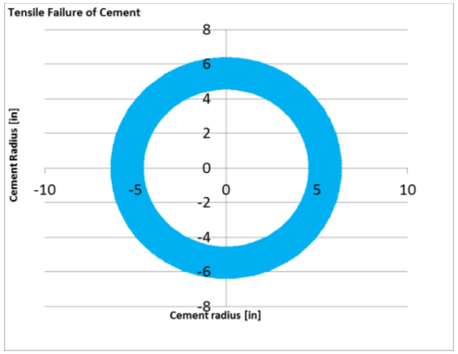
After exposure to 800 F (SPE-134422):
Conventional cement failed
Modified API cement passed

Abaqus Finite Element Analysis (FEA)

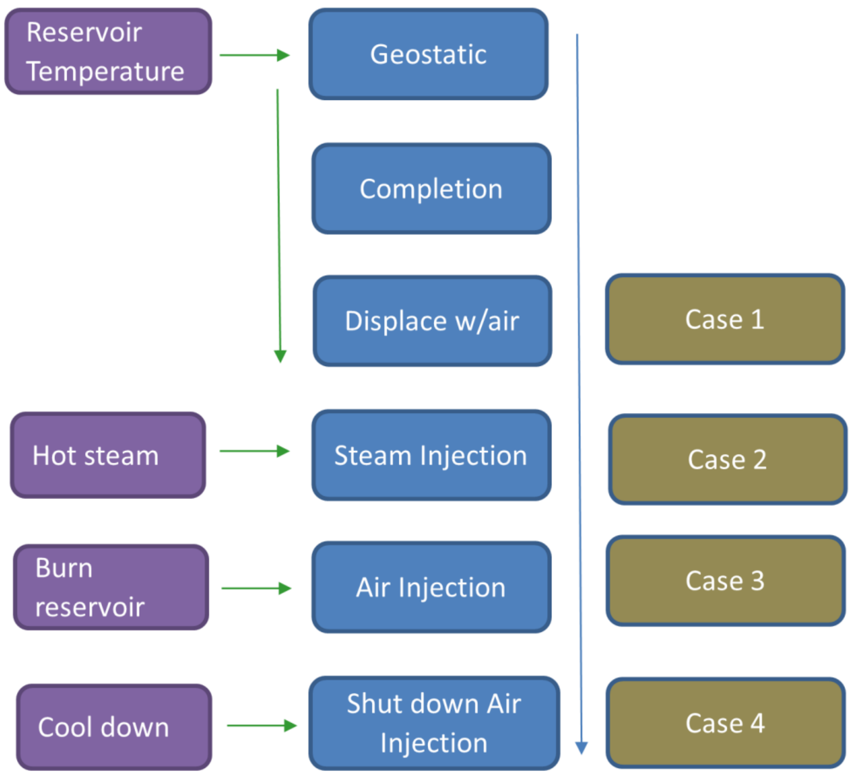
- Flexible tool for linear & non-linear element modeling
- Predicts the behavior of cement with different mechanical & thermal properties under various well-loading conditions
- Csg / cement / formation – only quarter of the model is simulated
- Many parameters are required to conduct the FEA study
- Stresses from Δp & ΔT can result in cement sheath failures
  - — Debonding risk
  - — tensile failure
  - — shear failure







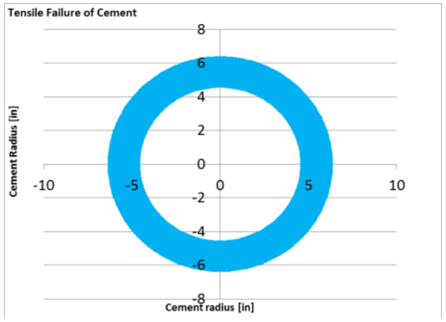
Simulation procedure: Thermal and Geo-mechanics coupling

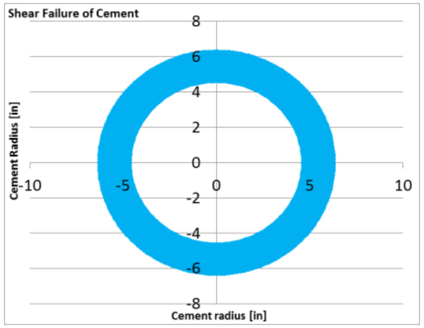


Simulations: Case 1 – Exchange Displacement fluid with Air

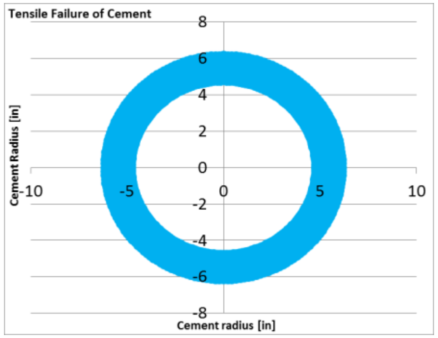
- Free of debonding risk
- **Blue: safe conditions**
- red: failure conditions

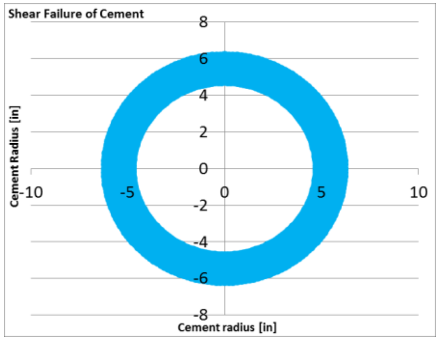
Lead cement sheath
Δp=-1,236 psi & ΔT= 0





Tail cement sheath
Δp=-1,390 psi & ΔT=0

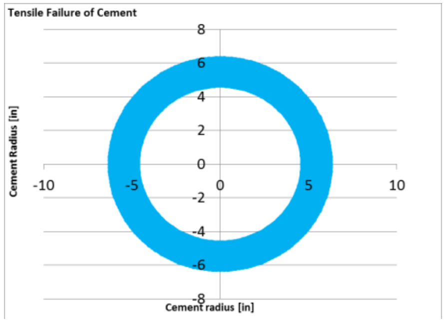


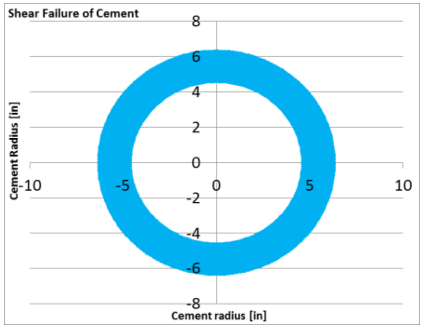


Simulations: Case 2 – Steam Injection to 567 F & 1,200 psi

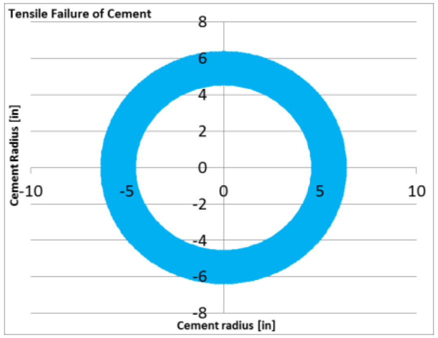
- Free of debonding risk
- **Blue: safe conditions**
- red: failure conditions

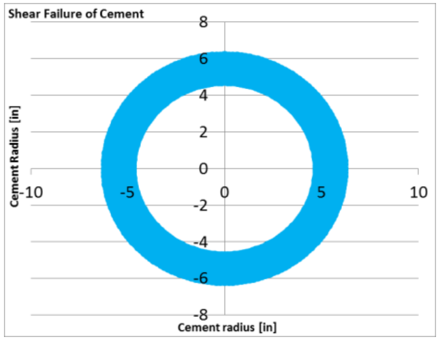
Lead cement sheath
Δp=-1,236 psi & ΔT=+155 F





Tail cement sheath
Δp=-190 psi & ΔT=+422 F

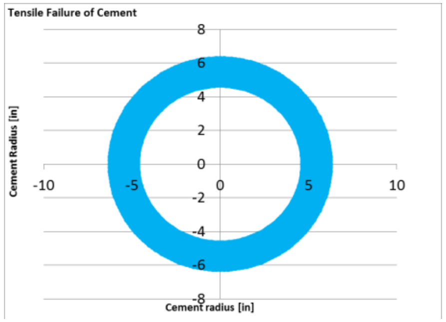


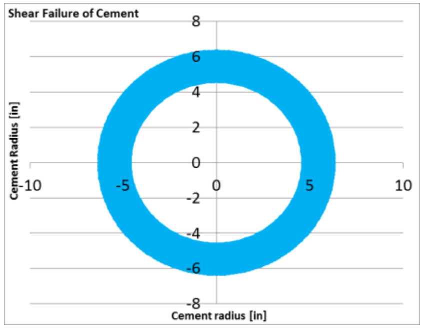


Simulations: Case 3 – Air Injection at 1,200 psi & 1,202 F

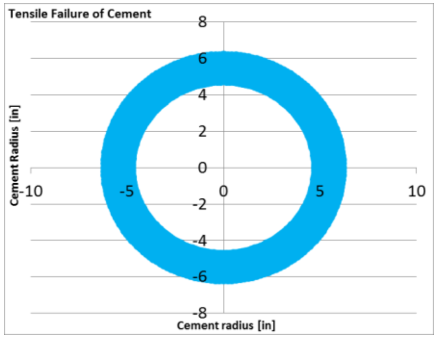
- Free of debonding risk
- **Blue: safe conditions**
- red: failure conditions

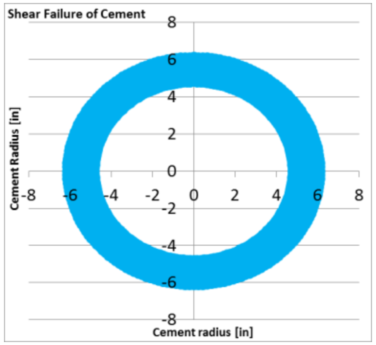
Lead cement sheath
Δp=-1,236 psi & ΔT=+247 F





Tail cement sheath
Δp=-190 psi & ΔT=+1,057 F

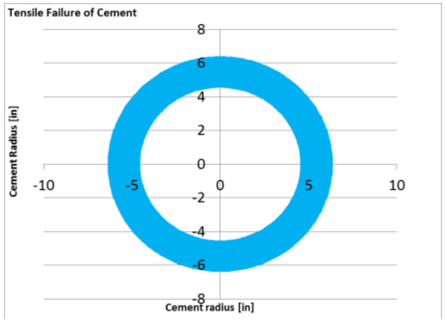


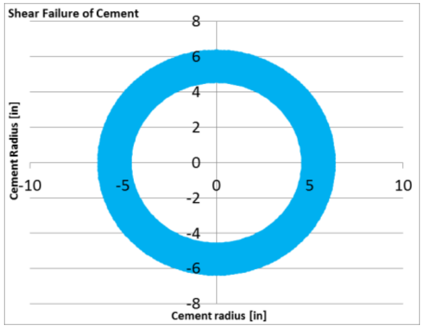


Simulations: Case 4 – Shut down Air Injection

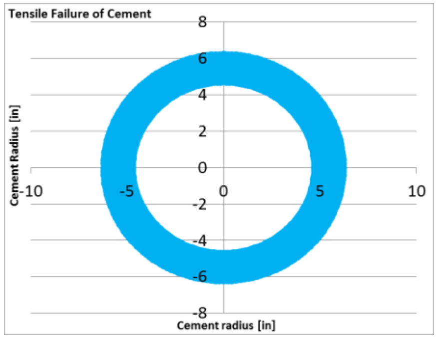
- Free of debonding risk
- Blue: safe conditions
- red: failure conditions

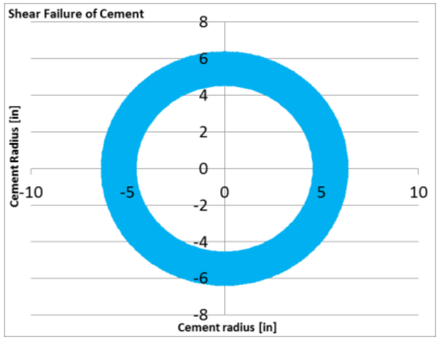
Lead cement sheath
Δp=-1,236 psi & ΔT=0





Tail cement sheath
Δp=-1,390 psi & ΔT=0





Conclusion

A 3D thermal and geomechanics coupling finite element analysis (FEA) model was built to analyze cement zonal isolation performance under in-situ status.

Thermal and pressure changes during drilling, completion, and in-situ combustion phase were calculated by the FEA model.

The model enables determination of tensile and/or shear failure occurrence, and where the failures occur according to the failure criteria.

The numerical simulation provides engineers a reliable and economic way of understanding cement zonal isolation performance.