Finite Element Analysis of Perforation Patterns in Production Liners Exposed to Subsidence

7 5/8” 39# Q-125 Perforated Section Analysis Compaction Study

NAPS-50-18

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INTERNATIONAL PERFORATING FORUM

Model

MATERIALS

Cement – Isotropic Elastic

Density - .083 #/in3

Modulus – 4,000,000 psi

Poisson's Ratio - .2

Formation – Isotropic Elastic

Density - .096 #/in3

Modulus – 1,450,000 psi

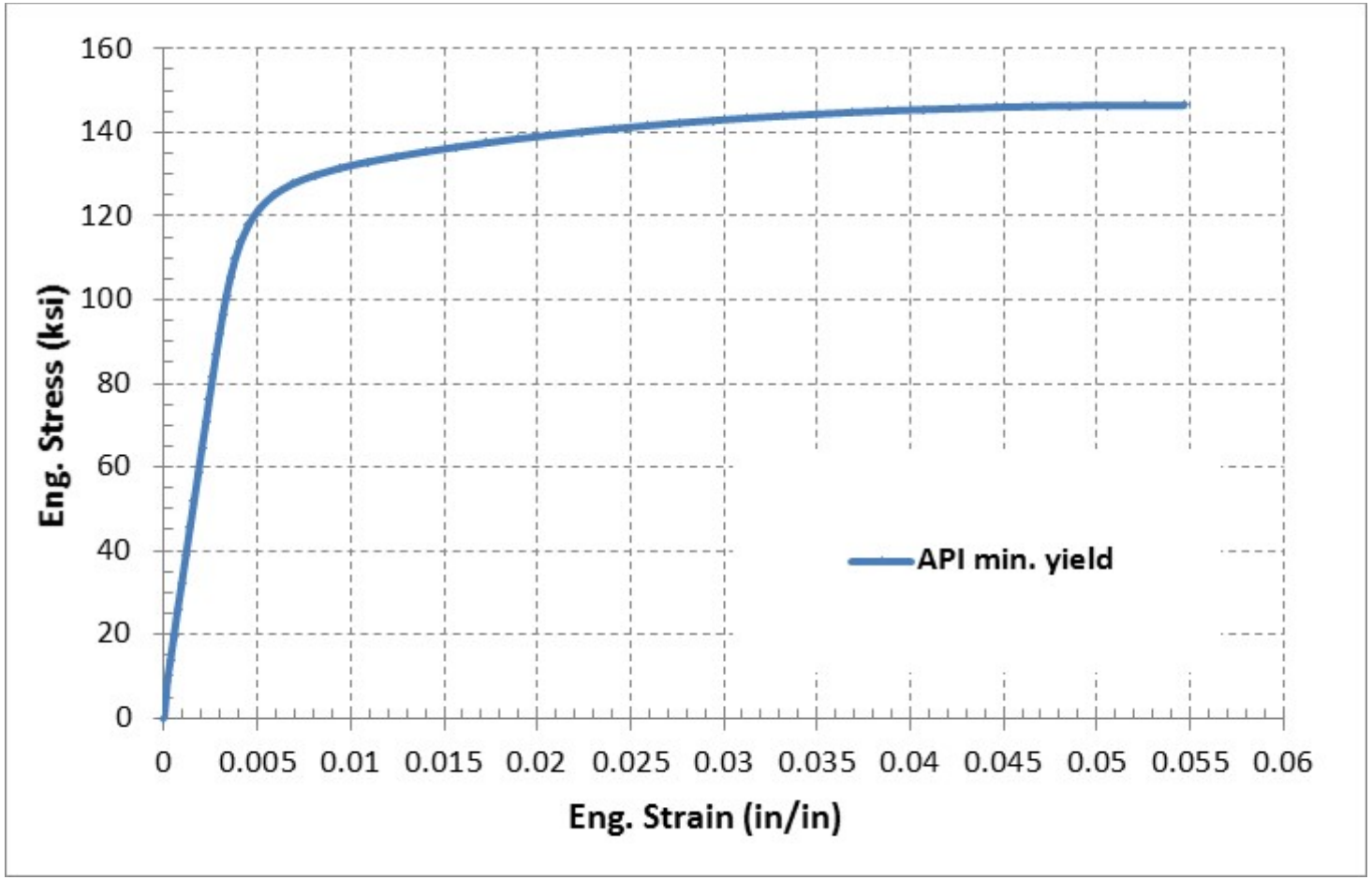
Poisson's Ratio - .2

Pipe – Q125 – Isotropic Elastic/Plastic

Density - .287 #/in3

Modulus – 30,000,000 psi

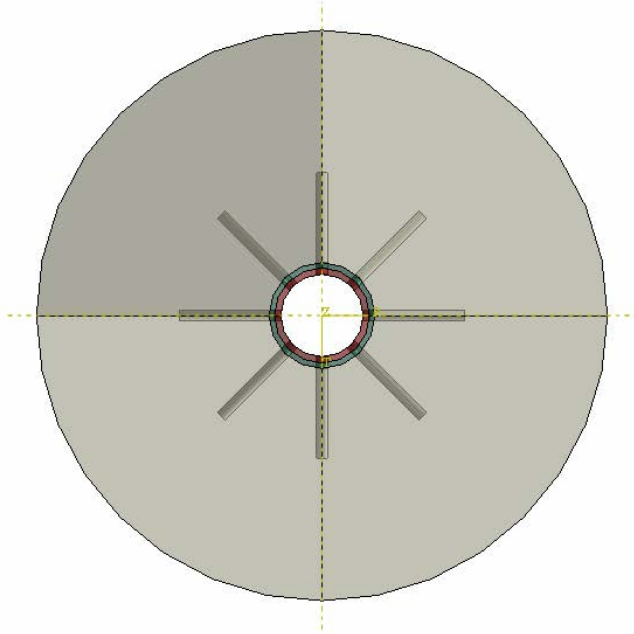
Poisson's Ratio - .29

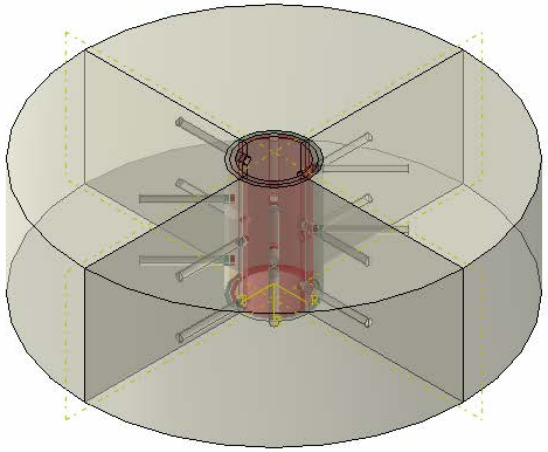


Model

MATERIALS

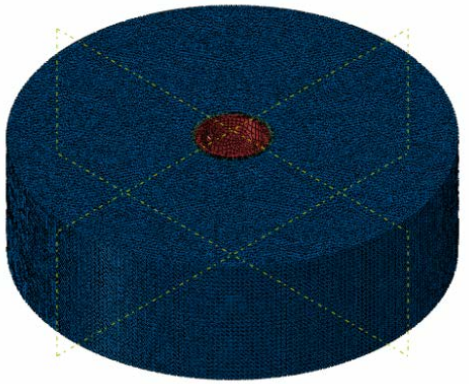
Pipe – 7.625” x 6.625” – Red Region
Cement – 8.5” x 7.625” – Green Region
Formation (Sandstone) – 45.75” x 8.5” – Grey Region
Length = 14”
Strain = 6% = .84”
Cross sectional area of pipe = 11.2 in^2
SMYS = 125,000 psi
Axial Force to Yield = 1399 kips
Bond Strength of Cement = 250 psi
Bond Area to Carry Yield Load = 250” = 20.83’ = (1398990/(pi*7.625*250)
Shear Stress on 14” Model = 4172 psi – Due to the short length of the model, the shear stresses at the interface will be artificially high
Perfect Bond Modelled
Perforation size = .88”
15 SPF
Phase 135 degrees
Helix 5.625 turns per foot
Perforation Depth/Length = 7.625”

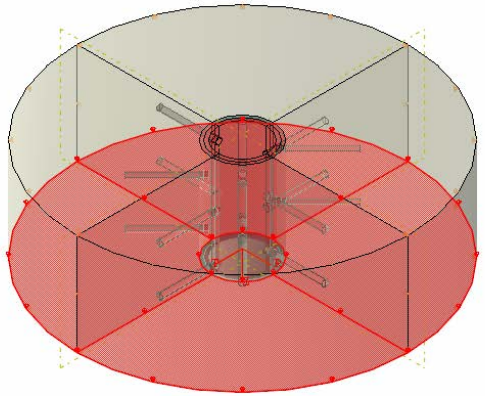


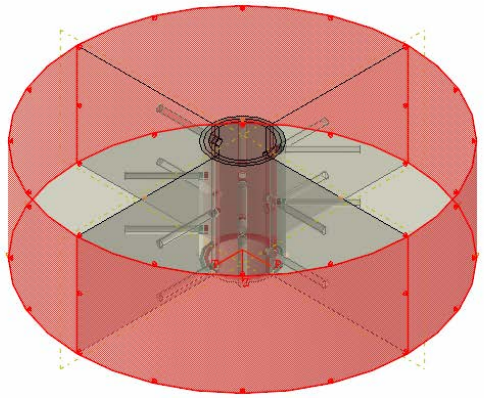


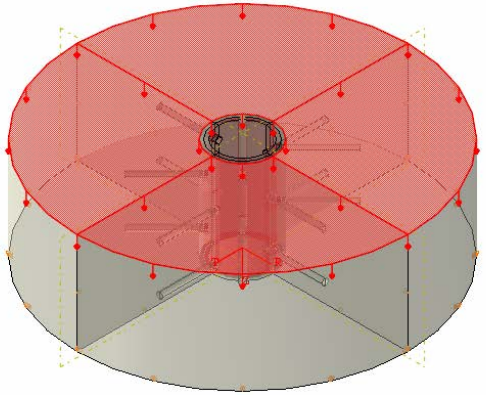
Boundary Conditions in Cylindrical Coordinates Applied Solely to the Formation

Axial Constraint – Z = 0
Radial Constraint – R = 0
Displacement Load – Z = .84”
476764 Elements

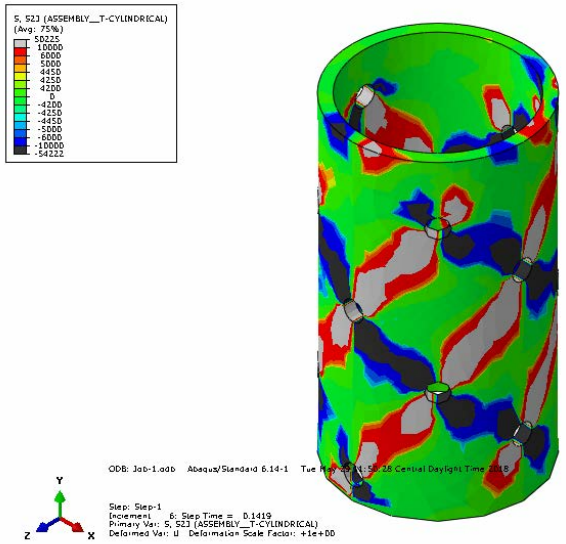




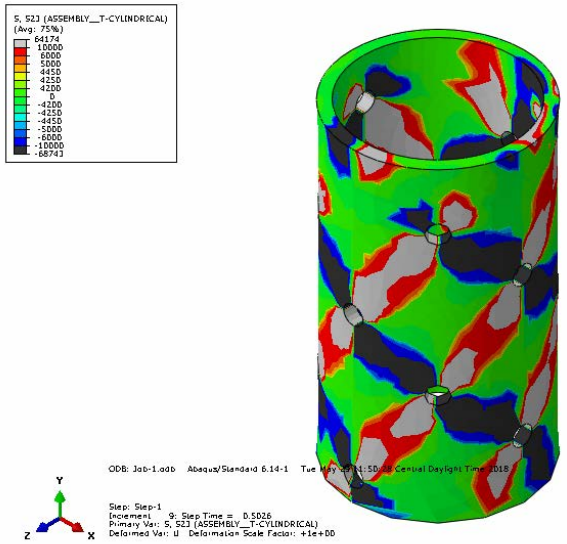




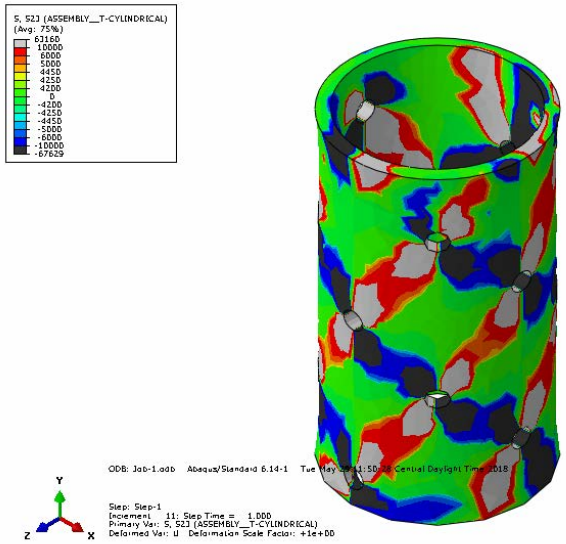
Shear Stresses at Pipe to Cement Bond Interfaces



.85 % Strain



3% Strain

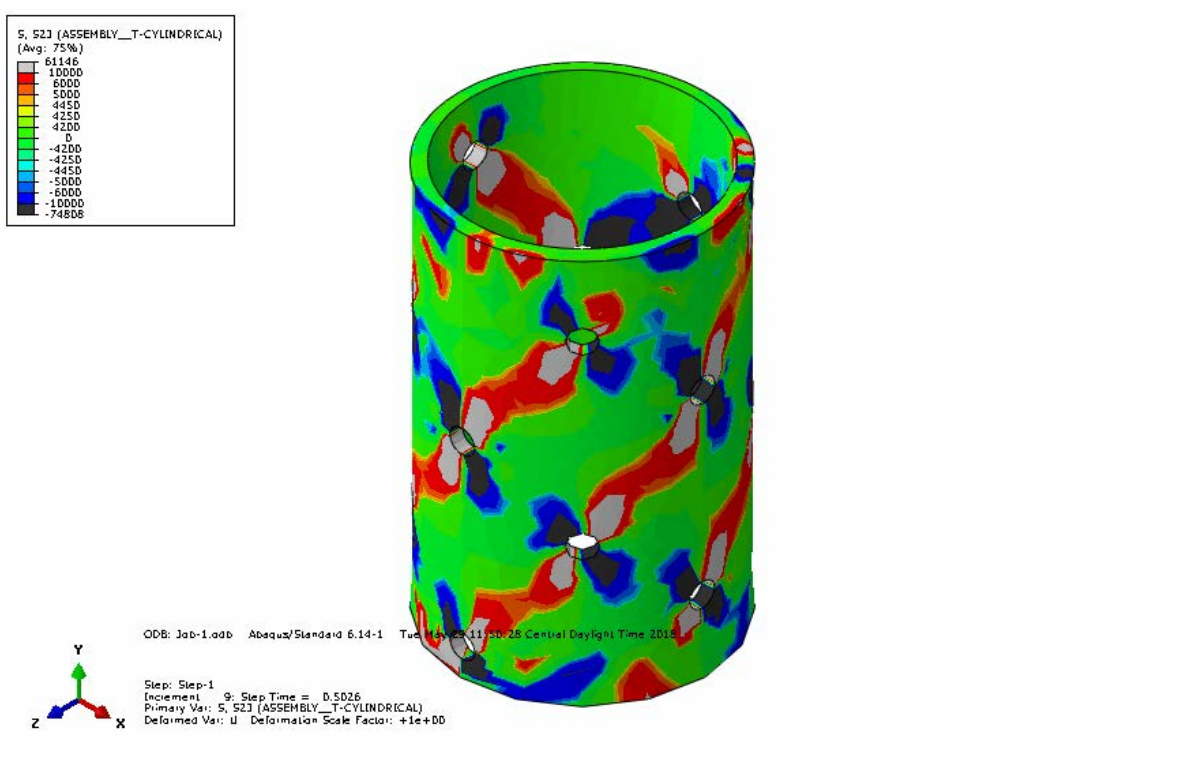


6% Strain

The conclusion is that bond strength is exceeded in regions where the shear stress exceeds 4450 psi (~4172+250)

It is feasible that the cement in the nonperforated section could transfer the compressive load from the formation into the pipe via the bond

Shear Stresses at Cement to Formation Bond Interfaces



6% Strain

Shear Stresses at the Bond Interface at the outer diameter of the cement sheath are similar, so the bond status at that interface could be questioned.

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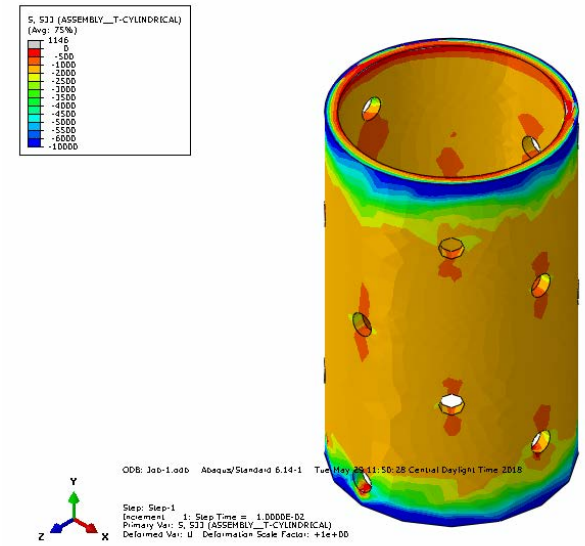
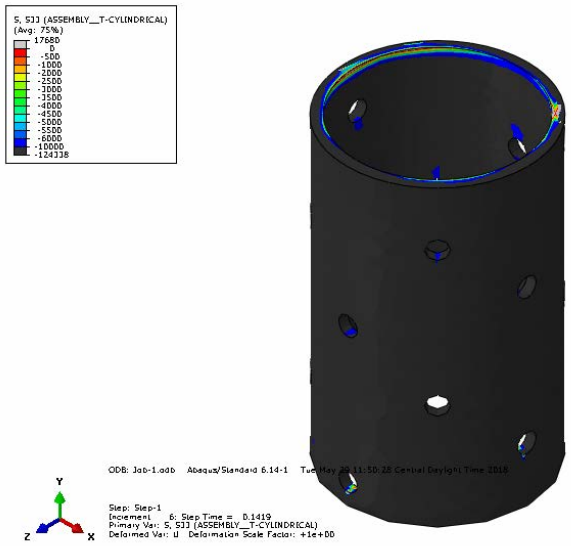
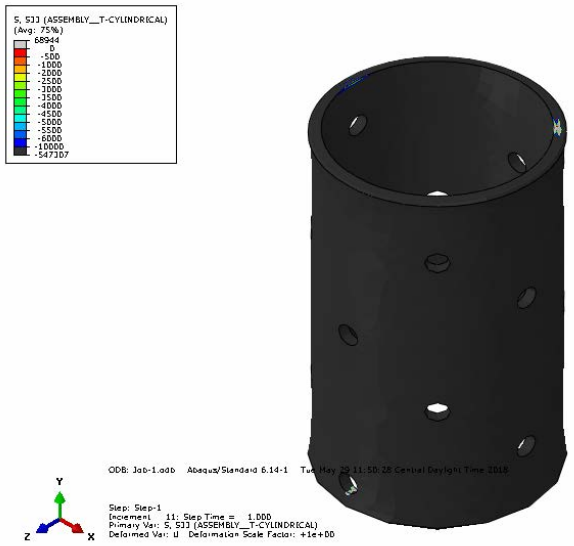
Compressive Axial Stress in the Cement Sheath



.06 % Strain



.85% Strain



6% Strain

The conclusion is that the cement exceeds its compressive strength (~4500 psi) rather early in the process

How the cement behaves, i.e. self healing, under the high hydrostatic loads between the pipe and formation requires further study

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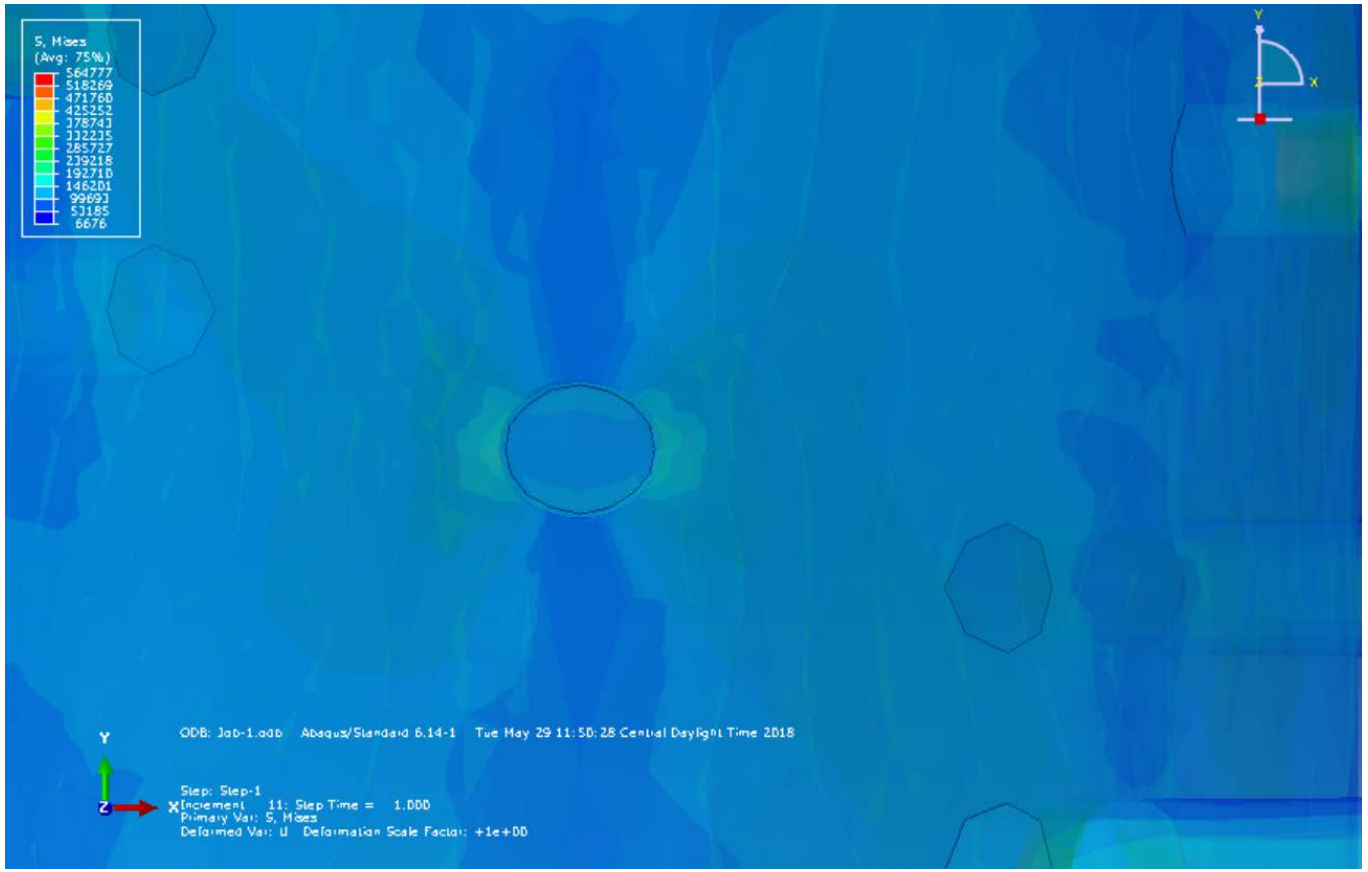
Ovalization of Perforations



6% Strain

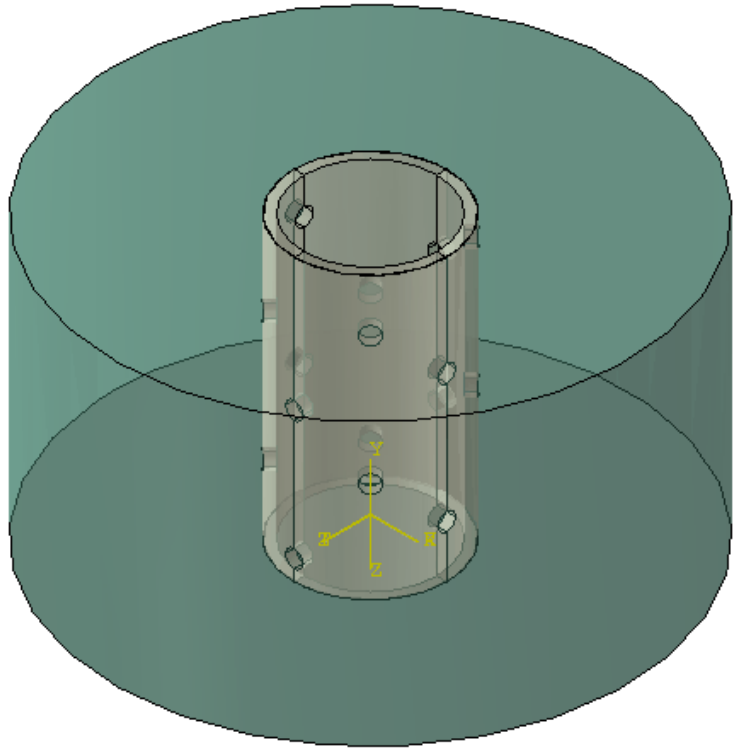
Affect on:

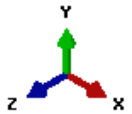
Hydraulic performance?

Sand Production?

What if Bond is Broken Between Cement & Pipe?

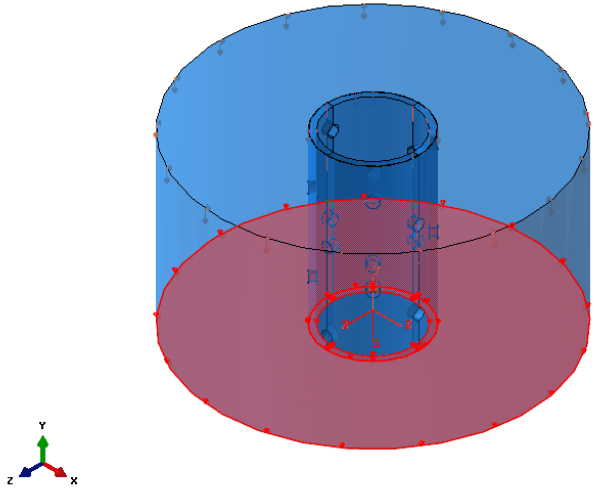
Pipe – 7.625” x 6.625” – Grey Region
Formation (Sandstone) – 7.625” x 25.5” – Green Region
Length = 14”
Strain = 6% = .84”
SMYS = 125,000 psi
Top Surface Free to Rotate
No Bond or Friction at the Interface Modelled – Multi-Body Contact
Perforation size, Pipe Only = .88”
15 SPF
Phase 135 degrees
Helix 5.625 turns per foot
Perforation Depth/Length = 7.625”

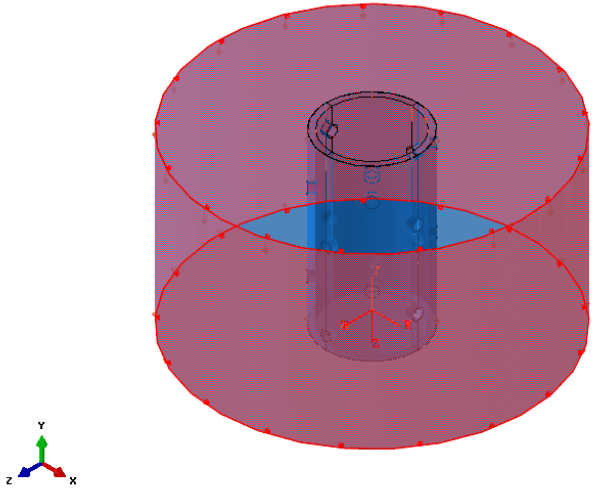


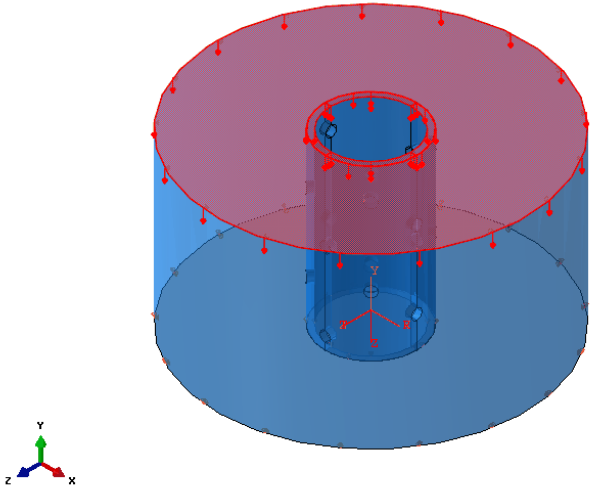


Boundary Conditions in Cylindrical Coordinates Applied to Pipe and Formation

Axial Constraint – Z = 0
Radial Constraint – R = 0
Displacement Load – Z = .84”

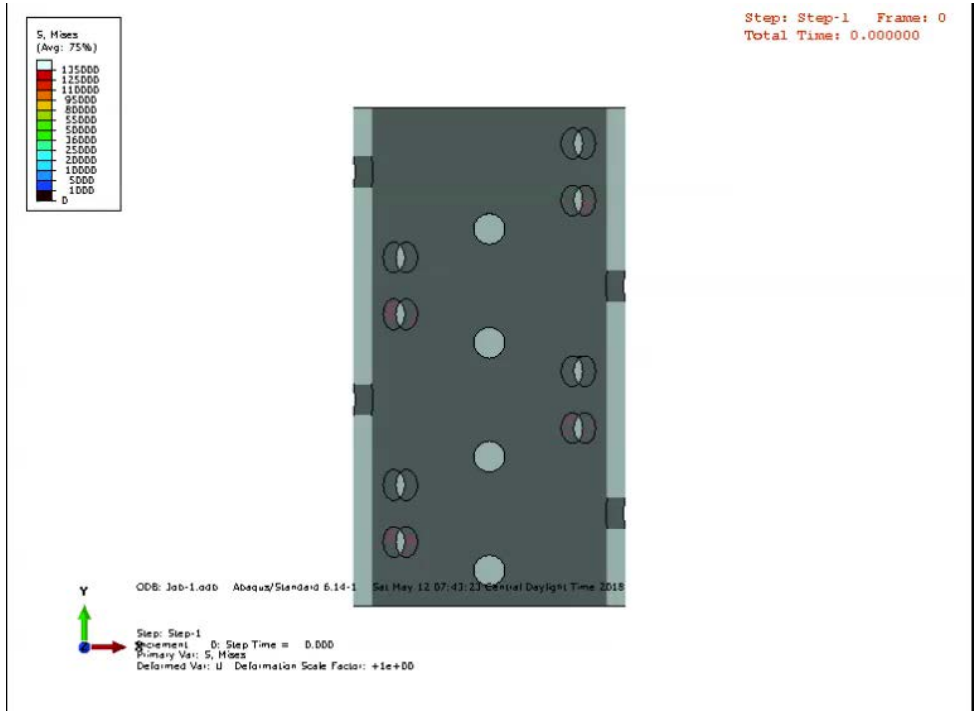


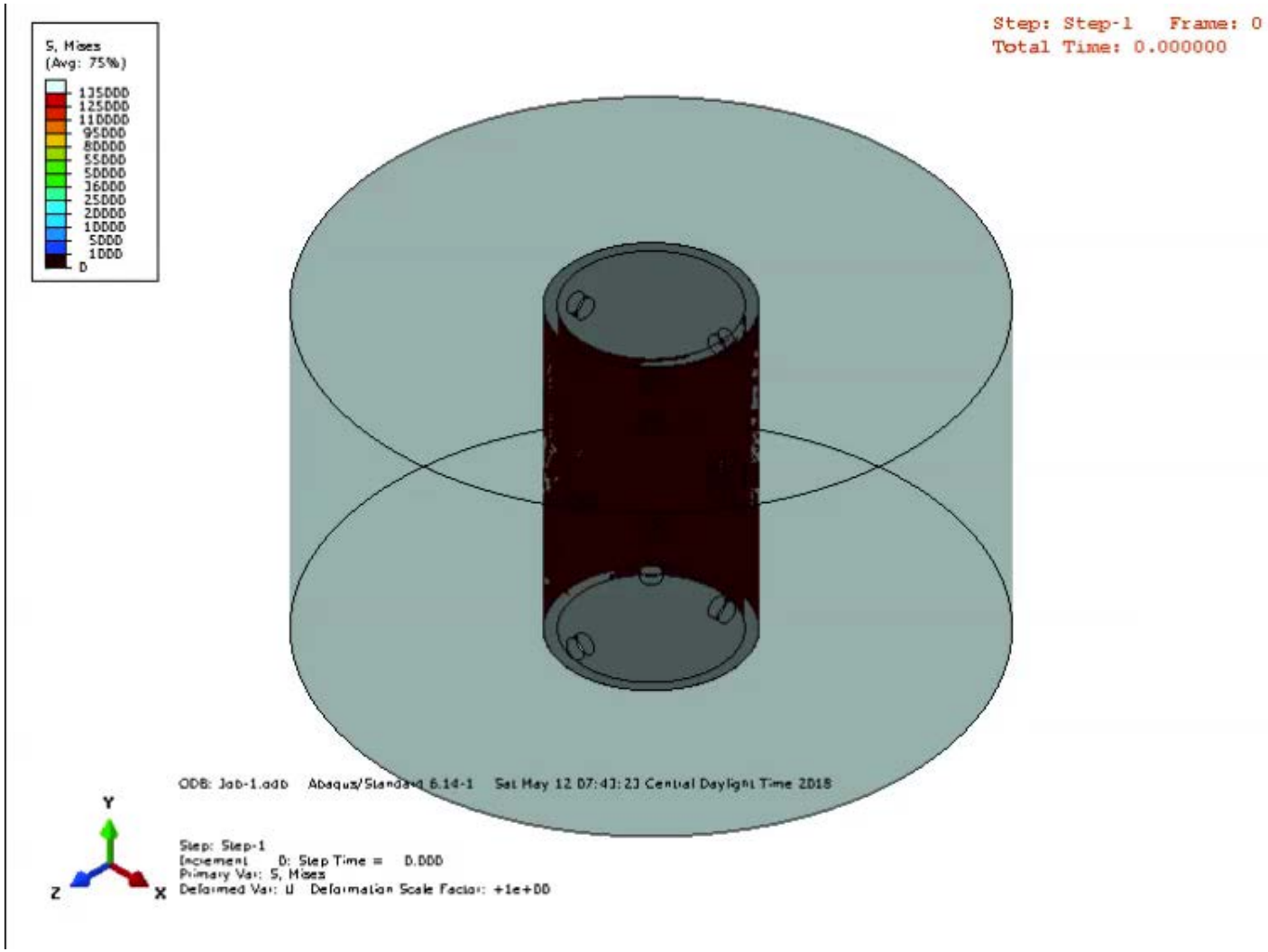




Note Tendency for Pipe to Rotate Relative to the Formation

Multi-Physics Approach Warranted?
Mechanical analysis at high strain rates
CFD of deflected geometries
Erosion studies with velocity profiles
Life estimates at regions of potential wash out





QUESTIONS? THANK YOU

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