Comparison of Experimental and FEM Results for 1st SAPL on Circular Invert-cut CMPs

Center for Underground Infrastructure Research and Education (CUIRE)
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Outline

- Objectives
- Experimental Results
- Material Properties
- FEM Model Setup
- Results
- Comparison and Analysis

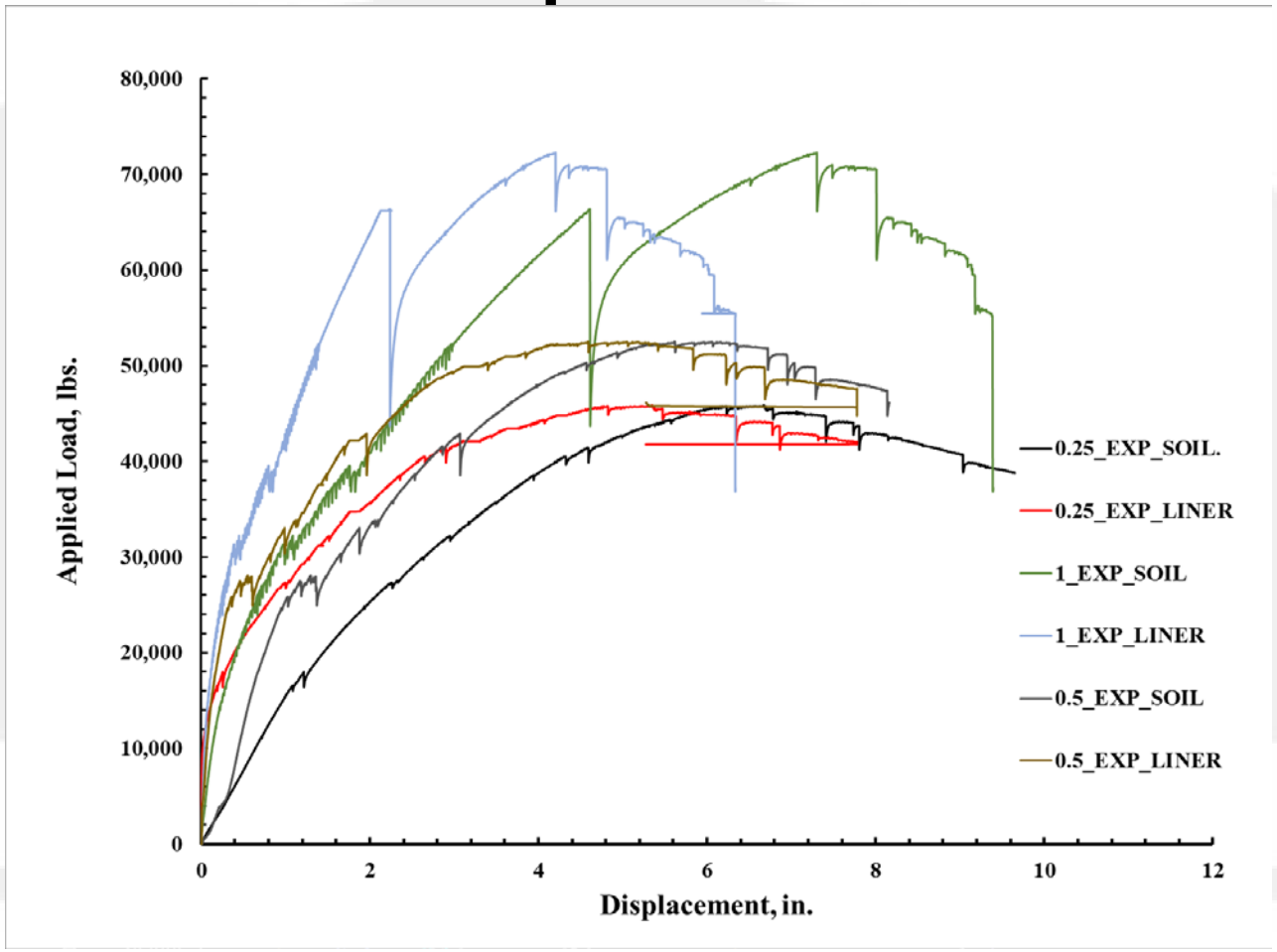
Objectives

- Compare the results of FEM to the experiment for the 1st Spray Applied Polymeric Liner (SAPL) on circular CMPs.

- Calibrate the FE Model for further parametric studies.

Experimental Results

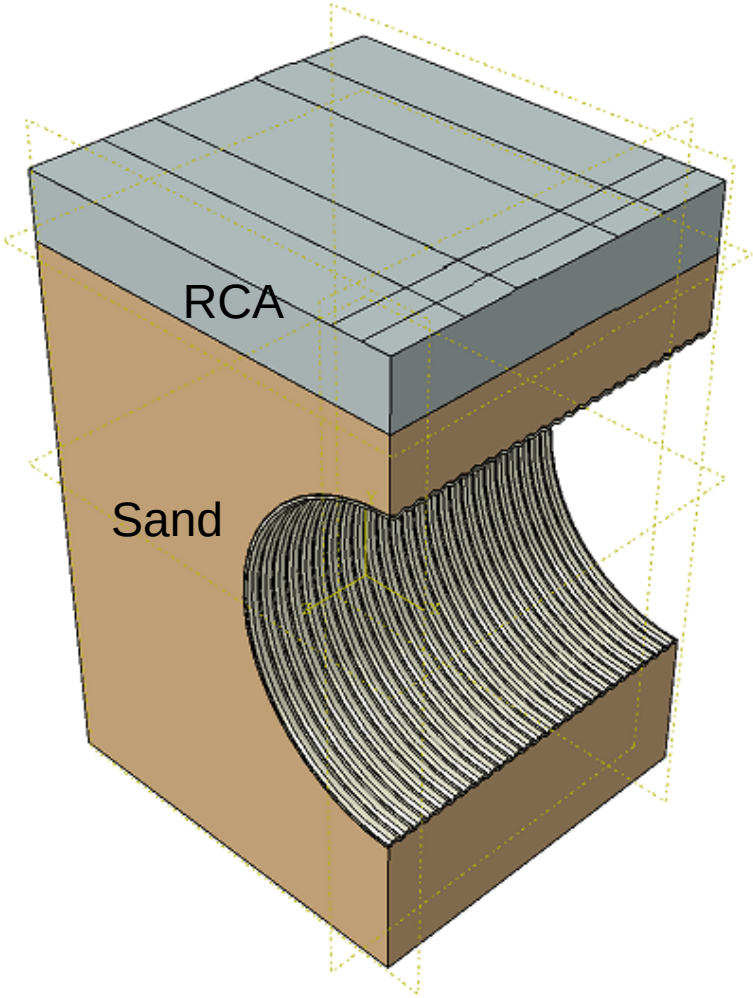
Load vs. Displacement Plots



FEM Model

Material Properties

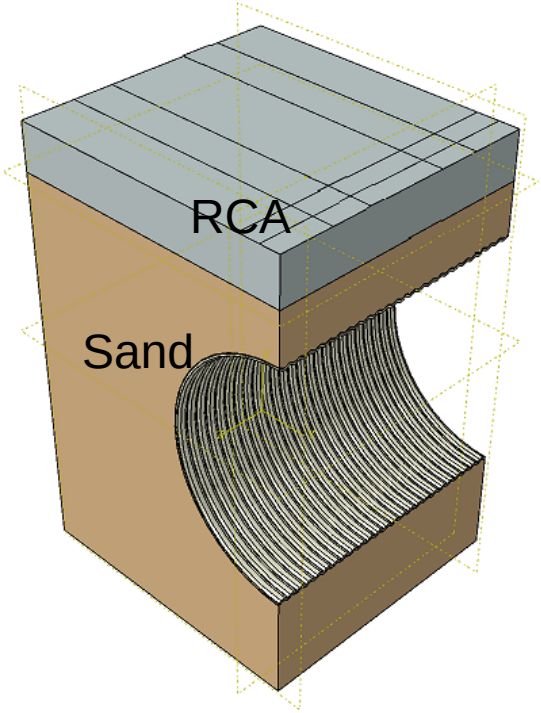
Property	Pipe	Sand
Plasticity Model	Elastic-Plastic	Drucker Prager
Density (lb./in^3)	0.284	0.057
Elastic Modulus (psi)	29,000,000	510
Poisson Ratio	0.3	0.3
Yield Stress (psi)	33,000	-
Ultimate Stress (psi)	45,000	-
Friction Angle (°)	-	32
Dilation Angle (°)	-	1



Top 1-ft Cover Soil Properties

- Top 1-ft of soil was replaced with TxDOT specified Grade D subbase layer which is also named as Recycled Concrete Aggregates (RCA).
- Drucker Prager Model was used to model the soil in FEM.

Description	Value	Unit
Density	125	pcf
Friction angle	39	degree
Elastic Modulus	1,000	psi
Poisson ratio	0.28	
Dilation angle	2	



Source: RCA Properties(Araulrajh (2016))

SAPL Properties

Description	Value	Unit
Yield strength	8,725	psi
Yield strain	1.52	%
Break strength	8,723	psi
Break strain	1.69	%
Young's Modulus	991,571	psi

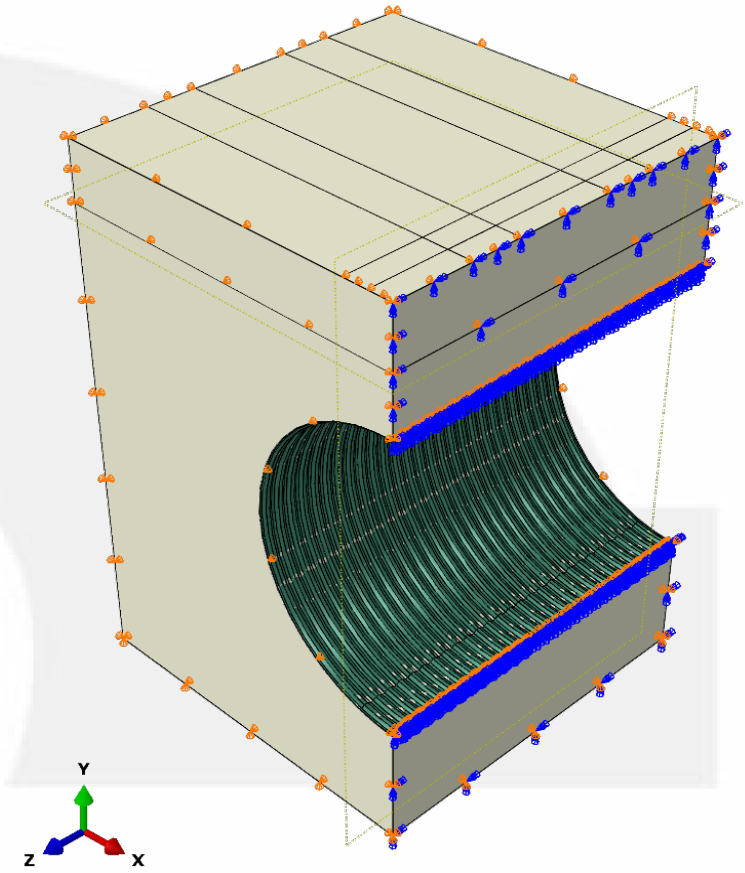
- Simple Elastic-plastic model was used to model the liner.

TENSILE PROPERTIES (ASTM D 638)						TEST RESULTS
Test Replicate Number	1	2	3	4	5	Mean
Tensile Yield Strength (psi)	8,725	7,843	6,554	7,174	7,114	**7,482**
Tensile Yield Strain (%)	1.52	1.17	0.90	1.03	1.01	**1.13**
Tensile Break Strength (psi)	8723	8657	7370	7955	8434	**8228**
Tensile Break Strain (%)	1.69	1.41	1.08	1.22	1.37	**1.35**
Young's Modulus (psi)	991,571	1,052,264	1,198,074	1,346,946	1,181,228	**1,154,016**

Source: Sprayroq (January 15, 2018)

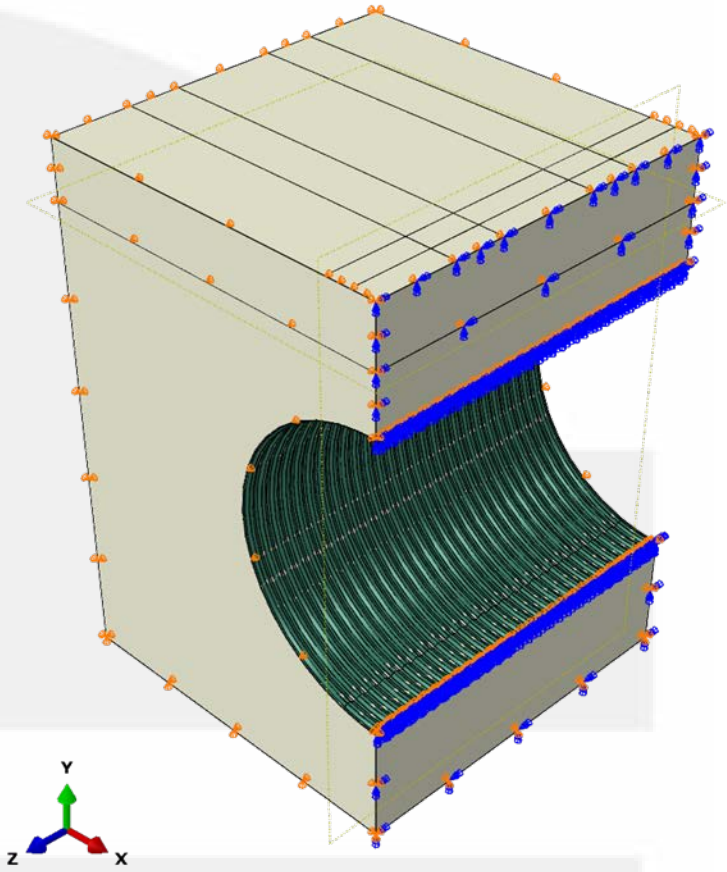
FE Modeling

- Pipe- Solid element
- Soil- Solid element
- Liner-Solid elements
- Axis symmetric model.
- Element type – C3D8R
- Interaction between pipe and soil – surface to surface interaction with friction coefficient of 0.5.
- Liner and Pipe Interaction-surface to surface interaction with no movement between them and friction coefficient of 1.



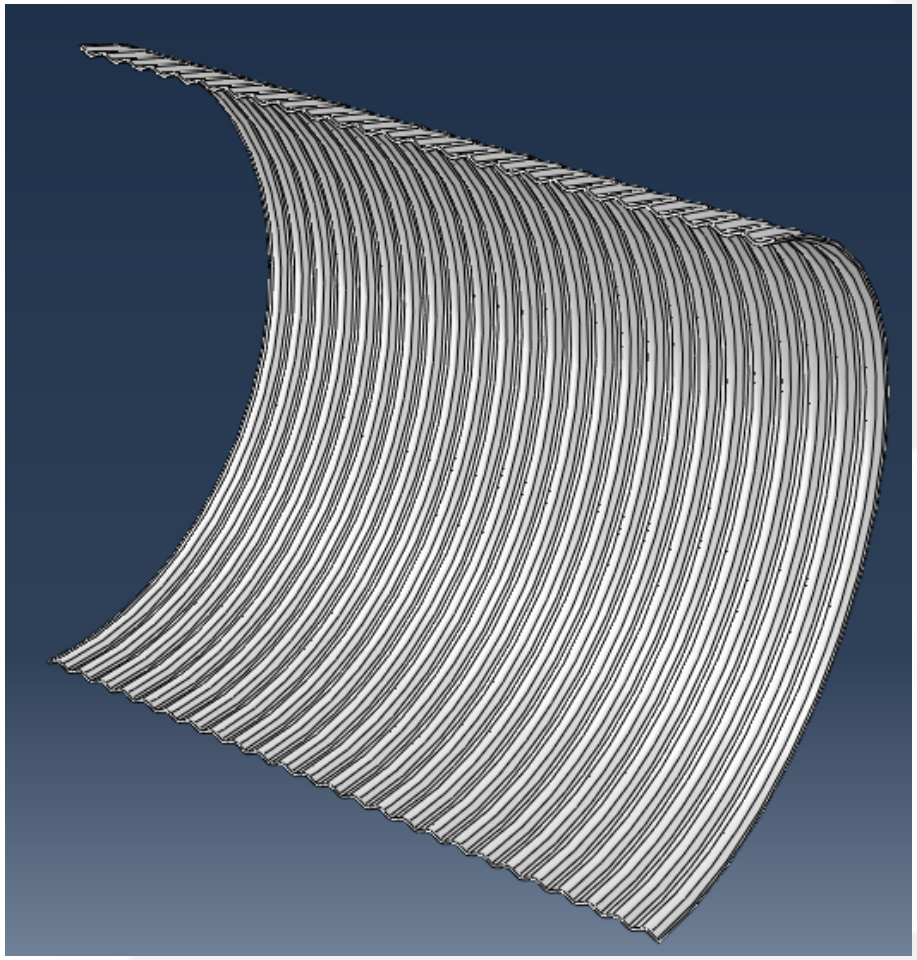
Boundary Conditions

- Vertical movement restrained at the bottom.
- Normal horizontal movement restrained at the sides.
- Symmetric boundary along YZ plane.

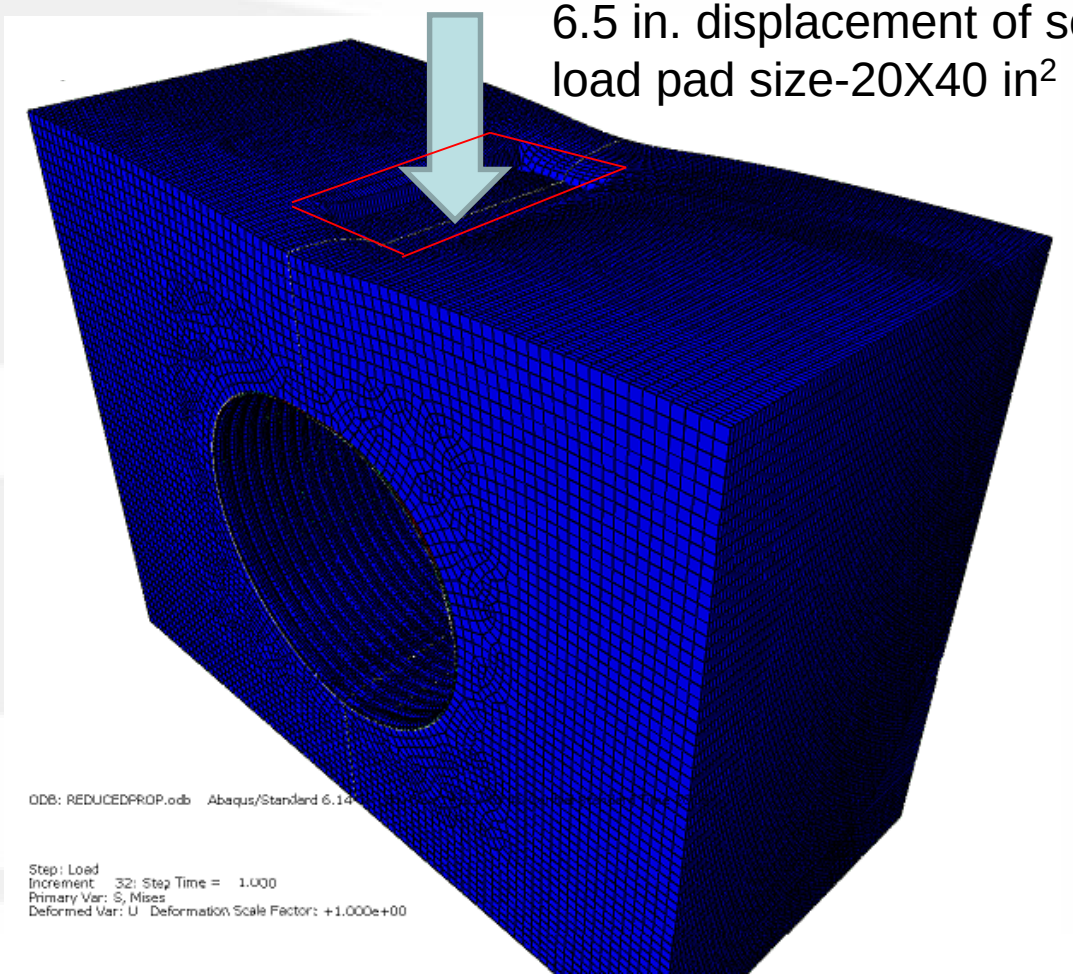


FEM Results
(0.25-in. SAPL)

Loading Conditions

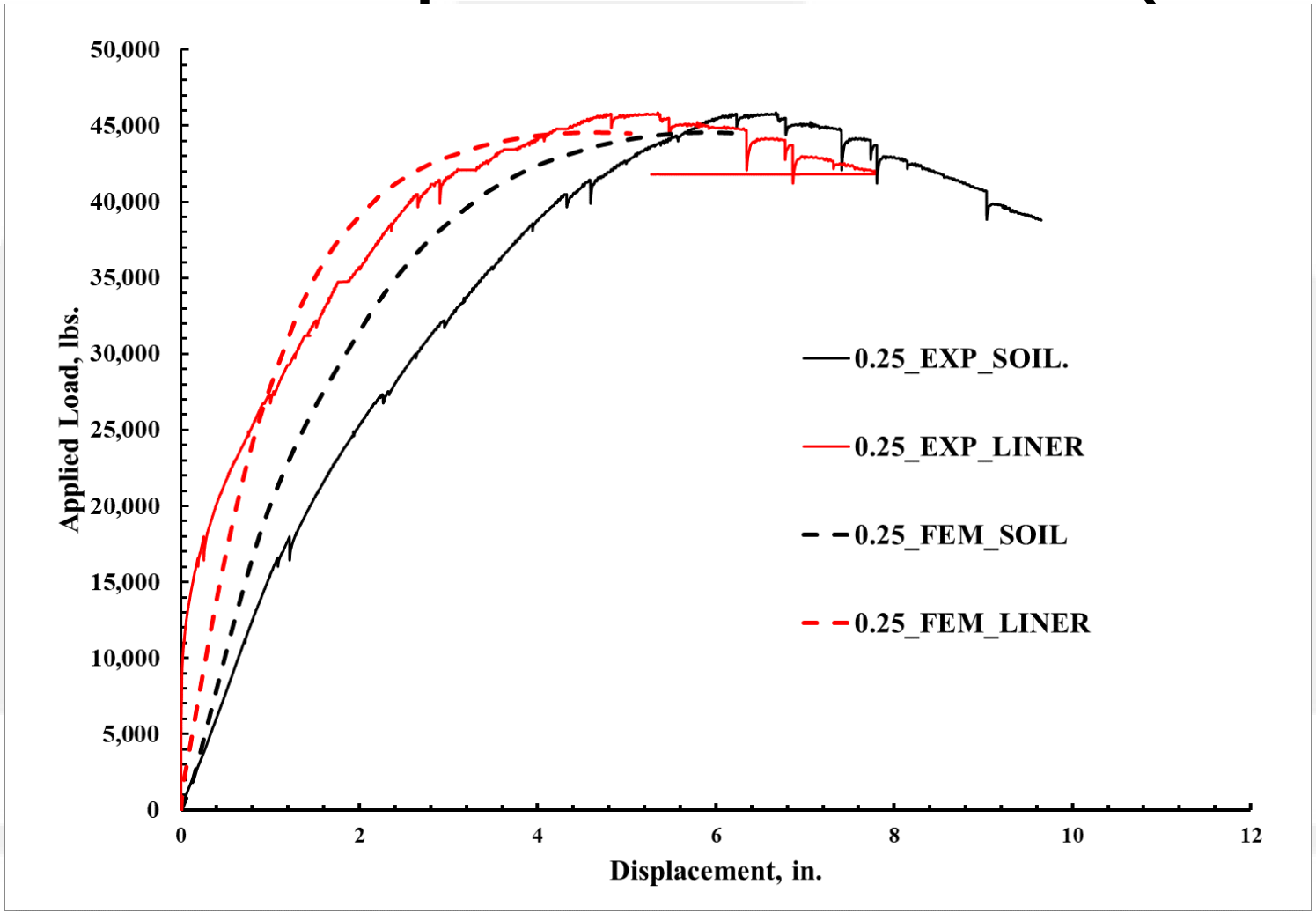


0.25-in. liner

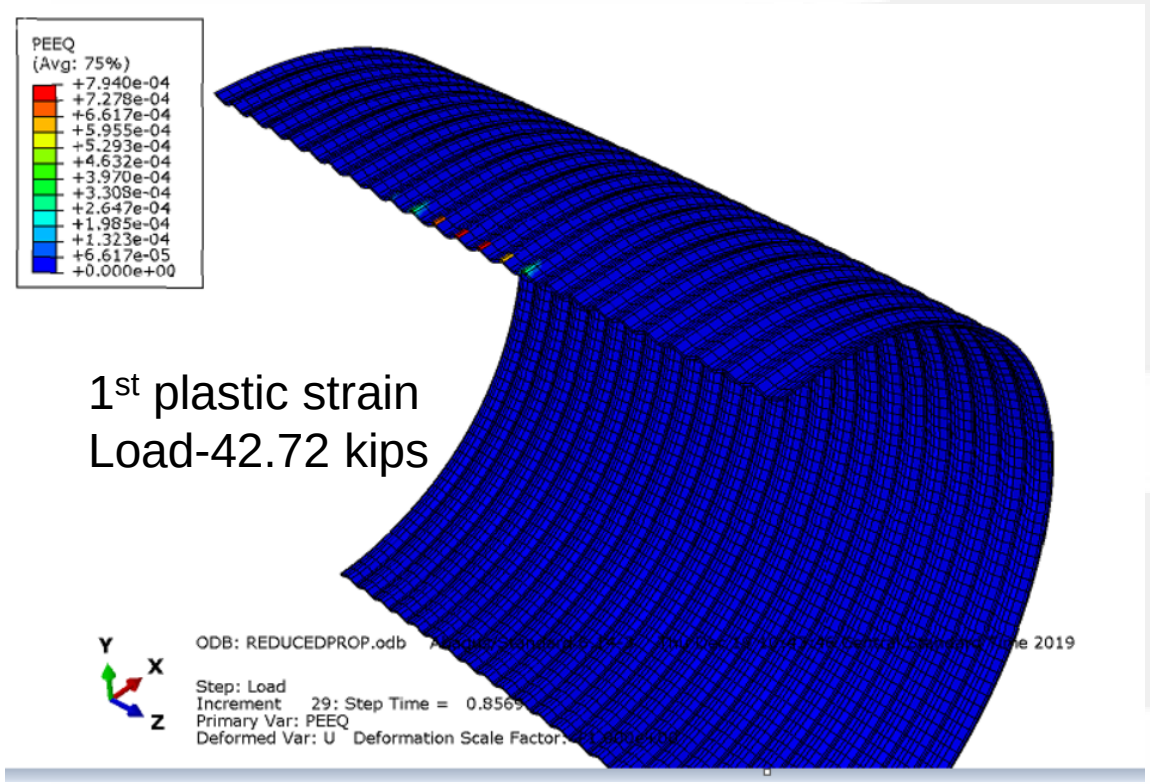


6.5 in. displacement of soil over the load pad size-20X40 in^2

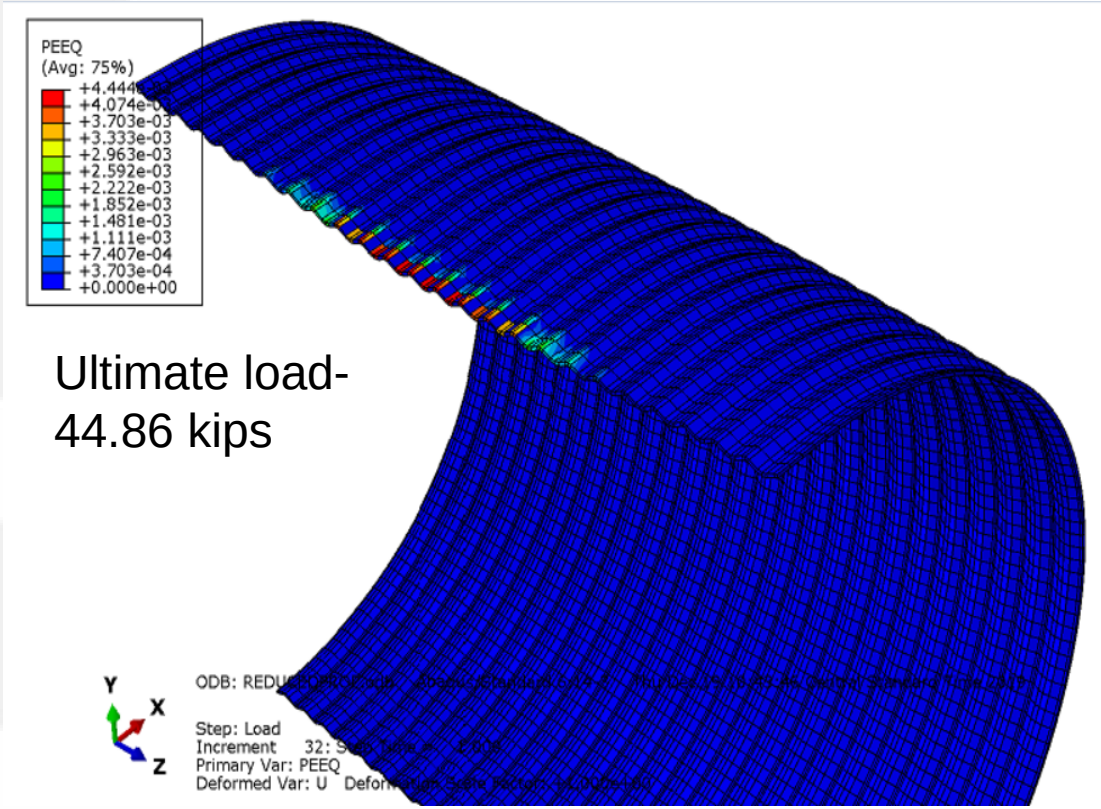
Load Vs Displacement Plot (0.25 in.)



Plastic Strain (0.25-in.)



1st plastic strain
Load-42.72 kips



Ultimate load-
44.86 kips

Comparison (0.25-in.)

Description	1st Plastic Strain		Ultimate load	
	FEM	Experimental	FEM	Experimental
Load (kips)	42.72	40	44.86	45.6
Soil displacement (in.)	5.26	4.5	6.5	7.7
Liner displacement (in.)	3.93	4.0	4.3	4.75

Earth Pressure Comparison (0.25-in.)

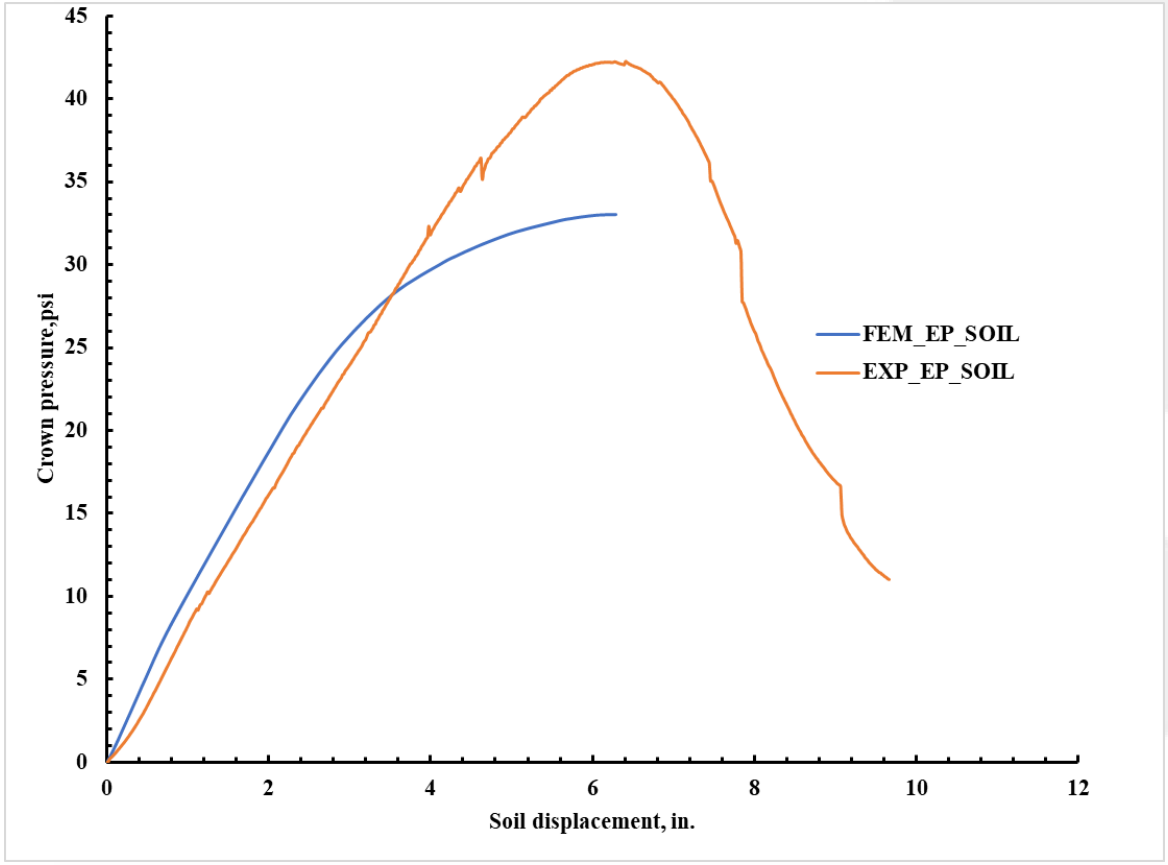


Fig. Pressure at Crown vs. Soil Displacement

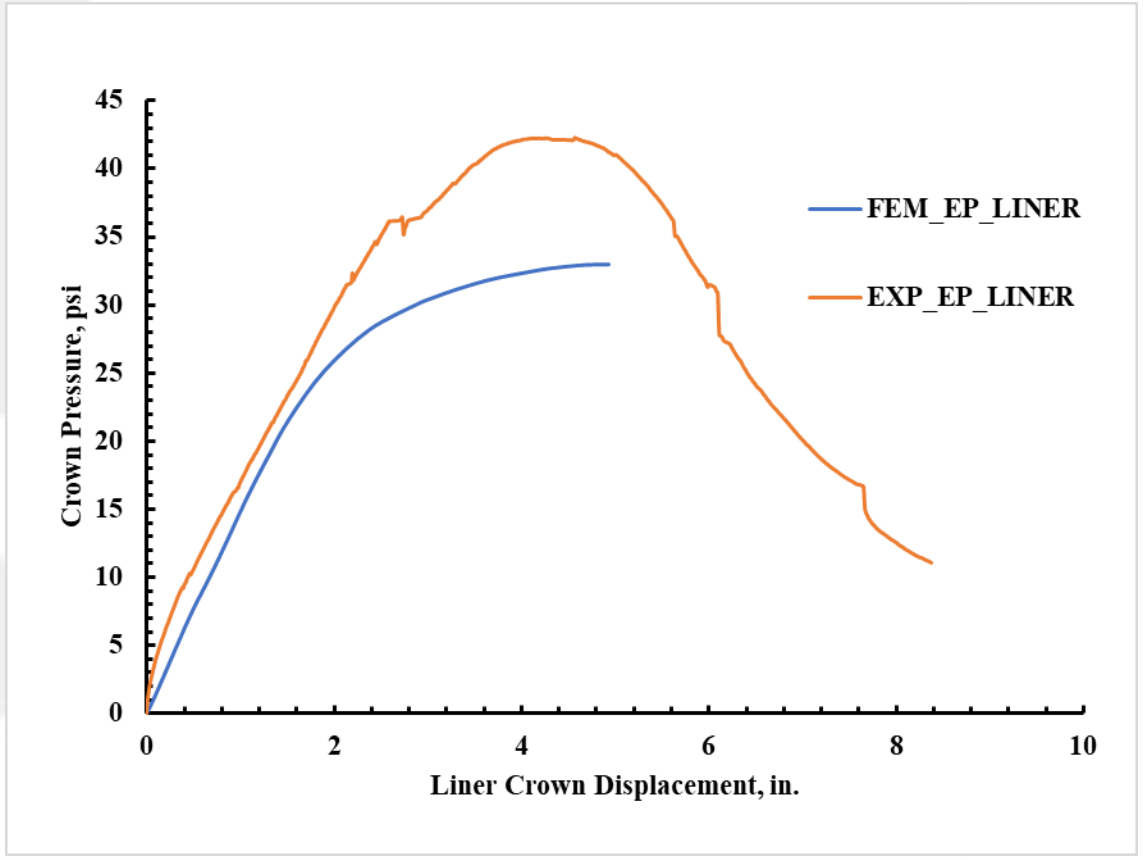


Fig. Pressure at Crown vs. Liner Displacement @ Crown

Earth Pressure Comparison (0.25-in.)

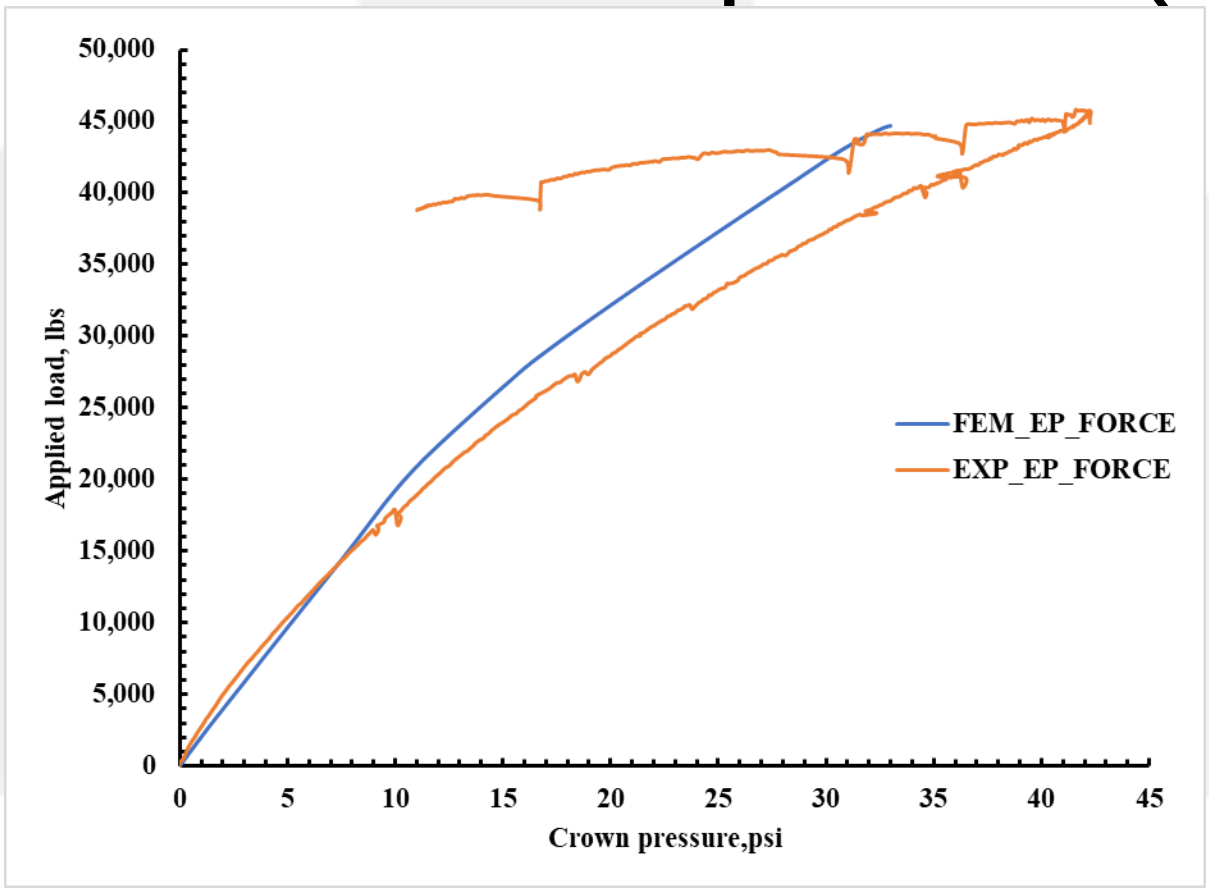
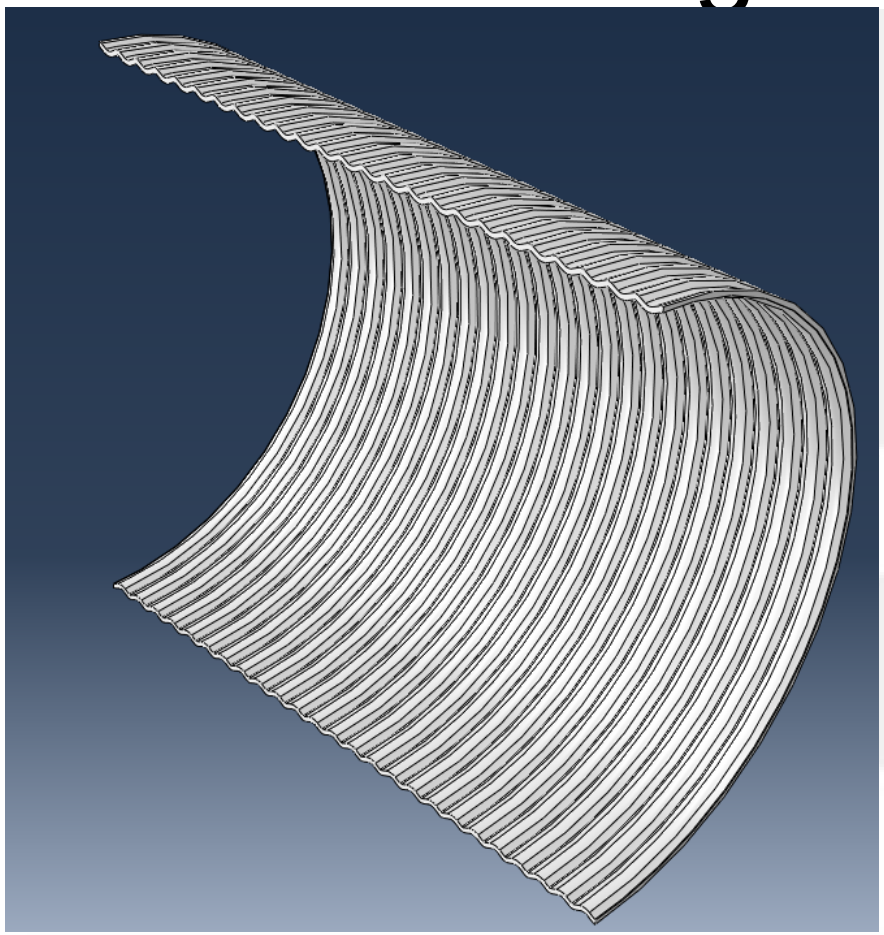
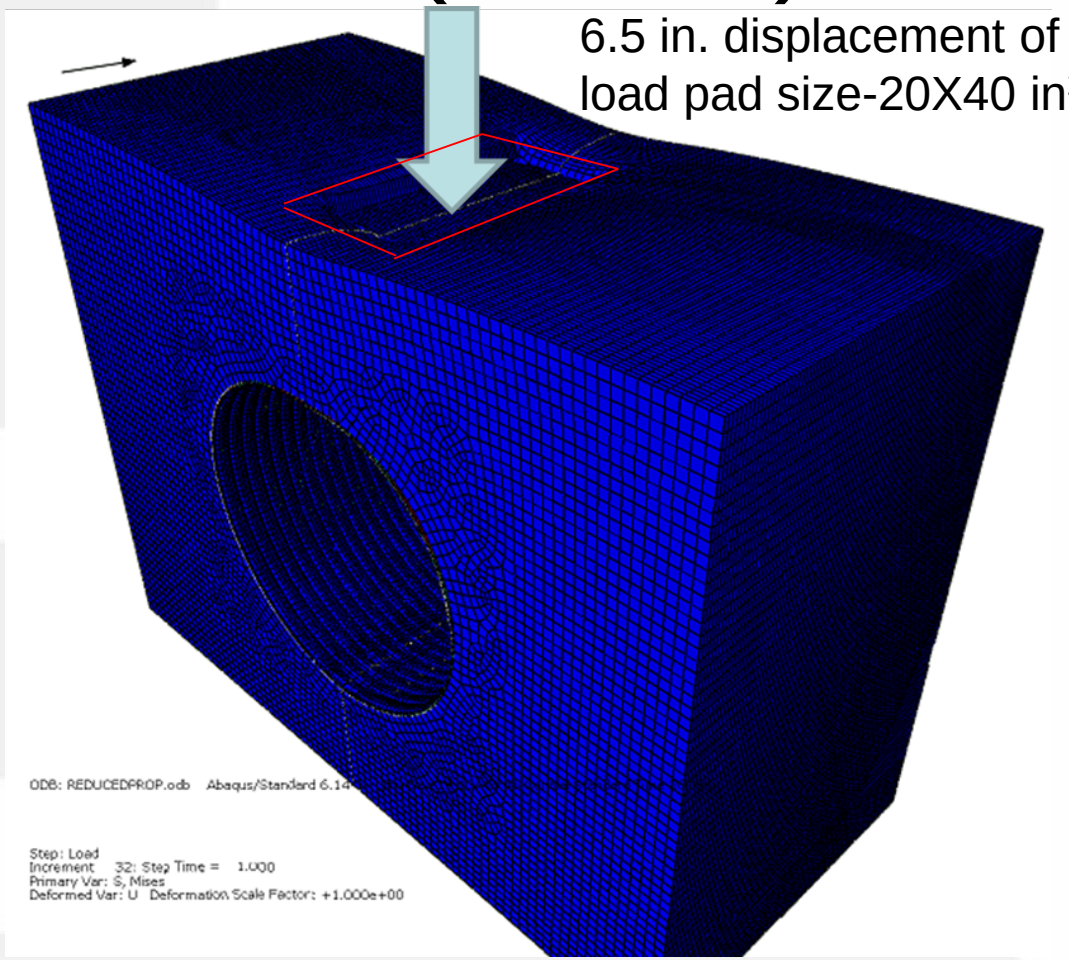


Fig. Applied Load vs. Pressure at crown

FEM Results
(0.5-in. SAPL)

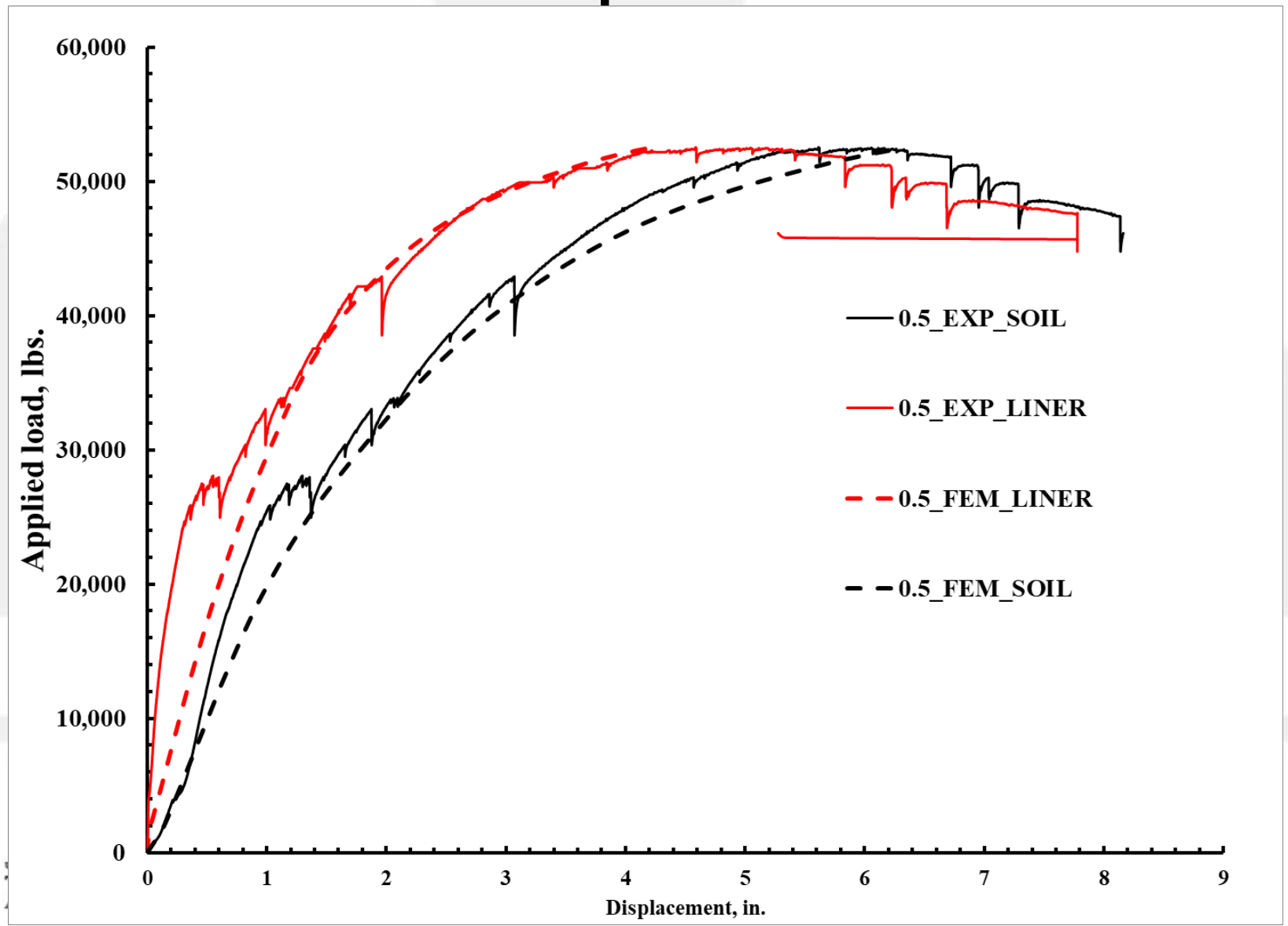
Loading Conditions (0.5-in.)



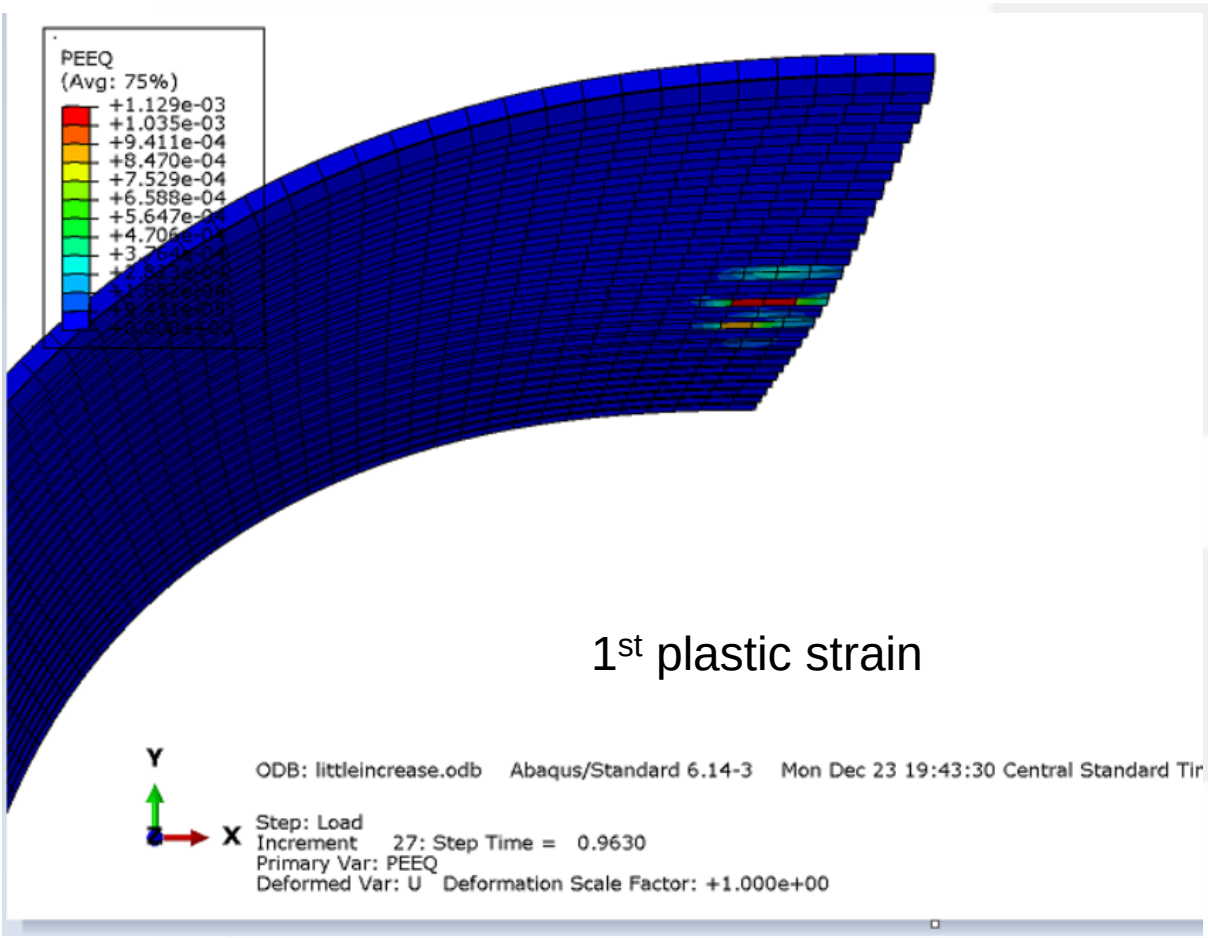


6.5 in. displacement of soil over the load pad size-20X40 in^2

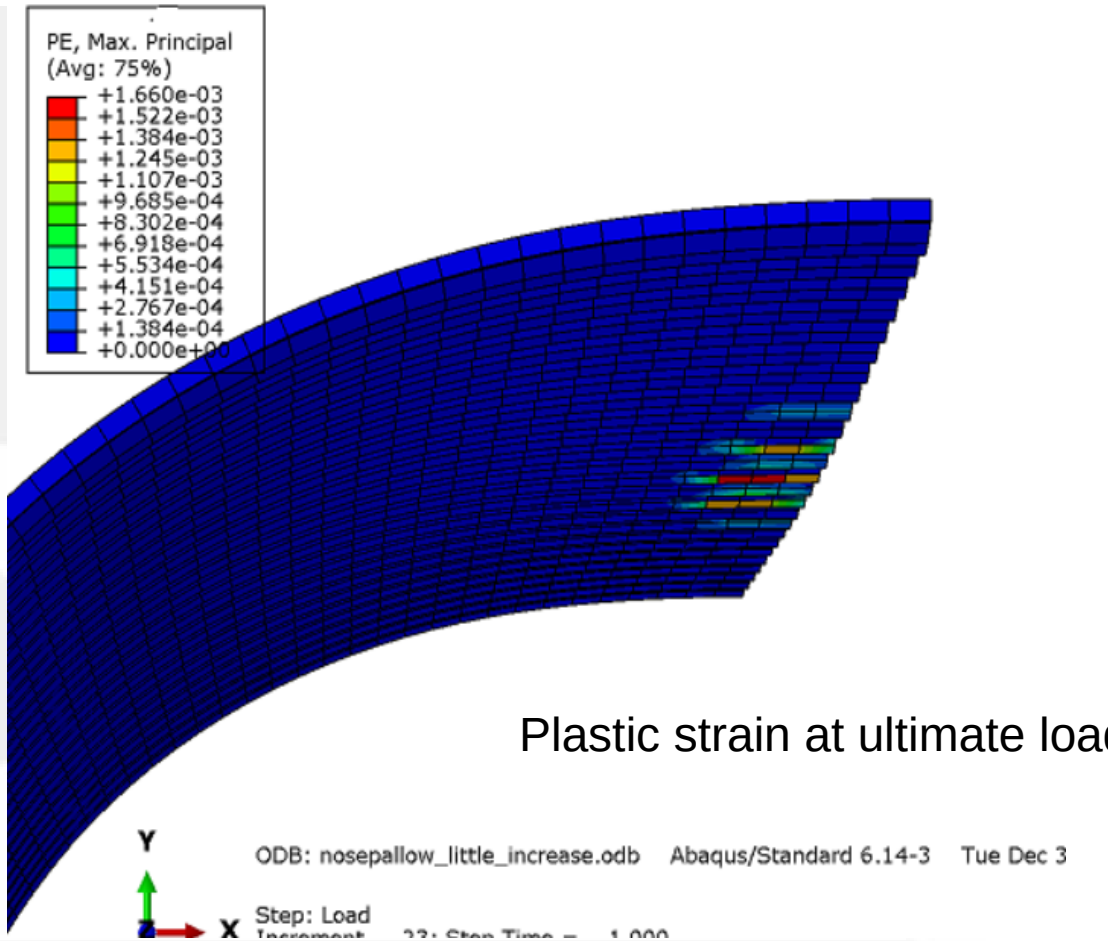
Load vs. Displacement Plot



Plastic Strain



1st plastic strain



Plastic strain at ultimate load

Comparison (0.5-in.)

Description	1st Plastic Strain		Ultimate Load	
	FEM	Experimental	FEM	Experimental
Load (kips)	48.4	46	52.34	52
Soil displacement (in.)	5.07	5.0	6.5	6.2
Liner displacement (in.)	3.085	3.0	4.09	4.5

Earth Pressure Comparison (0.5-in.)

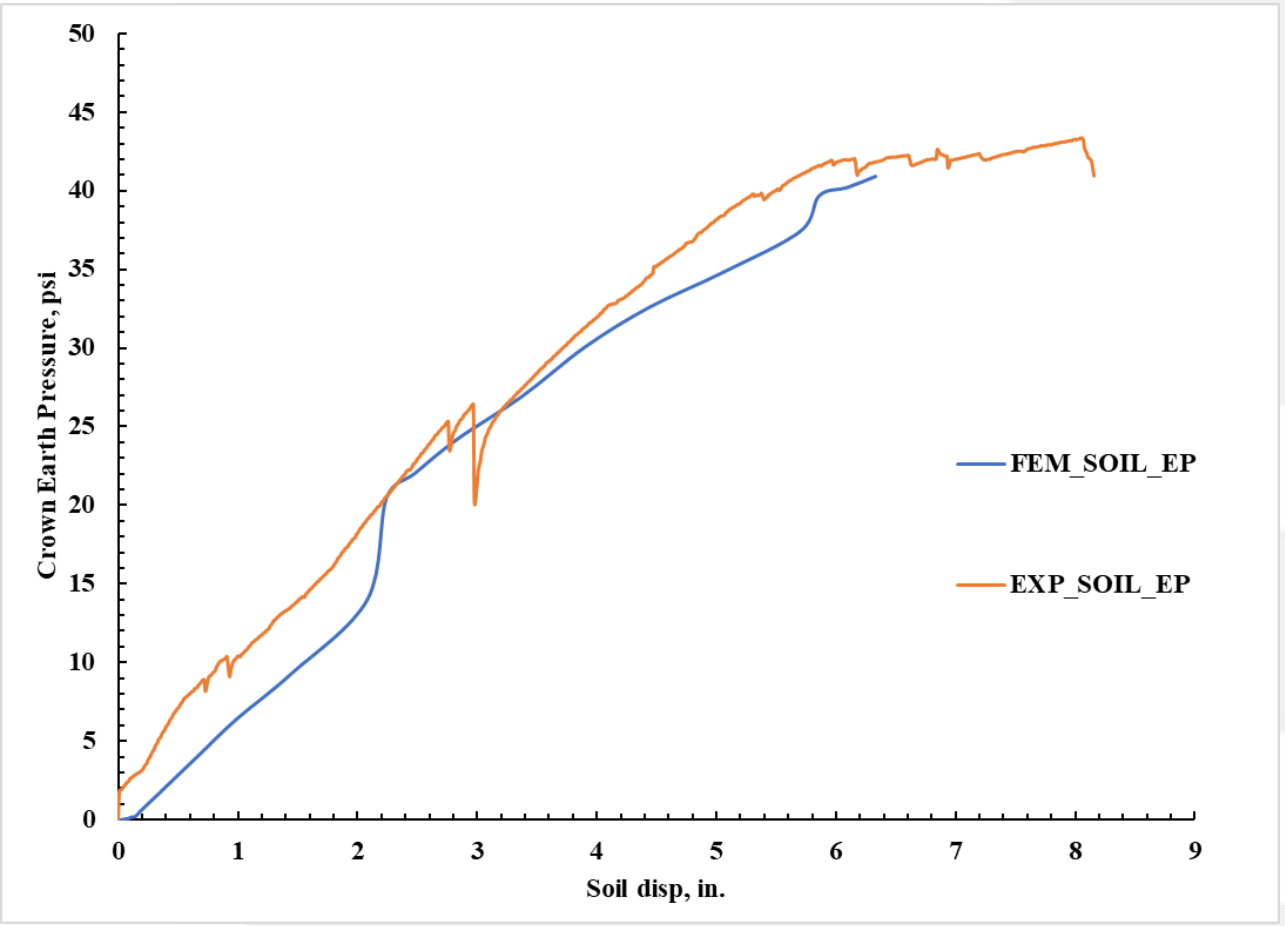


Fig. Pressure at Crown vs. Soil Displacement

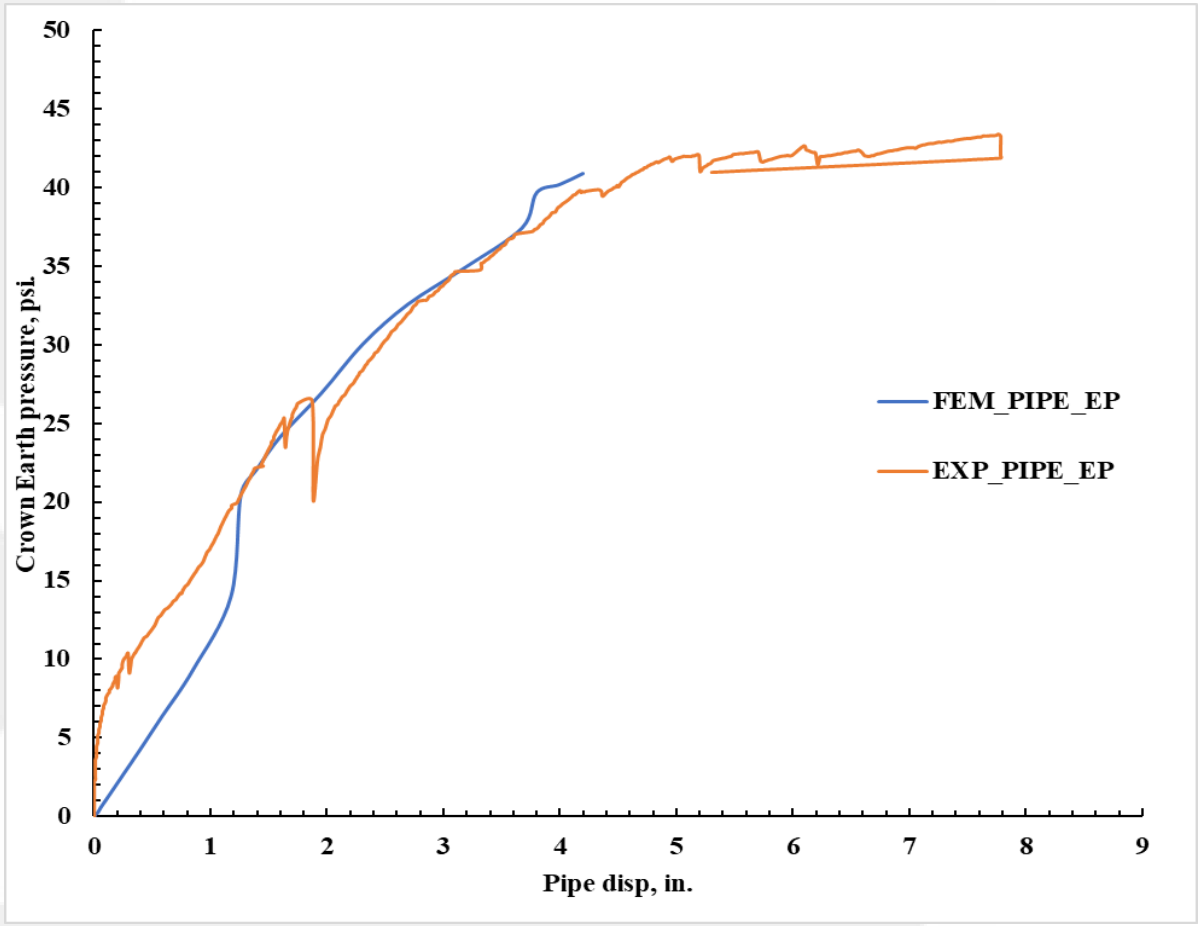


Fig. Pressure at Crown vs. Liner Displacement @ Crown

Earth Pressure Comparison (0.5-in.)

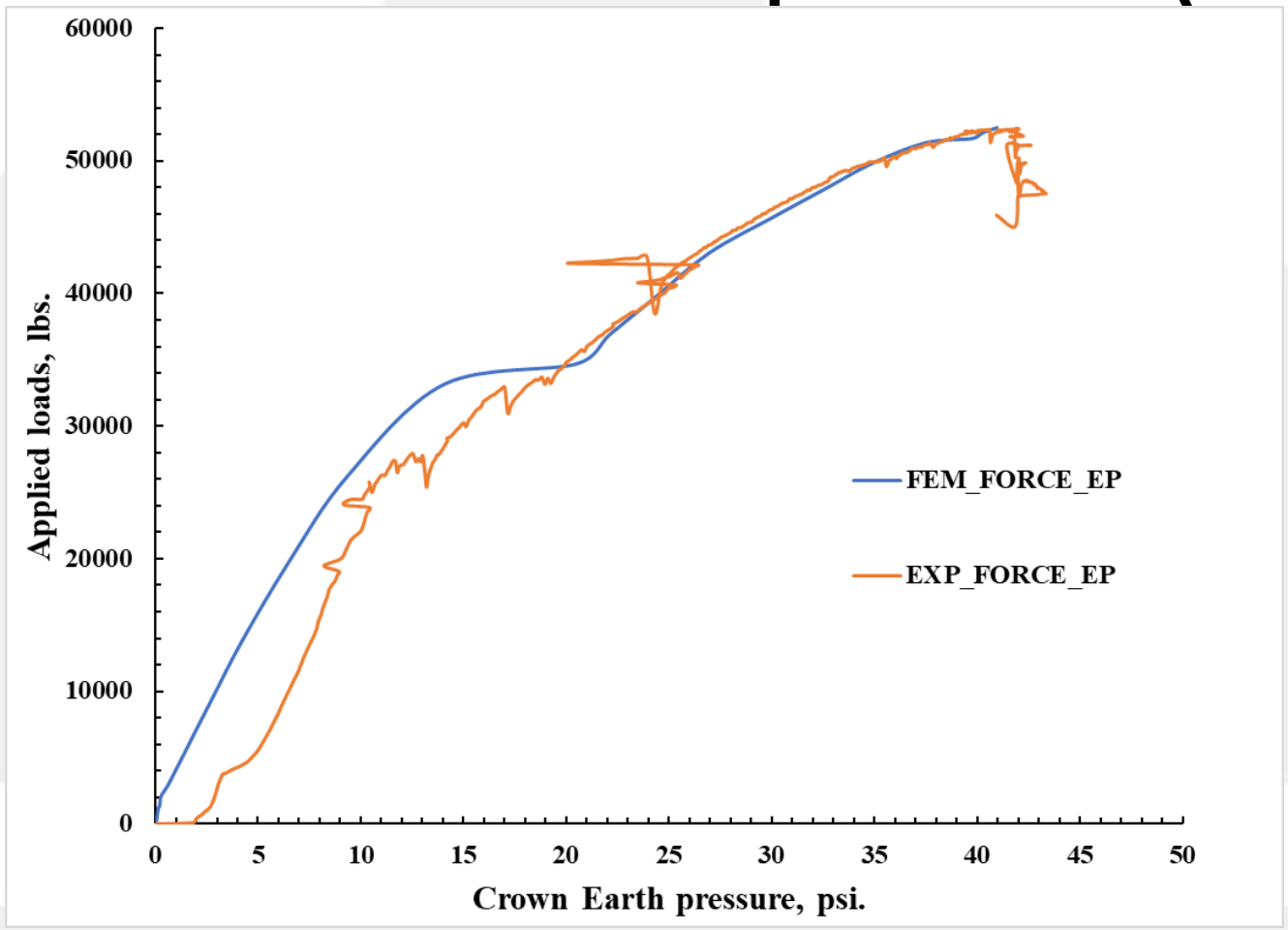
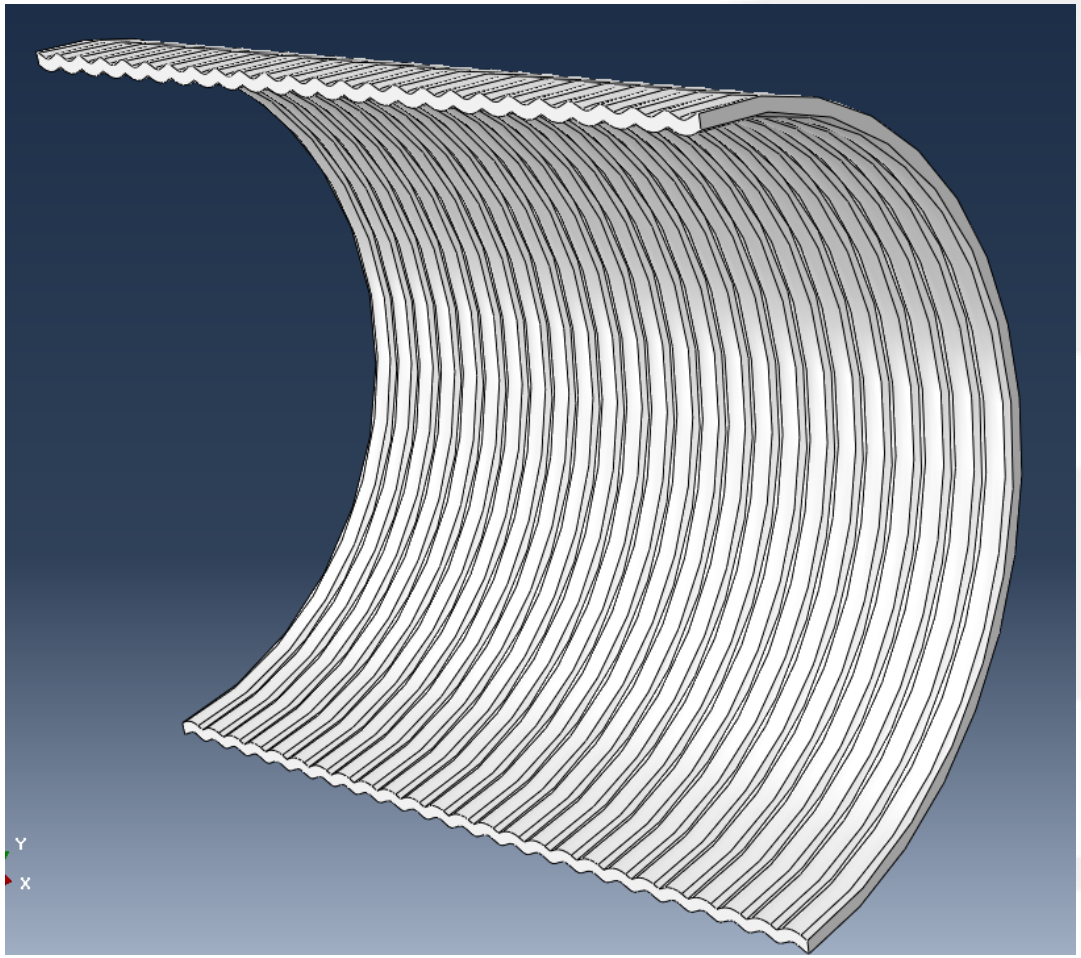


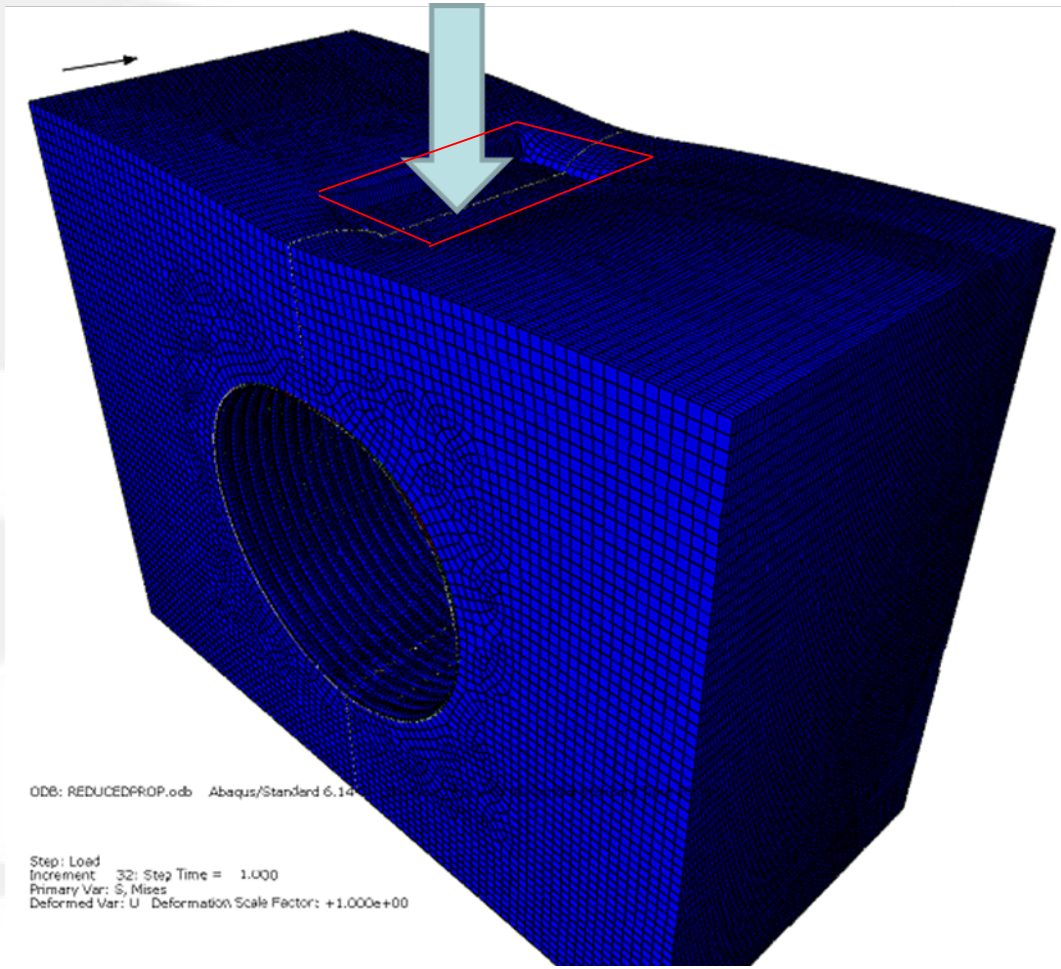
Fig. Applied Load vs. Pressure at crown

FEM Results
(1-in. SAPL)

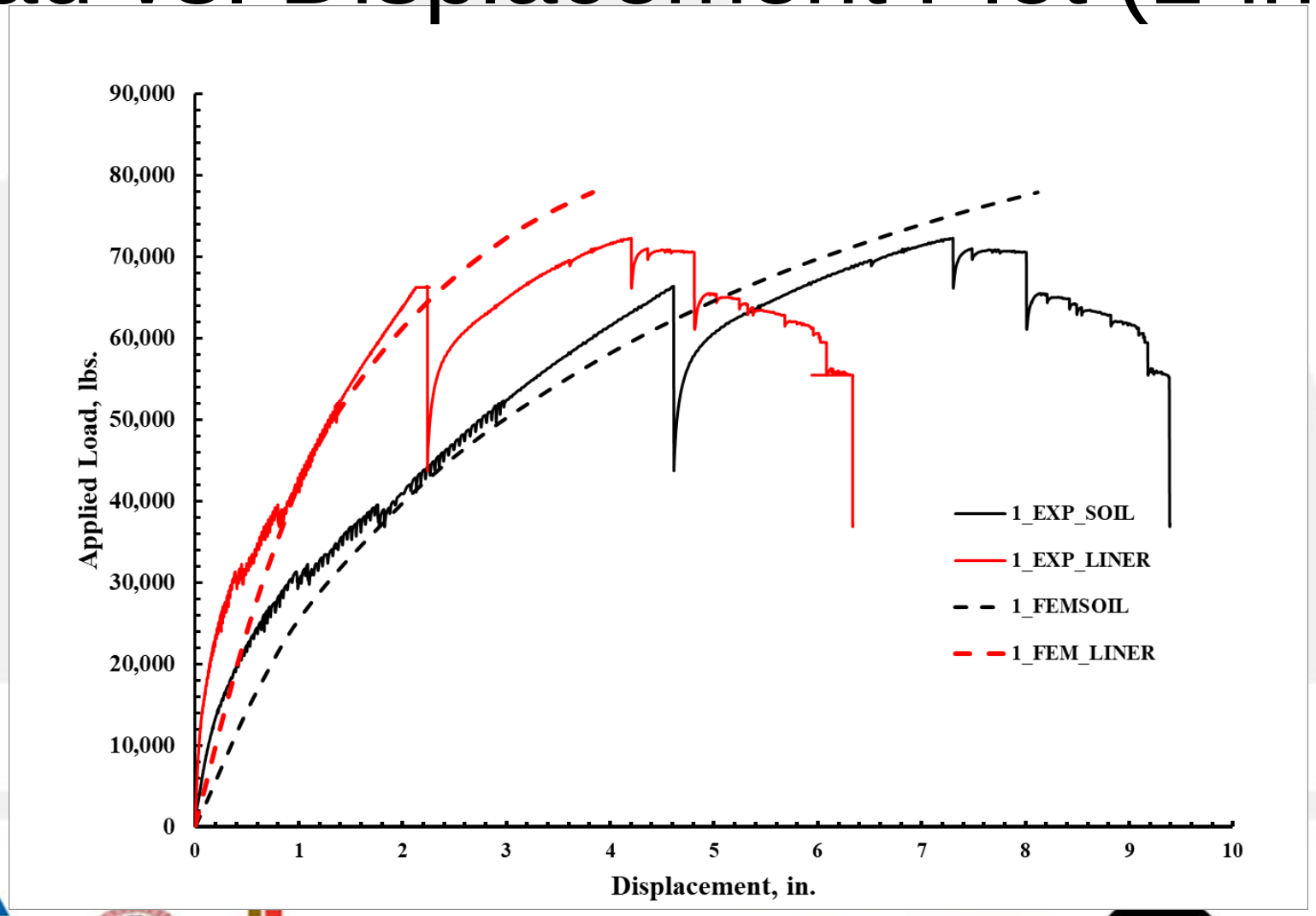
Loading Conditions

8 in. displacement of soil over the load pad size-20X40 in^2

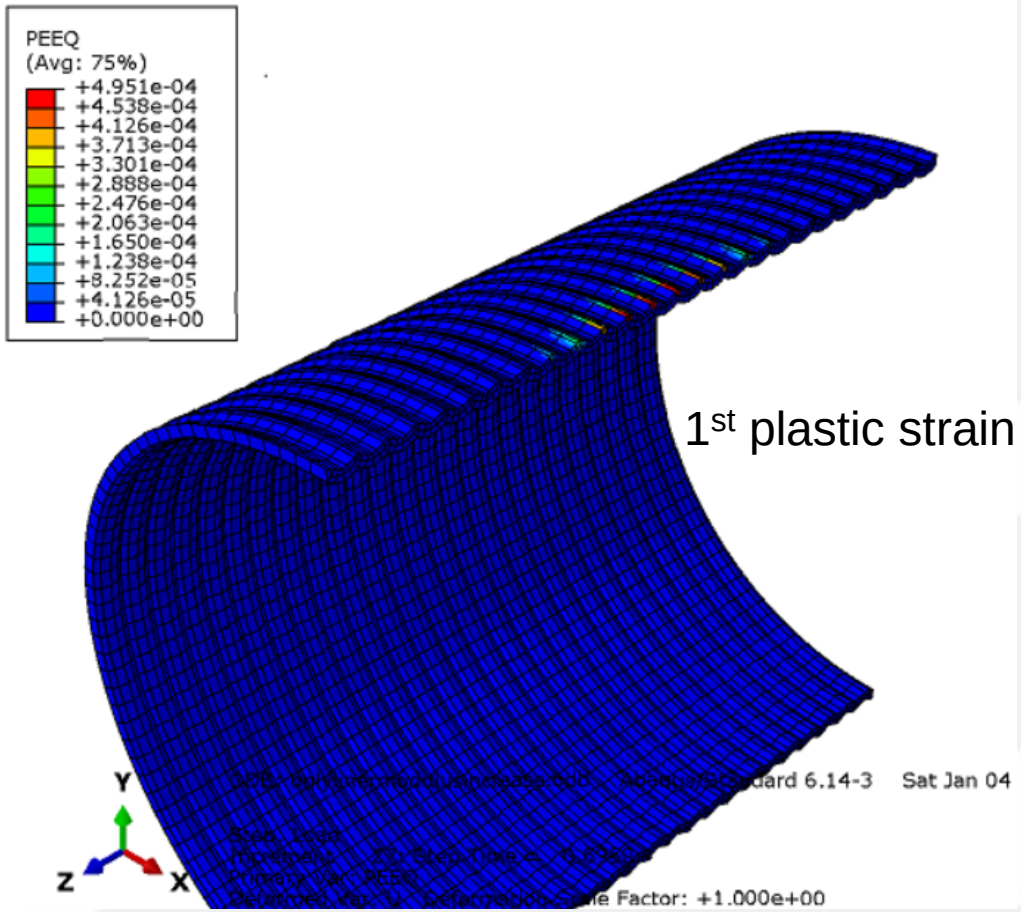




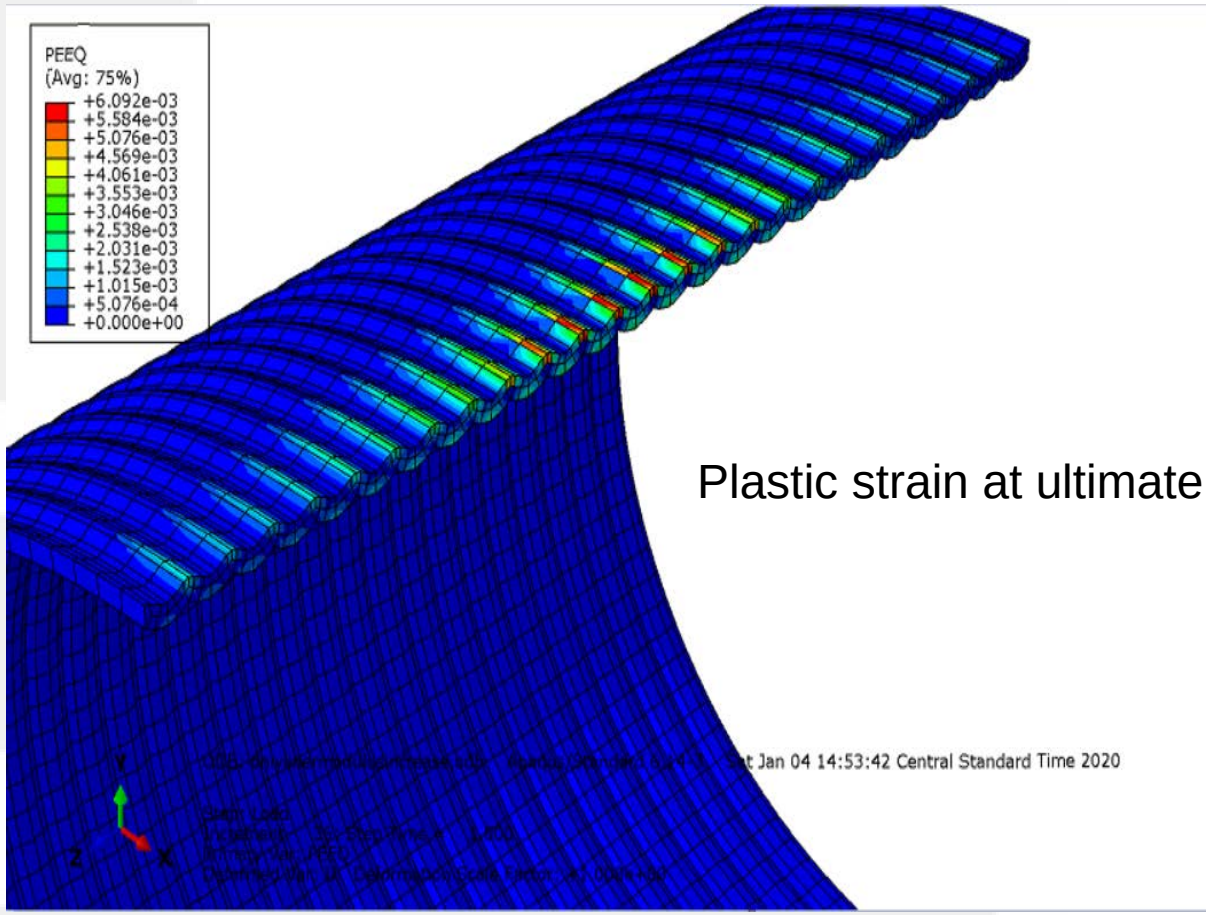
Load vs. Displacement Plot (1-in.)



Plastic Strain(1-in.)



1st plastic strain



Plastic strain at ultimate load

Comparison (1-in.)

Description	1st Plastic Strain		Ultimate Load	
	FEM	Experimental	FEM	Experimental
Load (kips)	64.1	65.0	74.4	72.0
Soil displacement (in.)	5.2	4.9	8	7.4
Liner displacement (in.)	2.48	2.4	3.73	4.0

Earth Pressure Comparison (1-in.)

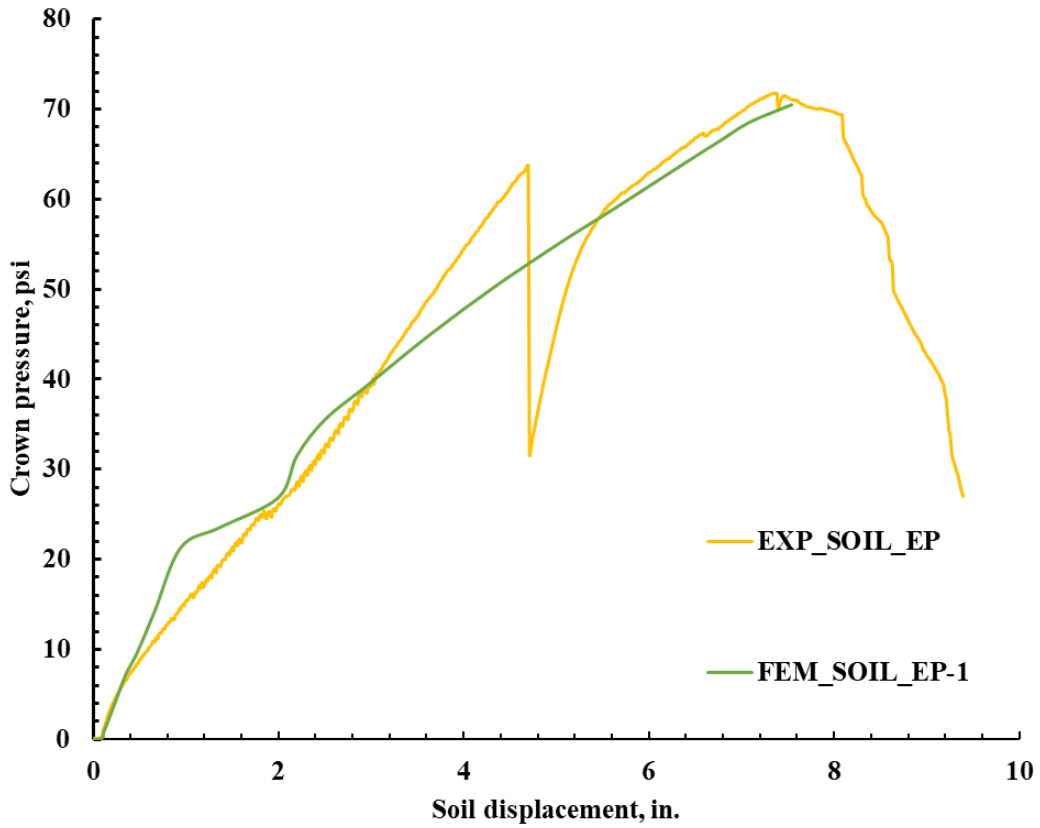


Fig. Pressure at Crown vs. Soil Displacement

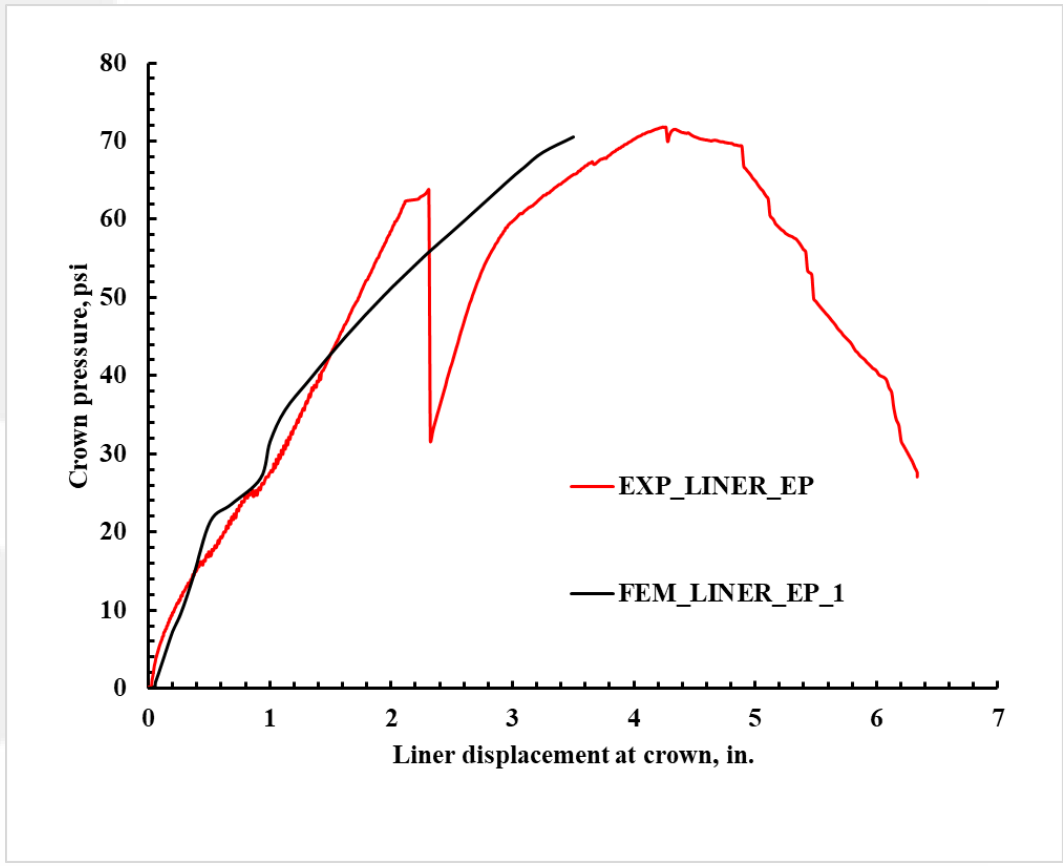


Fig. Pressure at Crown vs. Liner Displacement @ Crown

Earth Pressure Comparison (1-in.)

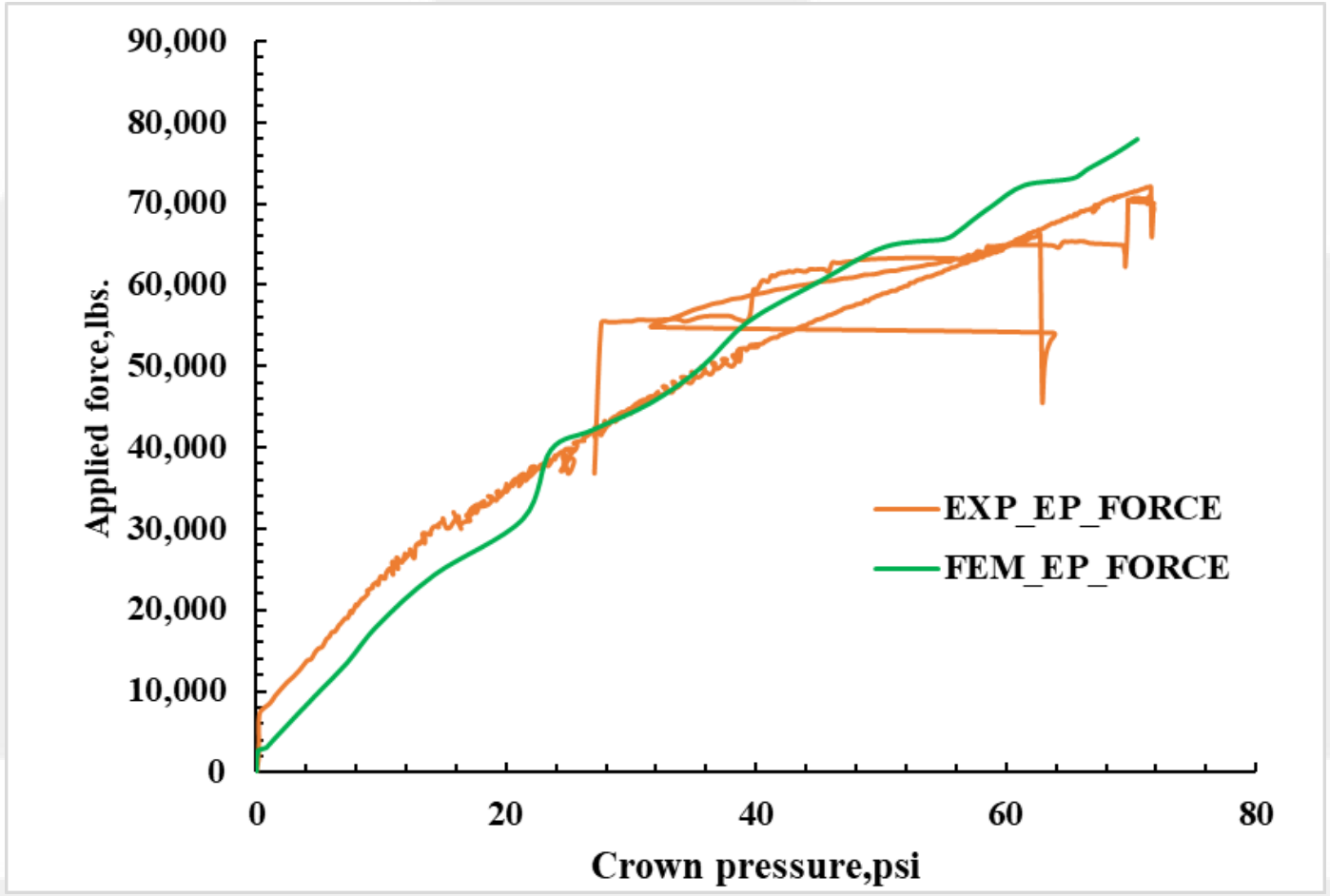


Fig. Applied Load vs. Pressure at crown

Conclusions

- The experimental and FEM results compare fairly.

- The lab test of the sprayed liner for this test is ongoing. Thus, the model could be further improved by using the exact material properties of the liner used in this test.

Next Steps

- Comparison of other experimental results such as strain gauge results will be made to calibrate the model accurately.

- Improvisation of the model to mimic the drop in the load at the first crack.

References:

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