Performance Evaluation of Embedded Stormwater Chambers Under Simulated Highway Truck Loads

Presenters

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Presentation Outline

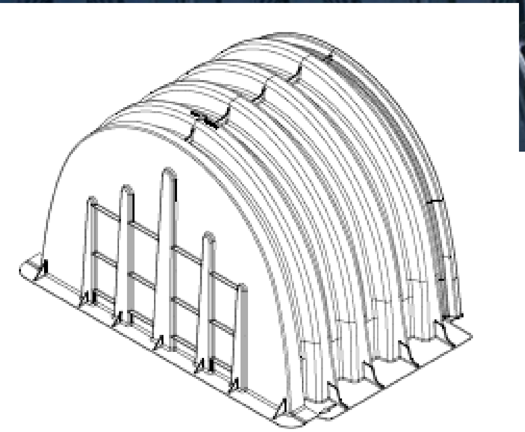
- Introduction
- Research Objectives
- Test Methodology
- Test Results and Discussions
- Finite Element Analysis
- Conclusions
- Recommendations

Source: Xerxes

Introduction

Xerxes HydroChain™ Chamber

- Application: Underground storage of stormwater runoff
- Material: Fiberglass reinforced plastic
- Industry Standards: AASHTO LRFD, ASTM F2787
- Load Rating: HL-93/H-20 vehicular load and earth load



Research Objectives

Conduct live load testing of Stormwater Chambers S29B

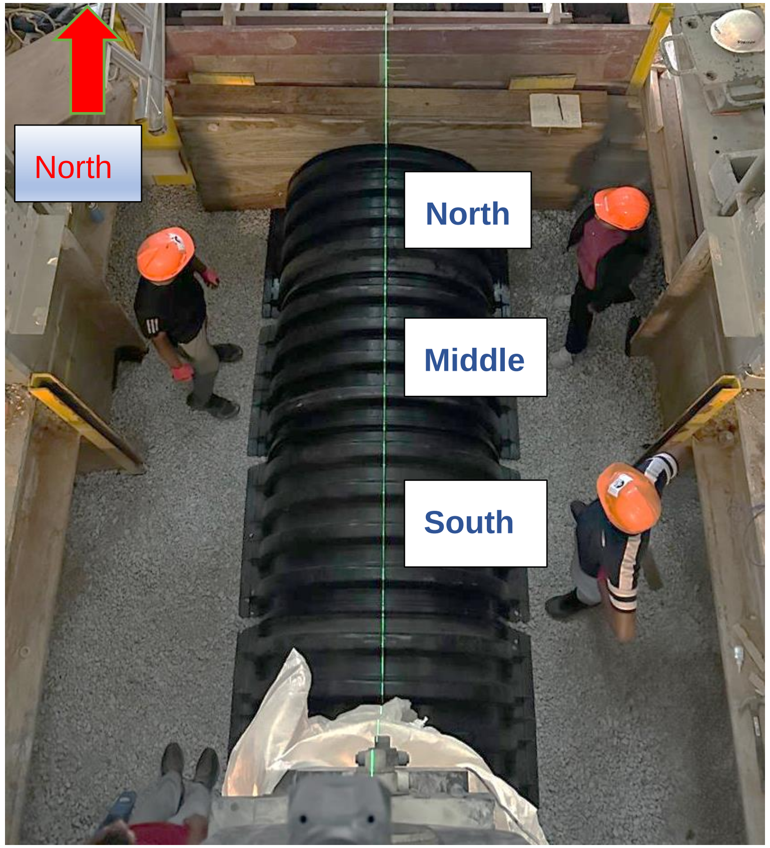
- Characterize installed performance by simulating highway truck loads at multiple depths of cover
- Analyze surface loads, pressure on chamber, deflection & strain at critical points
- Characterize failure modes
- Determine the ultimate strength
- Simulate structural behavior

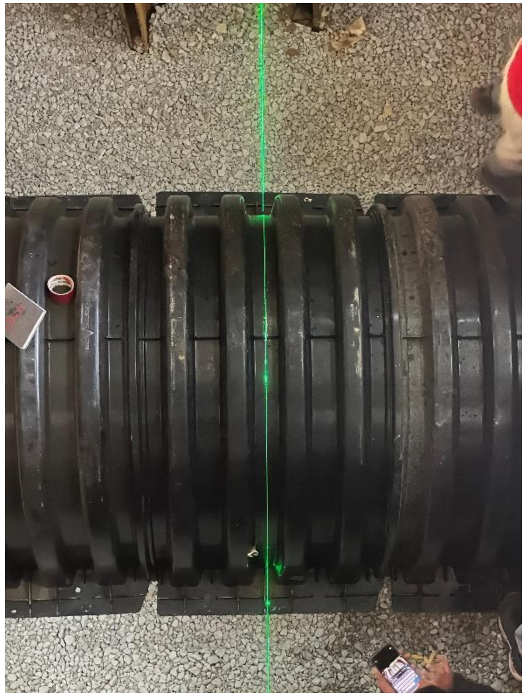
Test Methodology

Chamber Embedment

- Soil Pit Base: 6” well-compacted gravel (3/8“-2" /8-50mm) clean, crushed, angular stone
- Alignment in both X and Y directions
- Embedded with loose gravel
- Backfill with compacted gravel up to 24”

Test Methodology

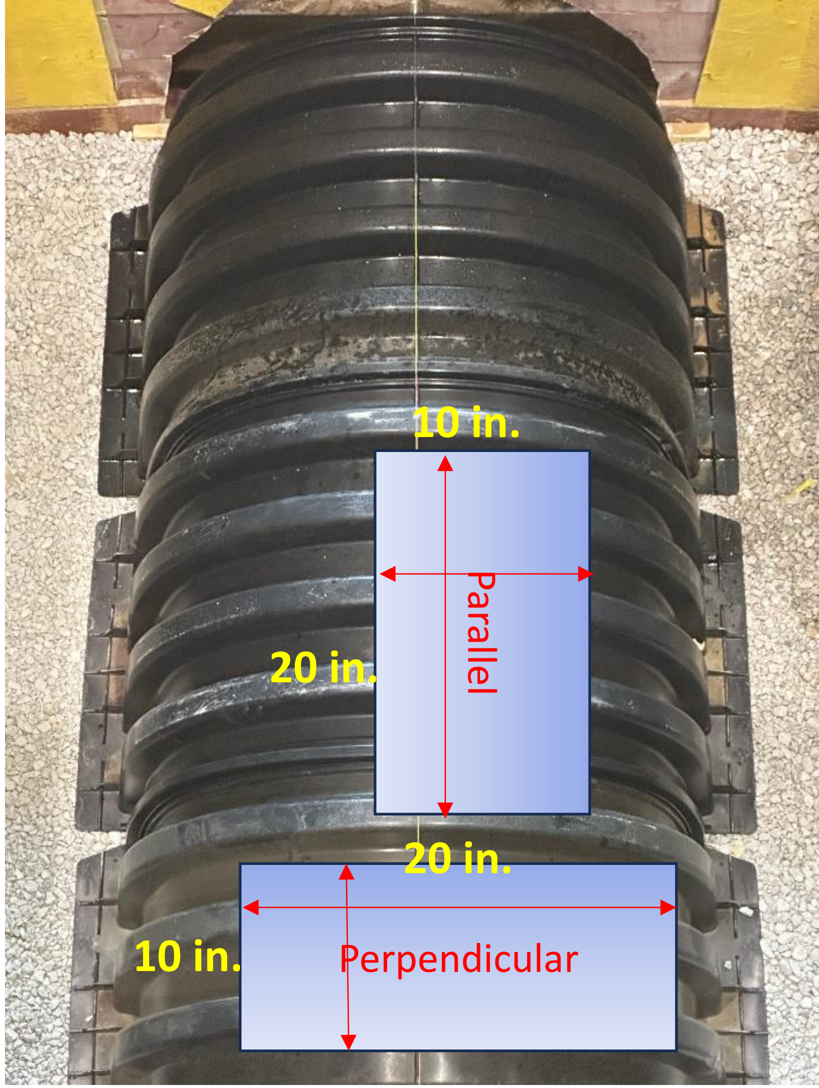




Test Methodology

Loading

- Live load based on AASHTO HL-93/H-20
- 330 kips Actuator
- 20 in. x 10 in. load plate
- Simulated static & dynamic loads
- Simulated design truck traveling perpendicular and parallel
- Static load: minimum 1 minute



Test Methodology

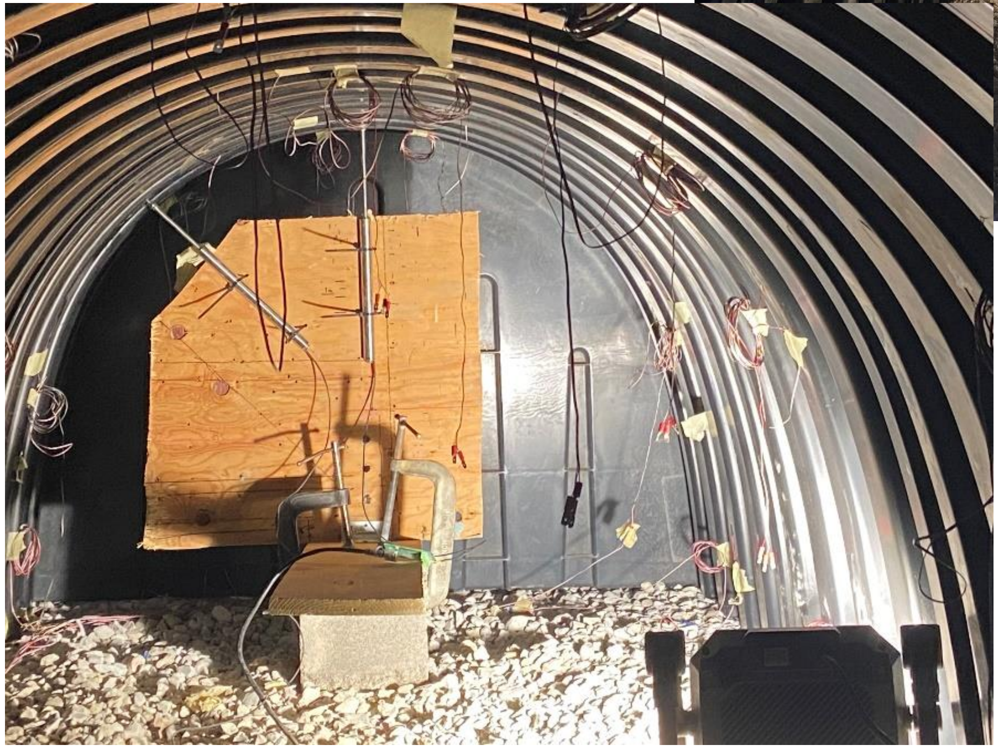
Instrumentation

- Strain Gauges: 7 on inner side; record strain at critical points
- Earth Pressure Cells: 3 at crown; measure pressure load

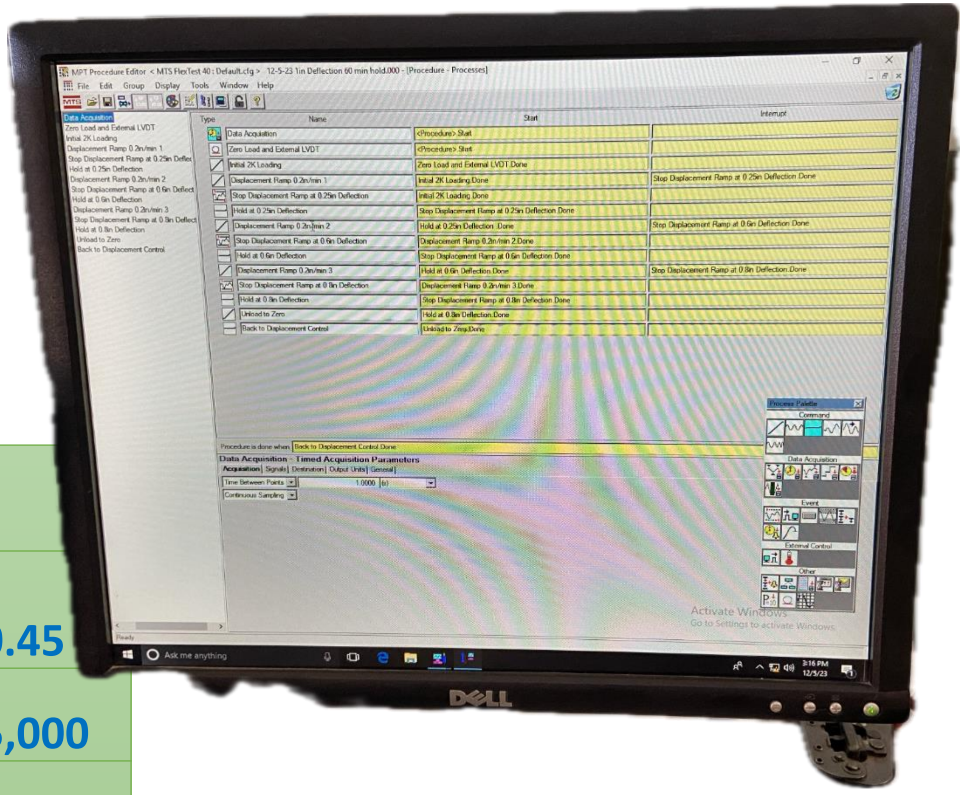
Test Methodology

Linear Variable Differential Transformer (LVDT)

- First LVDT: measures vertical deflection
- Second LVDT: measures deflection of shoulder

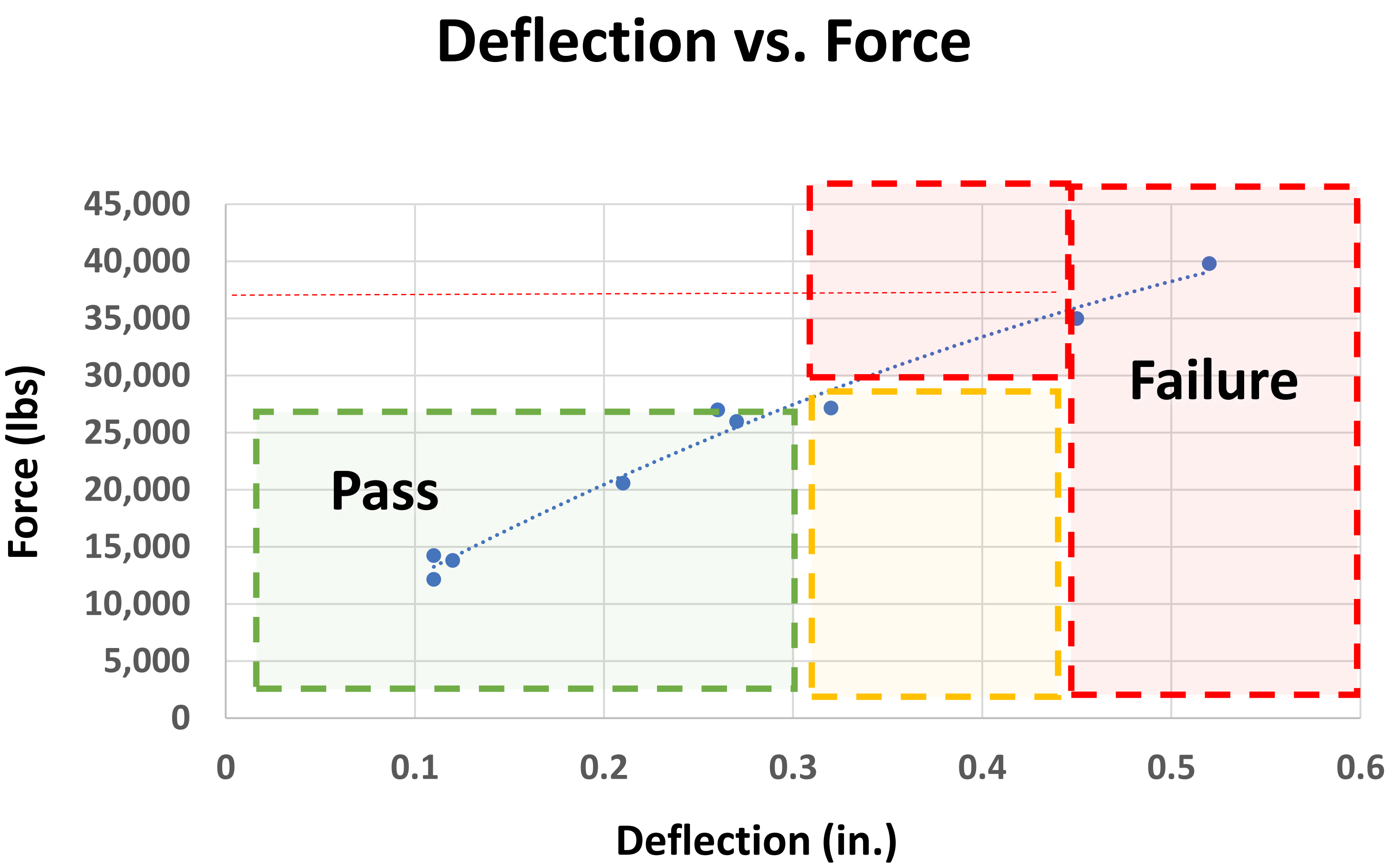


Test Results



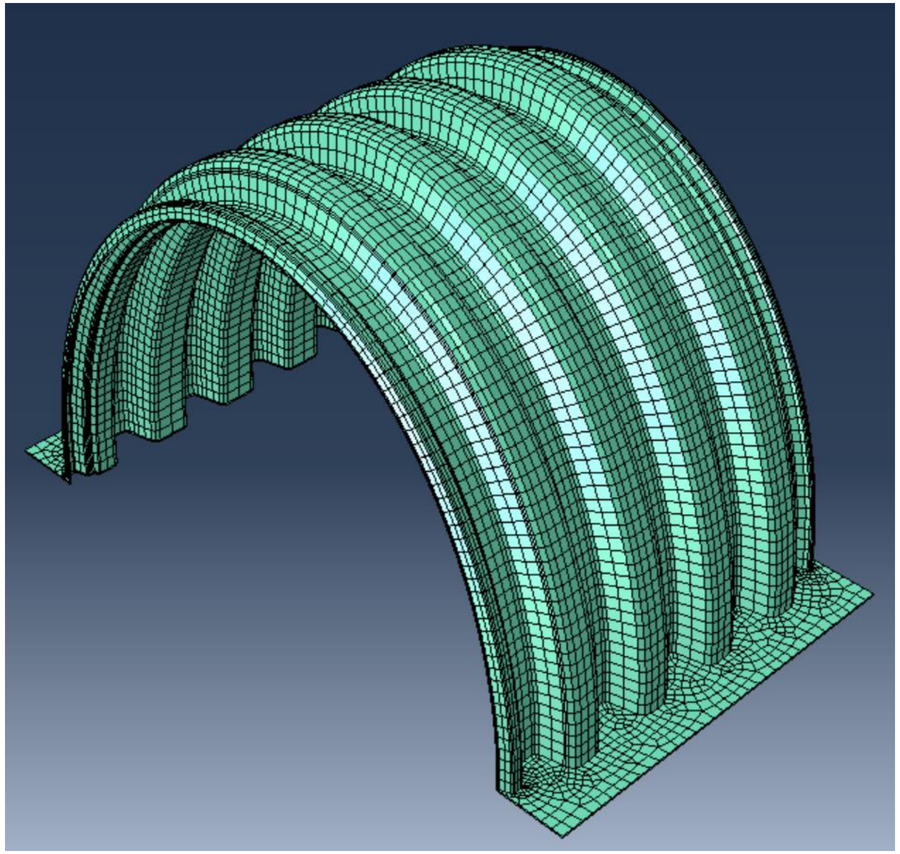
	Chamber ID	Orientation		1-minute Data		
Test 1	South	Perp	Deflection (in.)	0.12	0.27	0.45
			Force (lb)	13,815	26,000	35,000
Test 3	Mid	Paral	Deflection (in.)	0.11	0.26	0.52
			Force (lb)	14,240	27,000	39,800
Test 4	North	Perp	Deflection (in.)	0.11	0.21	0.32
			Force (lb)	12,175	20,585	27,164

Test Results



Finite Element Analysis (FEA)

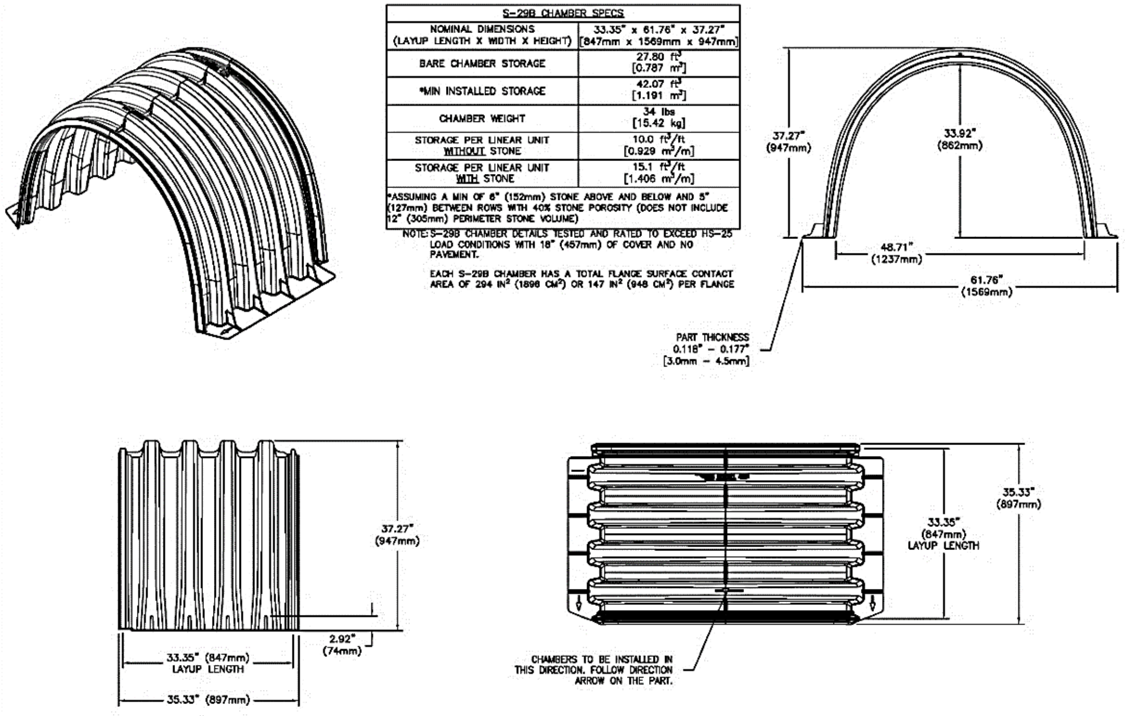
Simulated structural behavior using FEM in ABAQUS



FEA (Geometry)

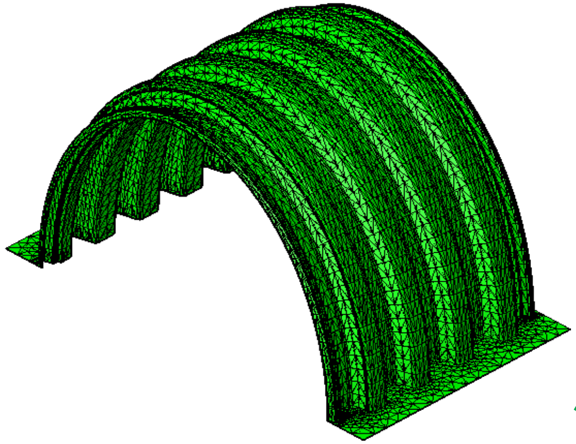
Generated 3D geometry in ABAQUS

- Chamber Dimensions: 61.76” x 37.27” x 33.35”
- Load pad size: 10” x 20” (parallel orientation)
- Soil Box Dimensions: 144” x67.27” x33.35”
- Soil Cover Depth: 24”



S-29B CHAMBER SPECS	
NOMINAL DIMENSIONS (LAYUP LENGTH X WIDTH X HEIGHT)	33.35" x 61.76" x 37.27" [847mm x 1569mm x 947mm]
BARE CHAMBER STORAGE	27.80 ft^3 [0.787 m^3]
*MIN INSTALLED STORAGE	42.07 ft^3 [1.191 m^3]
CHAMBER WEIGHT	34 lbs [15.42 kg]
STORAGE PER LINEAR UNIT WITHOUT STONE	10.0 ft^3/ft [0.929 m^3/m]
STORAGE PER LINEAR UNIT WITH STONE	15.1 ft^3/ft [1.406 m^3/m]

*ASSUMING A MIN OF 6" (152mm) STONE ABOVE AND BELOW AND 5" (127mm) BETWEEN ROWS WITH 40% STONE POROSITY (DOES NOT INCLUDE 12" (305mm) PERIMETER STONE VOLUME)



FEA (Material Properties - Chamber)

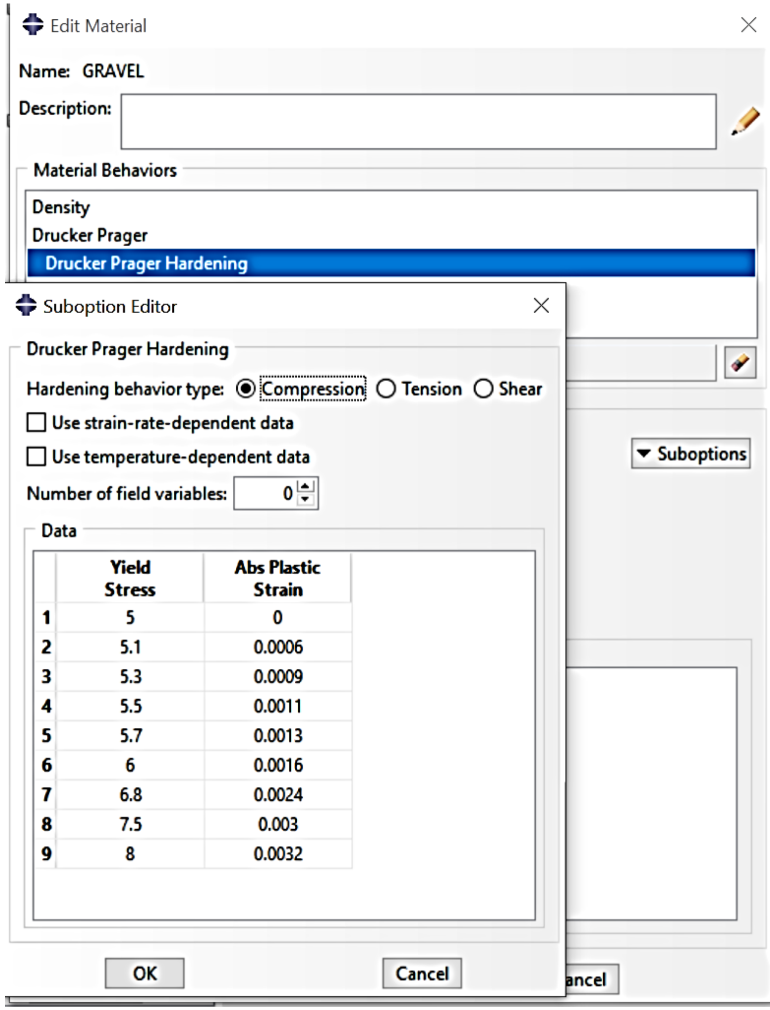
Model S-29B

- Determined by ASTM Standards
- Density: ASTM D792
- Flexural strength & modulus: ASTM D790
- Yield stress and plastic strain: ASTM D638

FEA (Material Properties - Soil)

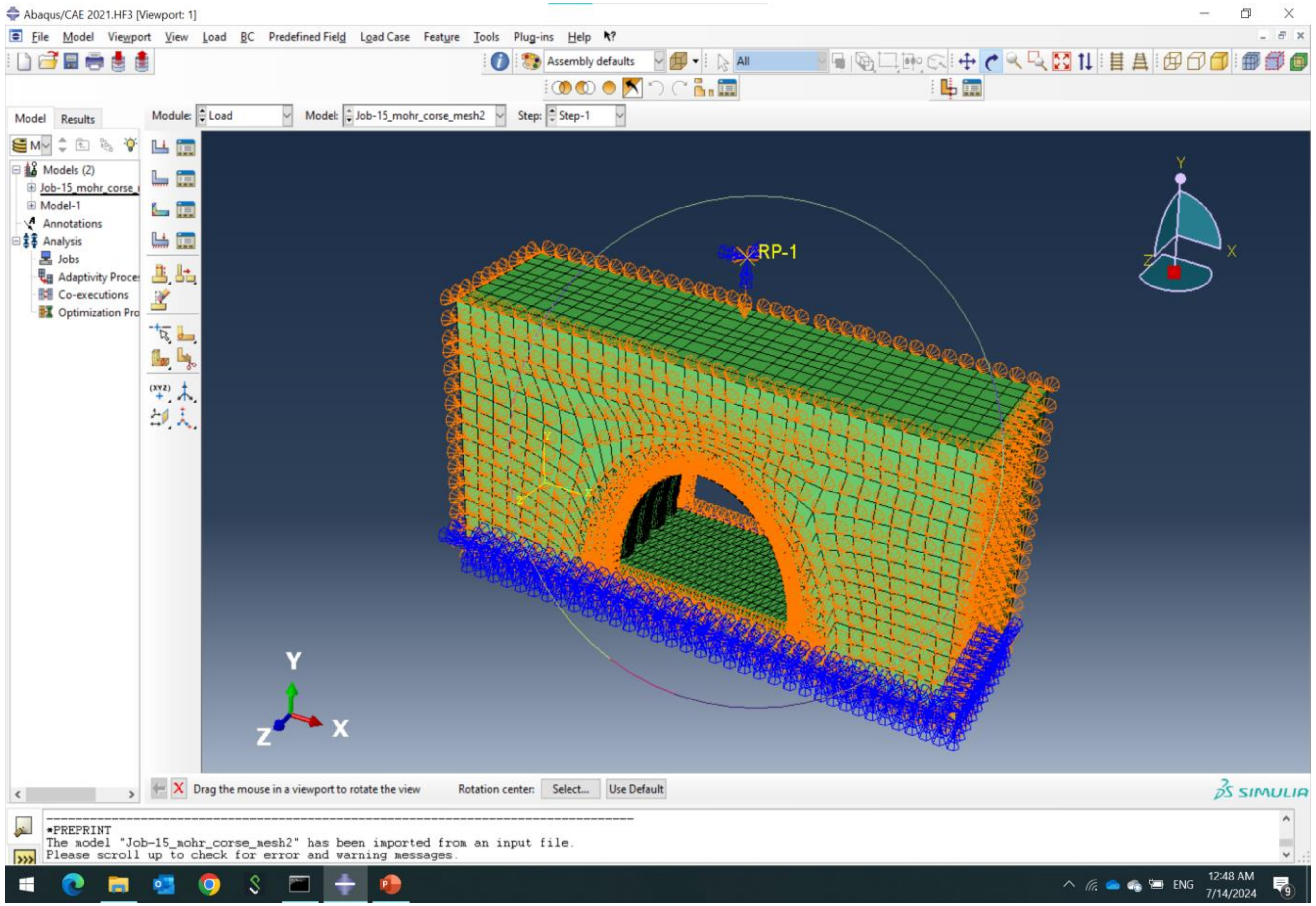
- Type of soil: coarse-grained gravel
- Modeling criteria: Drucker-Prager

Density (pcf) (Max. dry density)	130
Young's Modulus (psi)	1,100
Poisson Ratio	0.28
Angle of Friction (o)	37
Flow Stress Ratio	0.8
Ultimate Yield Stress	8
Plastic Strain	0.0032



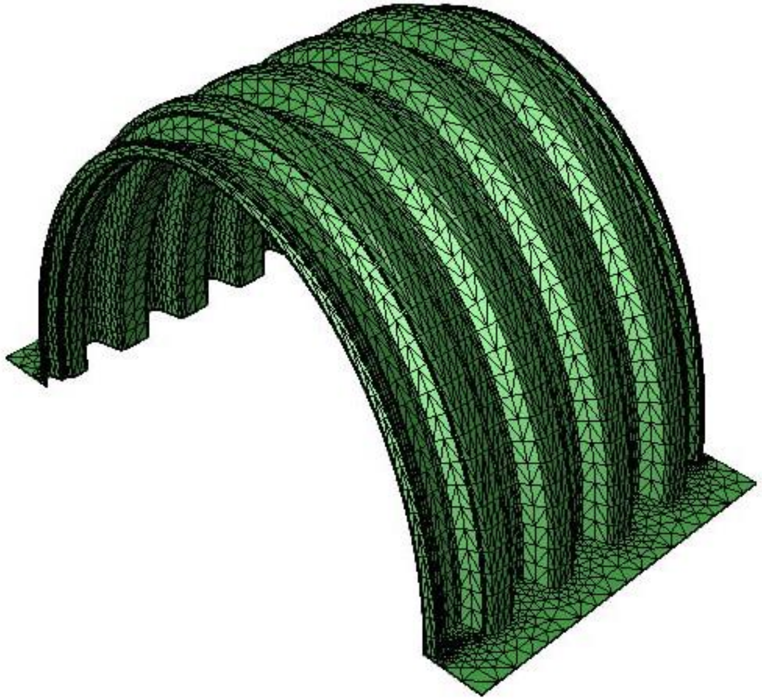
FEA (Loading, Boundary Condition and Interaction)

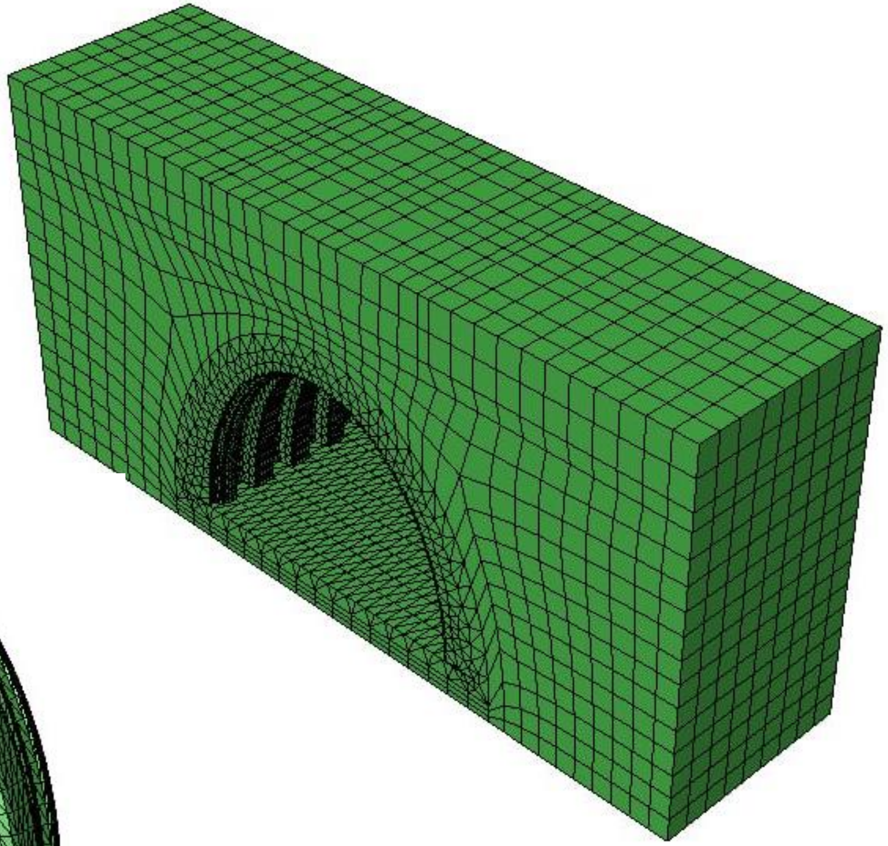
- Soil-Chamber Interaction: surface-to-surface contact; rough friction coefficient (1.0)
- Loading: displacement-controlled at 0.2“/min
- Boundary Conditions: restricted horizontal movement in X & Z directions



FEA (Meshing)

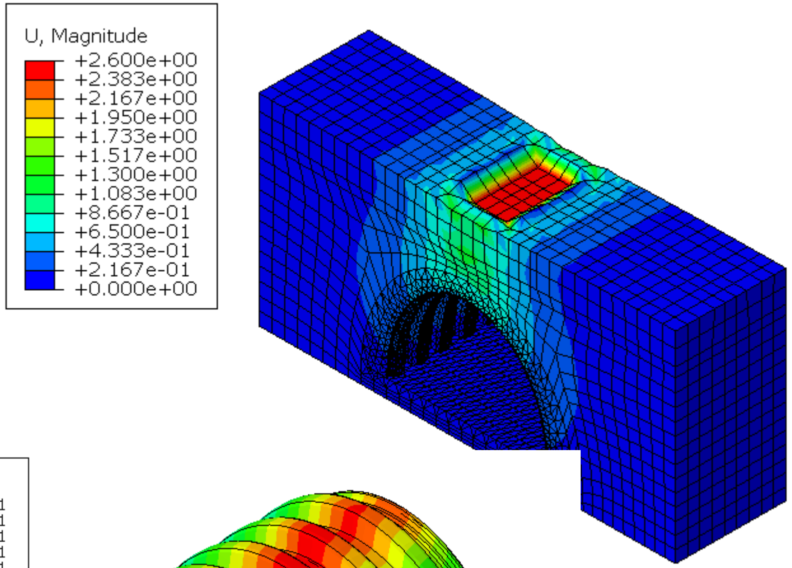
- Soil modeled using solid element type with 8 linear nodes (C3D8R)
- Chamber modeled using solid element type with 4 linear nodes (C3D4)

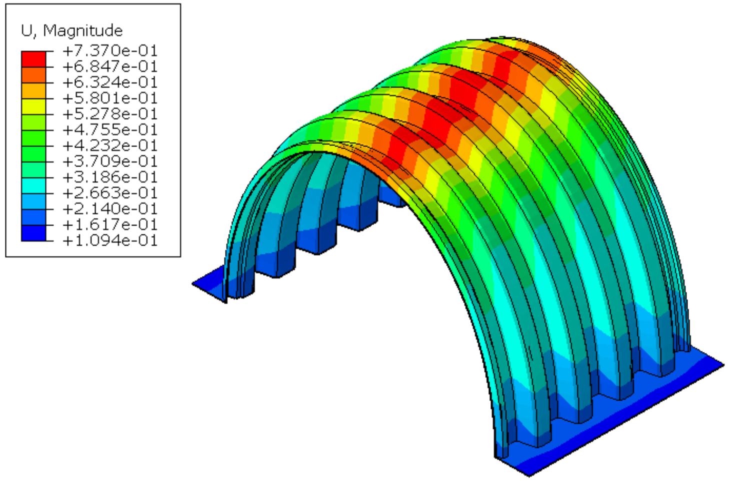




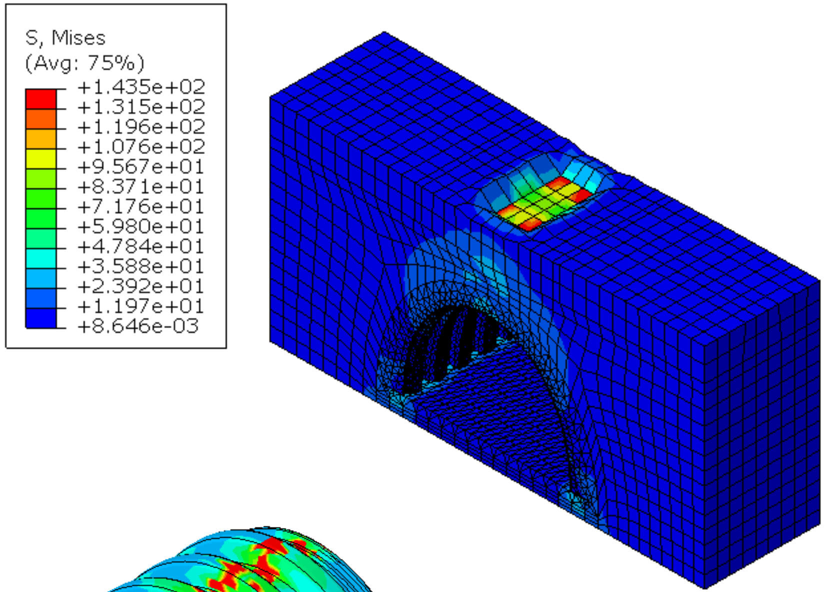
FEA (Analysis)

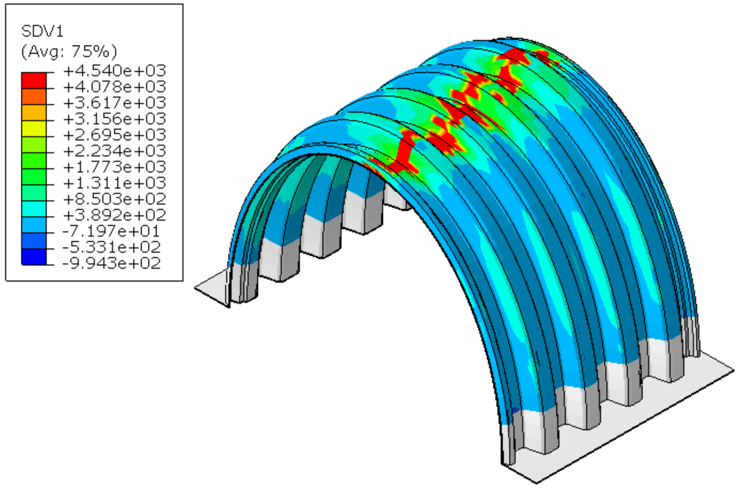
Displacement magnitude





Von Mises stress distribution

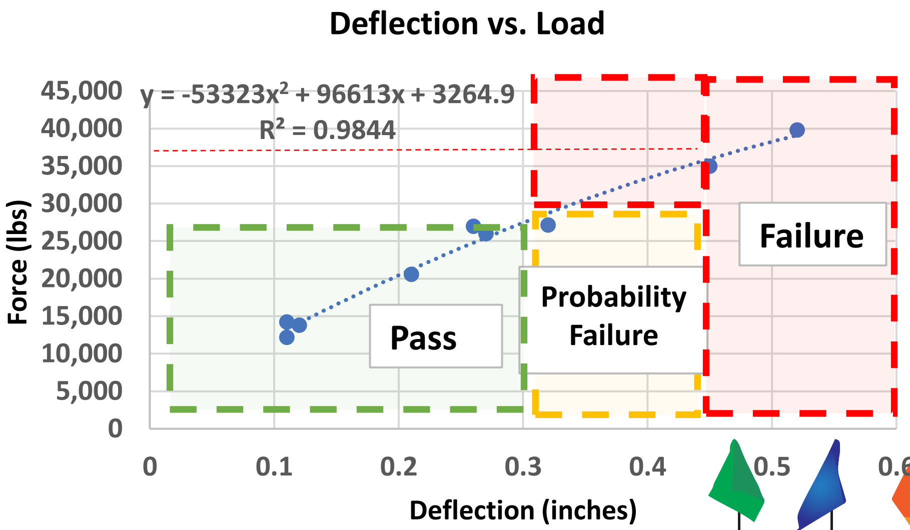




Experimental Results

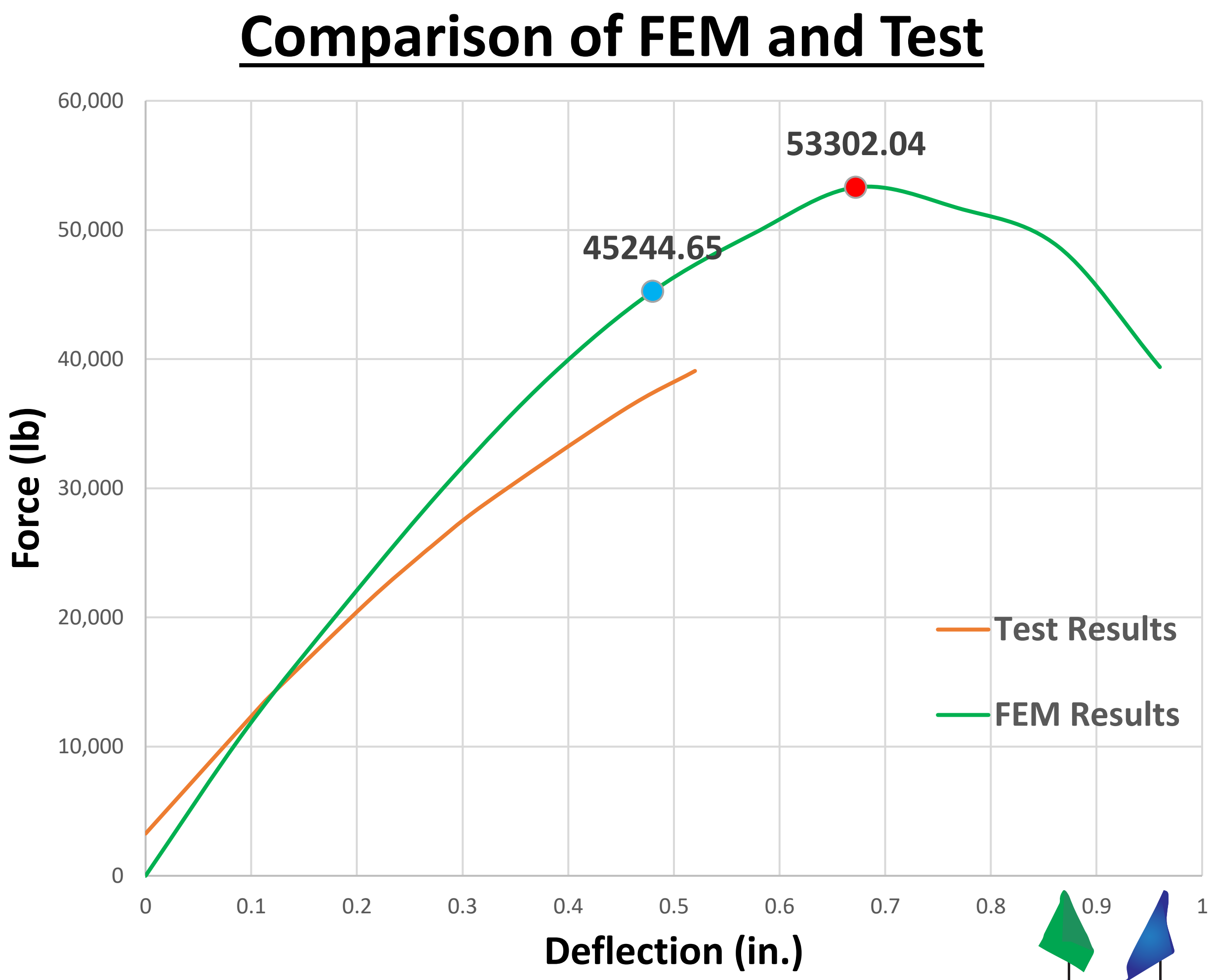
Normalized Data Using Polynomial Regression	
$y = -53323x^2 + 96613x + 3264.9$	
Deflection (in.)	**Force (lb)**
0	3,265
0.12	14,091
0.27	25,463
0.45	35,943
0.11	13,247
0.26	24,780
0.52	39,085
0.11	13,247
0.21	21,202
0.32	28,721

Summary Tests		
Test ID	Deflection	Force
	In.	lb
Test 1	0.12	13,815
	0.27	26,000
	0.45	35,000
Test 3	0.11	14,240
	0.26	27,000
	0.52	39,800
Test 4	0.11	12,175
	0.21	20,585
	0.32	27,164



FEM Results and Verification

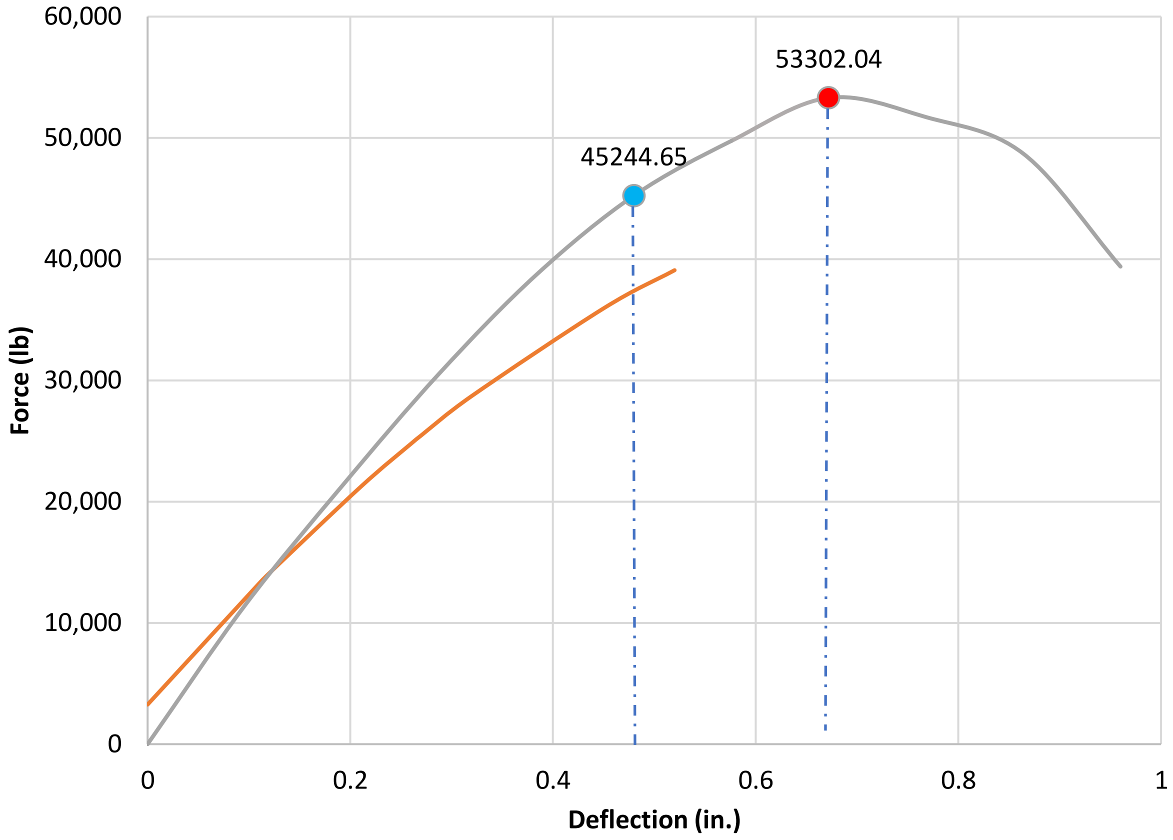
Deflection (in.)	Force (lb)		Difference
	Test	FEM	
0.11	13,247	12,875	3%
0.12	14,091	13,903	1%
0.21	21,202	23,044	-8%
0.26	24,780	27,878	-12%
0.27	25,463	28,845	-13%
0.32	28,721	33,304	-15%
0.45	35,943	43,212	-19%
0.52	39,085	47,120	-20%



FEM Results

	Deflection (in.)	Force (lb)	Pressure of Crown (psi)
Nonlinear	0.48	45244.65	30.24
Failure	0.67	53302.04	35.63

Force vs deflection



Conclusions

- Characterized structural performance: max pressure at crown, max vertical deflection, allowable service load,
- FEM analysis matched with experimental tests
- ASTM F2787 standard was validated using both FEA and the experimental test for the Chamber

Recommendations

- Conduct additional tests at other cover depths
- Improve and develop FEM analysis in different parameters

Research Contributors

- Dr. Mo Najafi, P.E., F. ASCE., BC.PLW, Professor of Civil Engineering
- Blaine Weller, Director, Engineering Technology, Xerxes
- Jordan Ornquist, Team Lead, Sr. Stormwater Engineer, Xerxes

Thank You!

Questions?

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