PT Slab-on-Ground
Technical Session 5

Optimizing Shallow Slab-on-Grade Foundation Designs: Efficient Stiffness vs. Excessive Mass

Speaker: Anna Olveda

and Florian Aalami

8:30am – 9:20am

Evaluating Performance of Ribbed vs Void Formed Shallow Foundations

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PT-Structures VISICON

WAFFLEMAT™
A SMARTSENSE STRUCTURAL SYSTEM

pti POST-TENSIONING CONVENTION
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Learning Objectives

At the end of this presentation, you will be able to…

- Assess the geometry of the foundation for efficiency
- Evaluate the effects of different tendon layouts
- Understand the effects of stiffness relative to the concrete neutral axis and tendon placement
- Holistic view of construction practices relative to the overall value of the design

Fundamental Drivers of SOG Performance

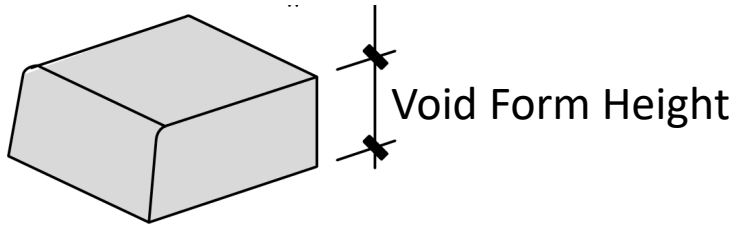
Independent from applied code, calculation method or soil conditions, the performance of two alternative designs can be evaluated using these factors:

- Bending Stiffness is the #1 determinant of performance
- Precompression provided by PT delays cracking and ensures inherent stiffness can be fully utilized
- Profiled PT can offset applied moments

Parametric Study of Different Geometries

Keeping the moment of inertia stiffness constant, we compare the performance of three different shallow foundation configurations:

- Traditional ribbed slab
- Non collapsable void form foundation
  - 8.5 in
  - 12 in



Sample Project

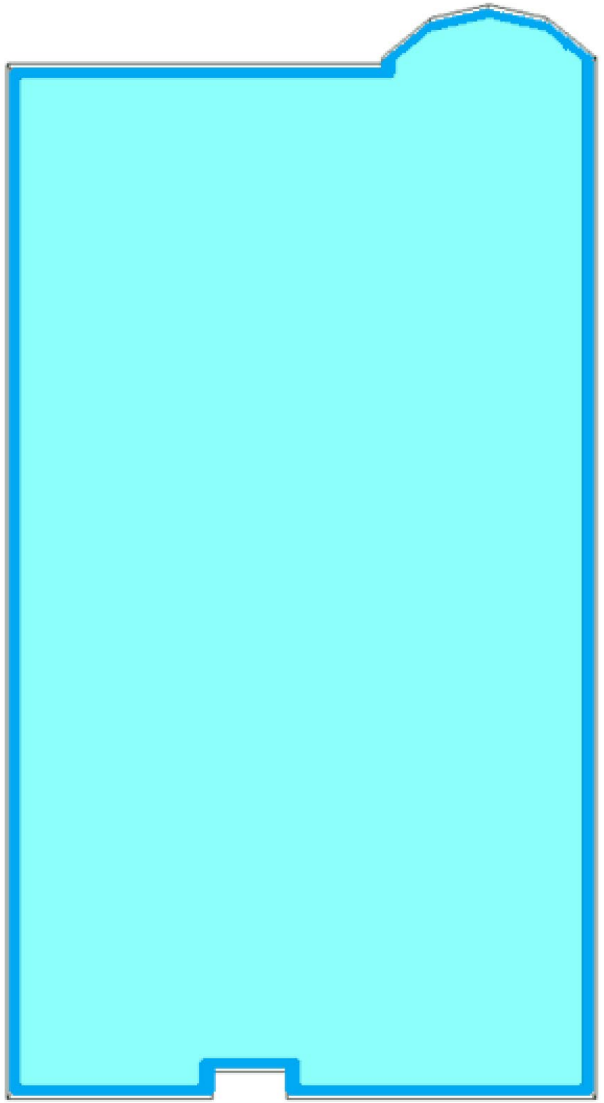
Common 40 ft x 70 ft footprint

PVR (inches)	Center Lift		Edge Lift	
	E_m (feet)	Y_m (in)	E_m (feet)	Y_m (in)
1	8.3	-0.96	4.2	1.33
4	6.1	-2.33	3.5	3.8

Loading:

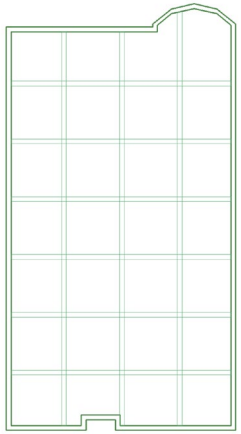
1,200 plf around perimeter

40 psf interior live load



Calibrated Models to Have Same Stiffness

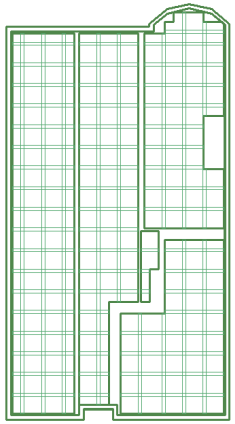
Maintaining minimum stiffness in long direction was governing factor



Traditional –
Plan View

I_{short} = 161,491 in^4

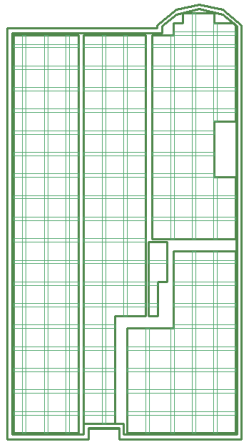
I_{short} = 245,897 in^4



8.5” Void Form –
Plan View

I_{short} = 219,103 in^4

I_{short} = 250,366 in^4



12” Void Form –
Plan View

I_{short} = 204,444 in^4

I_{short} = 250,034 in^4

Traditional Ribbed Foundation

Data

Exterior Beam: 10” x 28”

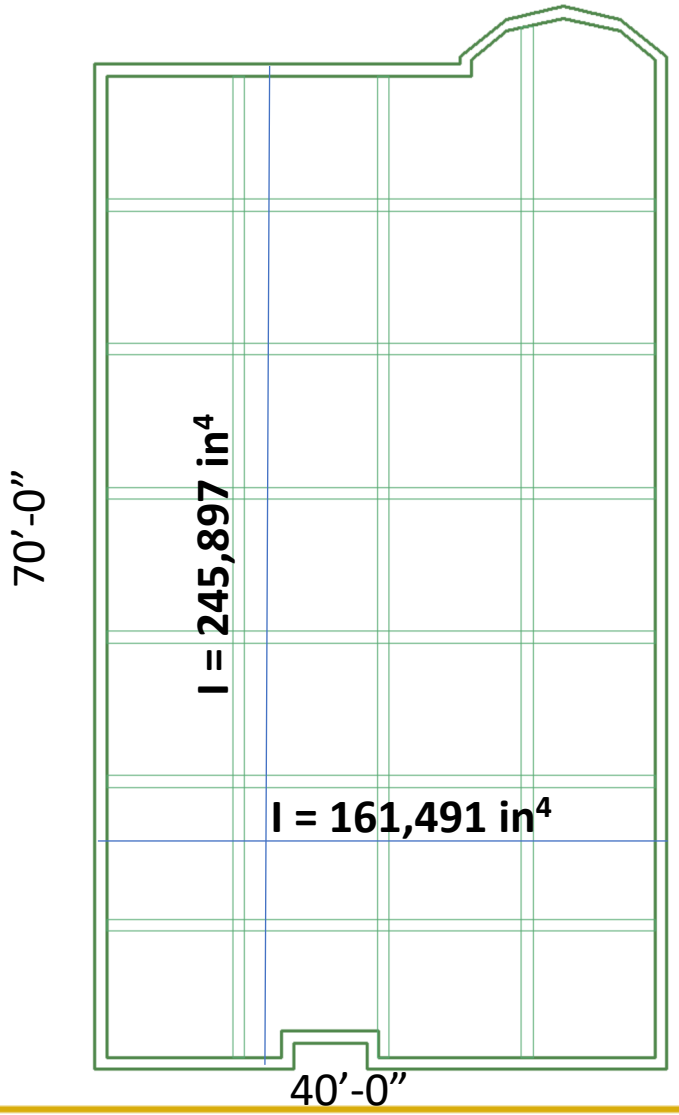
Interior Beam: 10” x 24”

Slab Thickness: 4”

Area: 2,799 ft^2

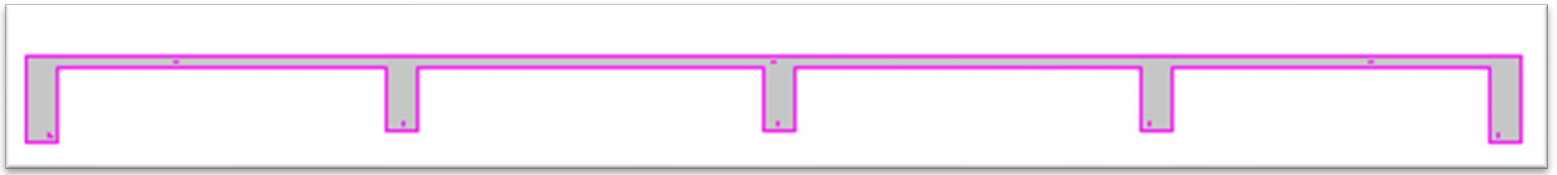
Concrete Volume: 71 cu yds

Concrete Volume with waste factor: 88 cu yds



Traditional Ribbed Foundation

Expectation



Reality

8.5 in Voided Slab

<u>Data</u>

Exterior Beam: 10” x 36”

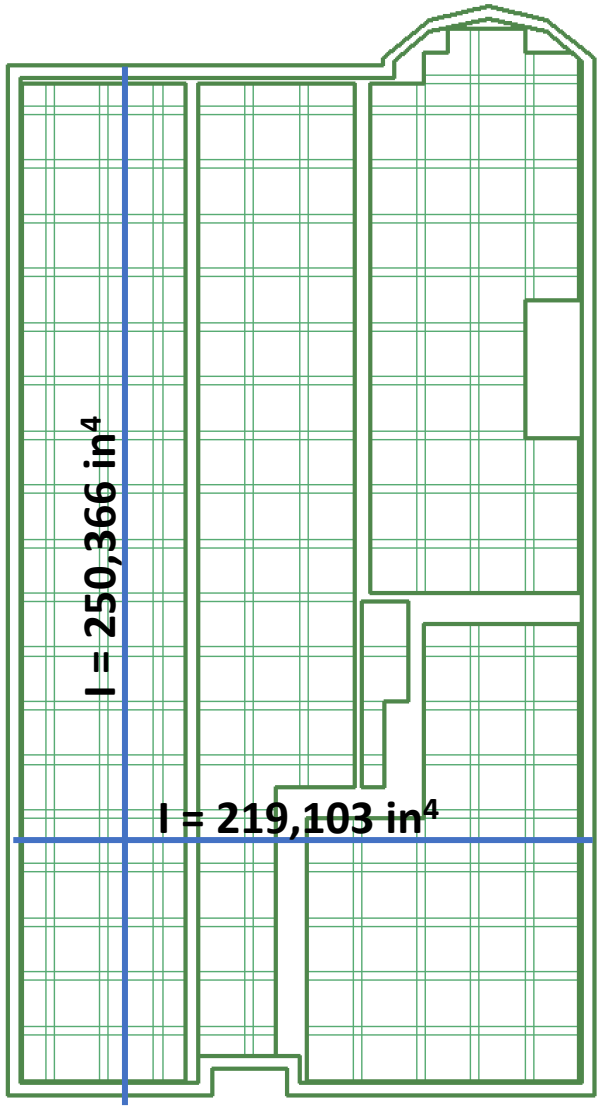
Void Form Boxes = 738 – 8 ½” Boxes

Slab Thickness: 4”

Area: 2,799 ft^2

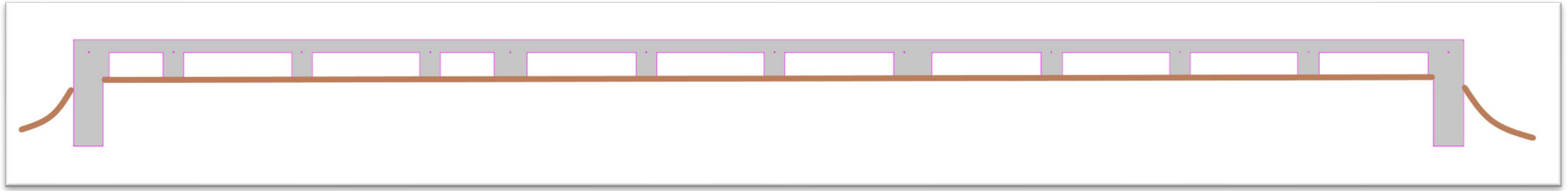
Concrete Volume: 77 cu yds

Concrete Volume with waste factor: 79 cu yds



8.5 in Voided Slab

Expectation



Reality

12 in Voided Slab

<u>Data</u>

Exterior Beam: 10” x 34”

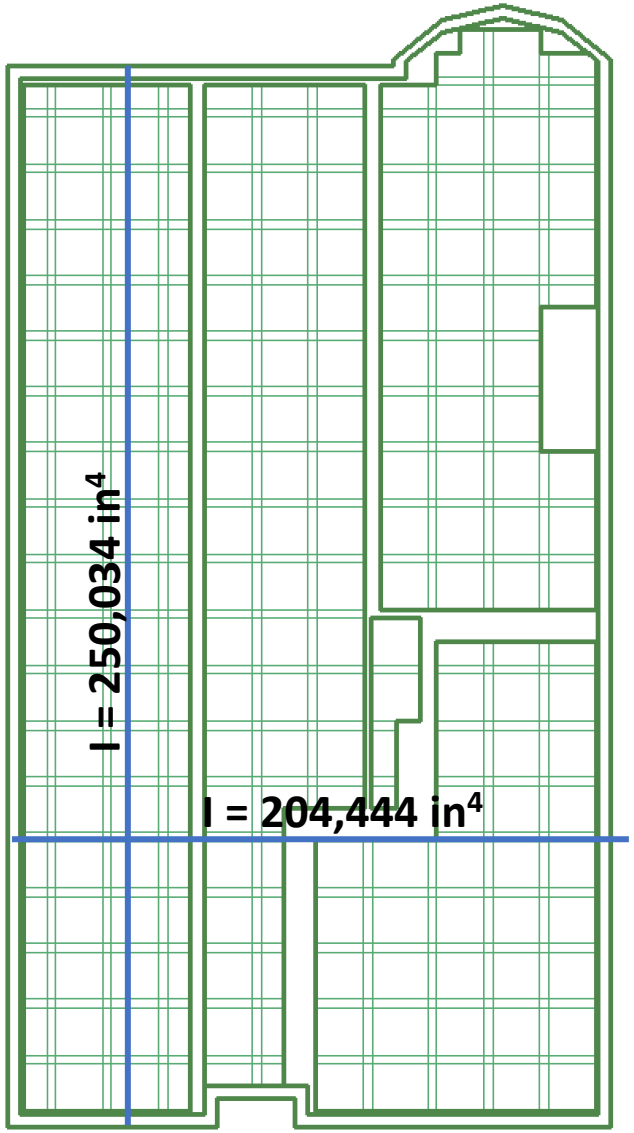
Void Form Boxes = 738 – 12” Boxes

Slab Thickness: 4”

Area: 2,799 ft^2

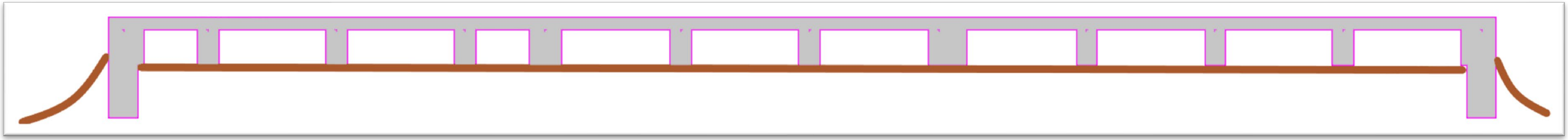
Concrete Volume: 85.5 cu yds

Concrete Volume with waste factor: 87.5 cu yds



12 in Voided Slab

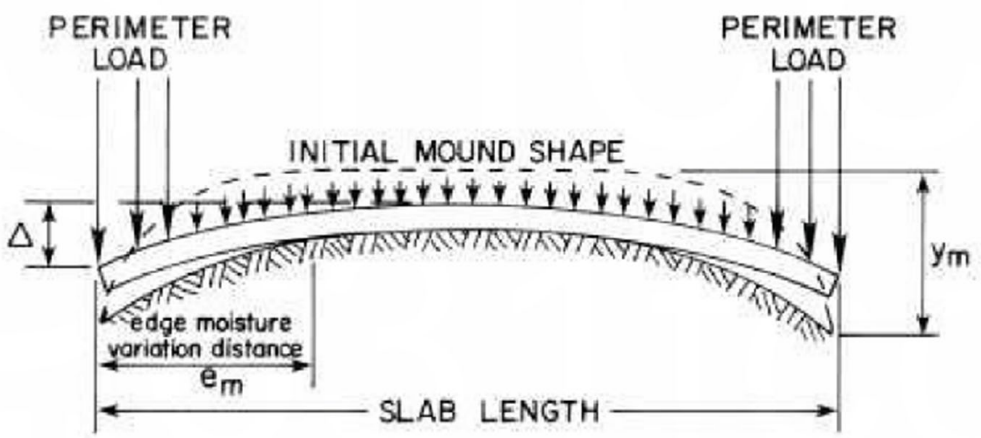
Expectation



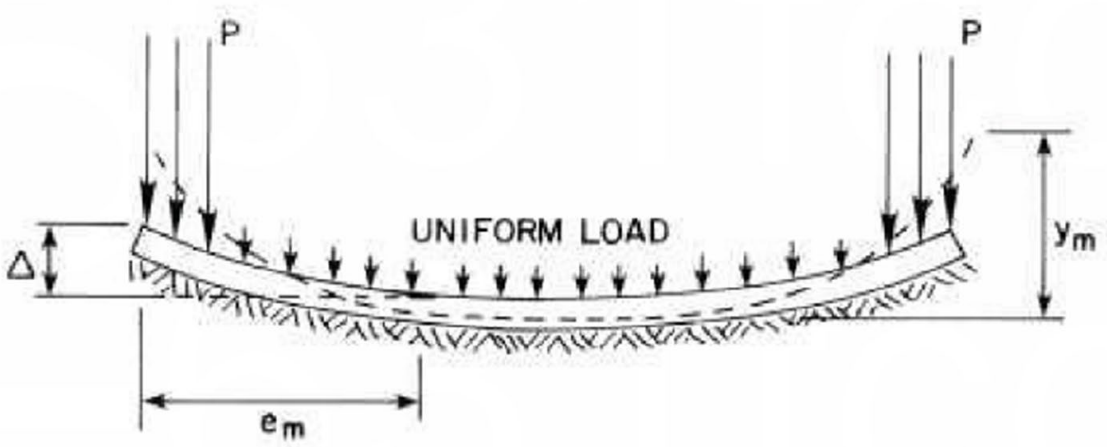
Reality

Evaluation of Deflection Performance

Using Finite Element Analysis, subject all 3 slabs to exact same soil loading conditions:

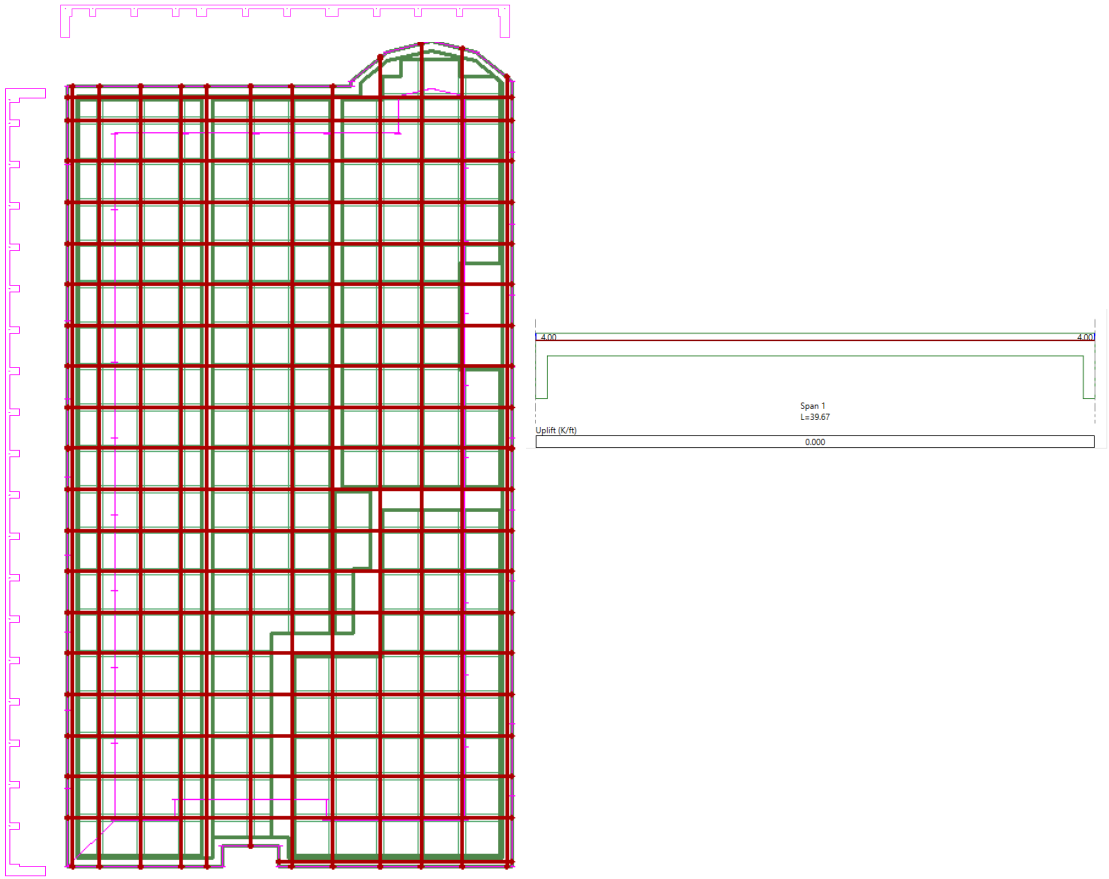


Edge Drop

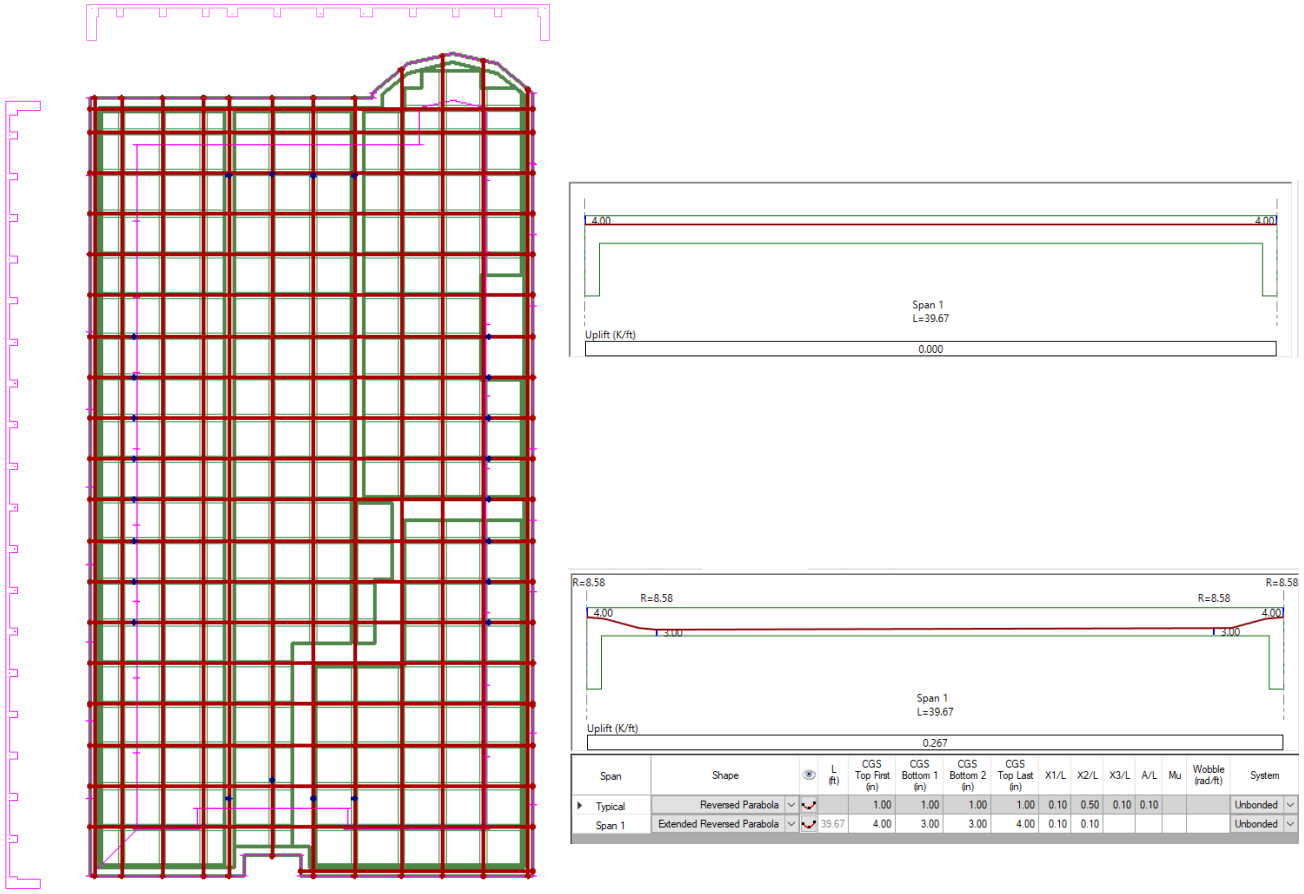


Edge Lift

Tendon Location & Placement



Tendon Layout 1

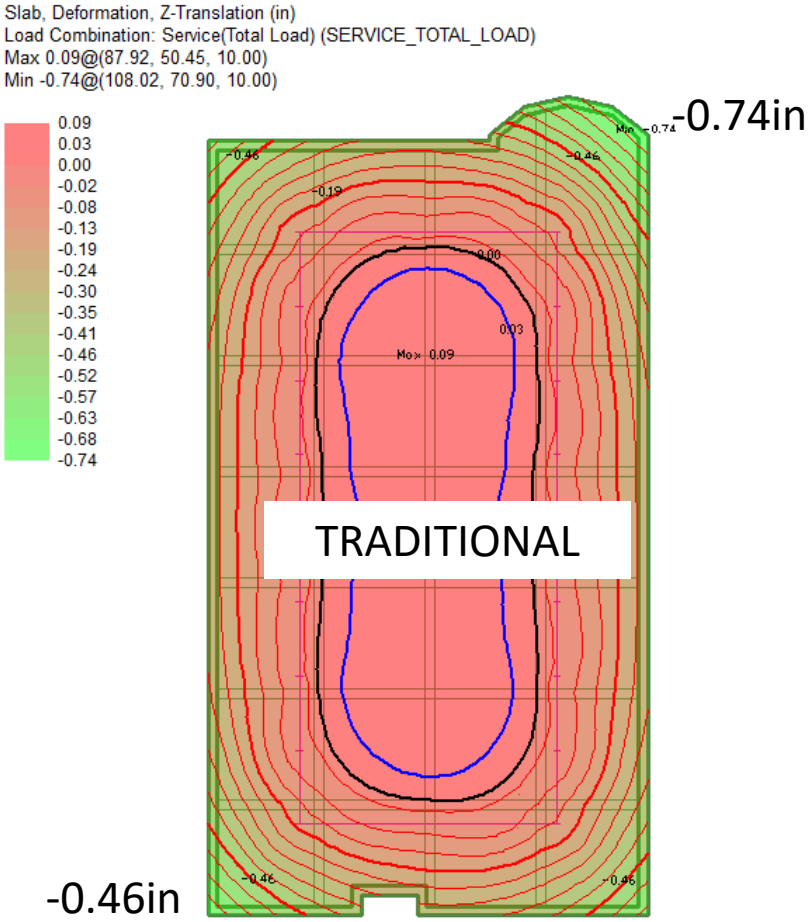


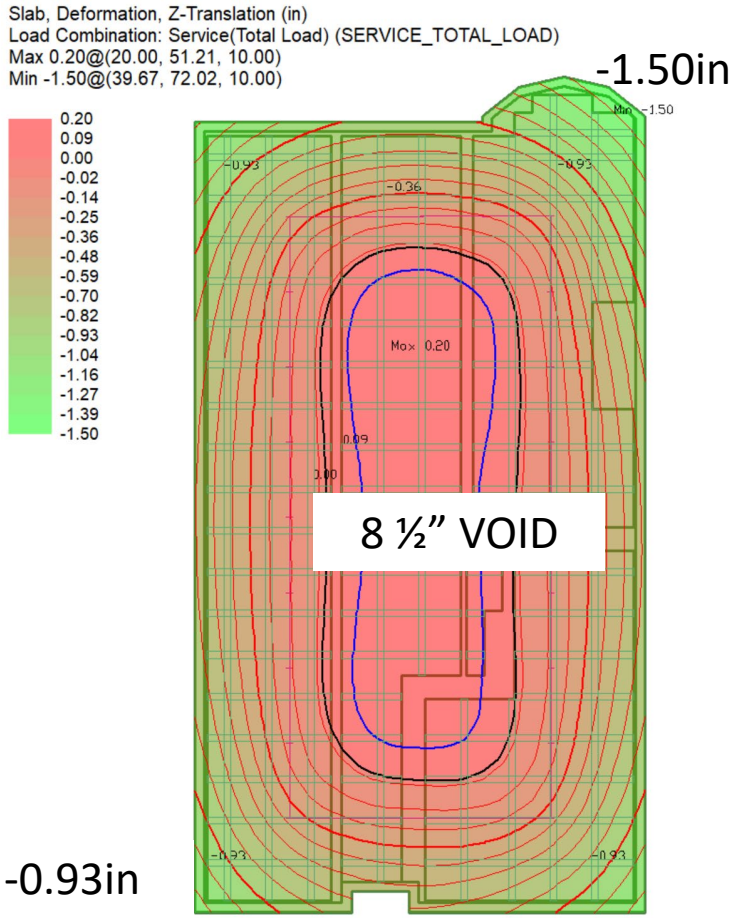
Span	Shape	L (ft)	CGS Top First (in)	CGS Bottom 1 (in)	CGS Bottom 2 (in)	CGS Top Last (in)	X1/L	X2/L	X3/L	A/L	Mu	Wobble (rad/ft)	System
Typical	Reversed Parabola		1.00	1.00	1.00	1.00	0.10	0.50	0.10	0.10			Unbonded
Span 1	Extended Reversed Parabola	39.67	4.00	3.00	3.00	4.00	0.10	0.10					Unbonded

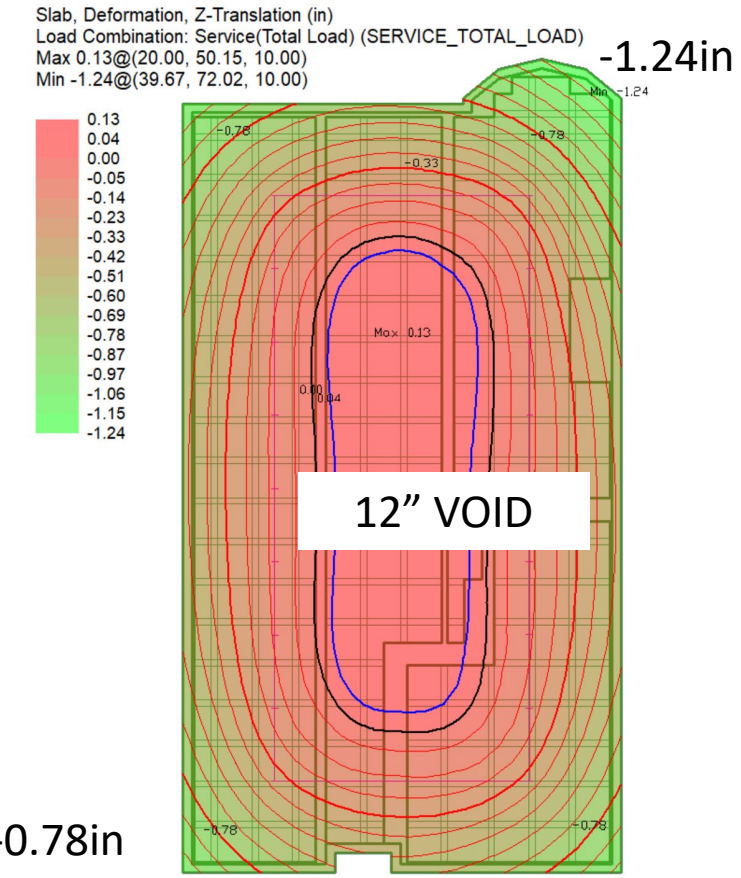
Tendon Layout 2

Void Forms Tendon Layout 1

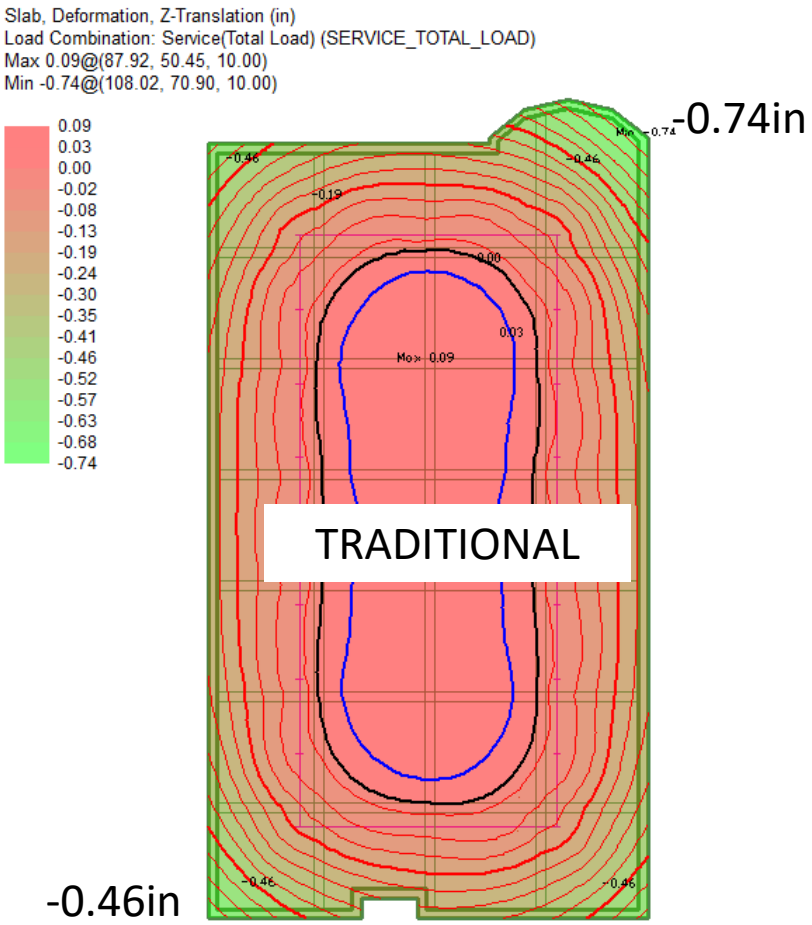
Edge Drop – 1 in – Theoretical Analysis

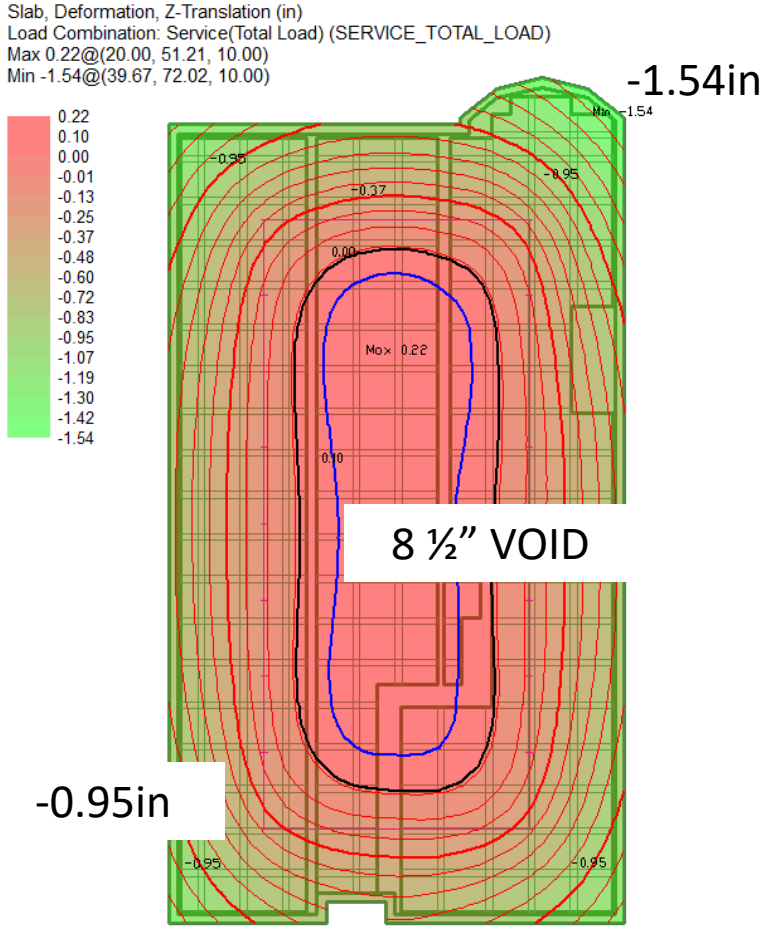


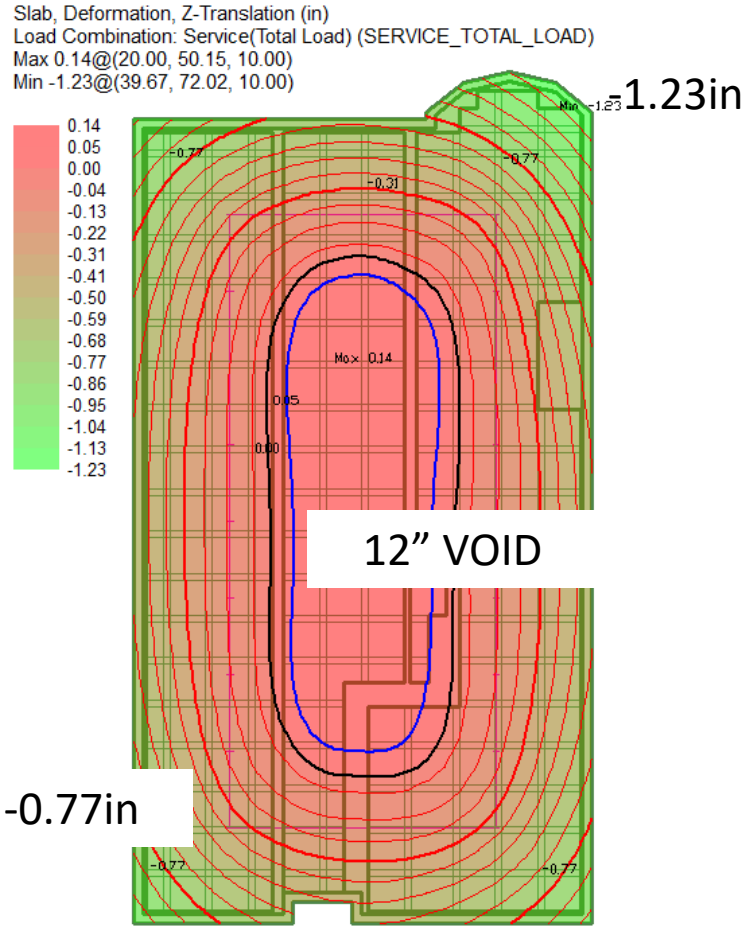




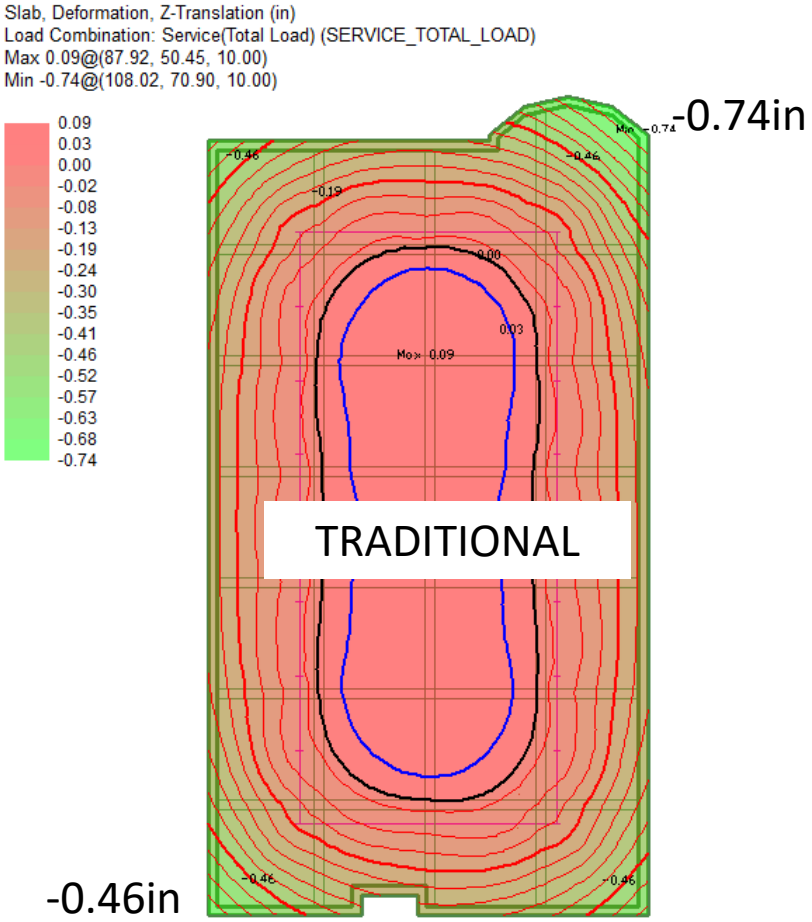
Edge Drop – 1 in – Theoretical Analysis

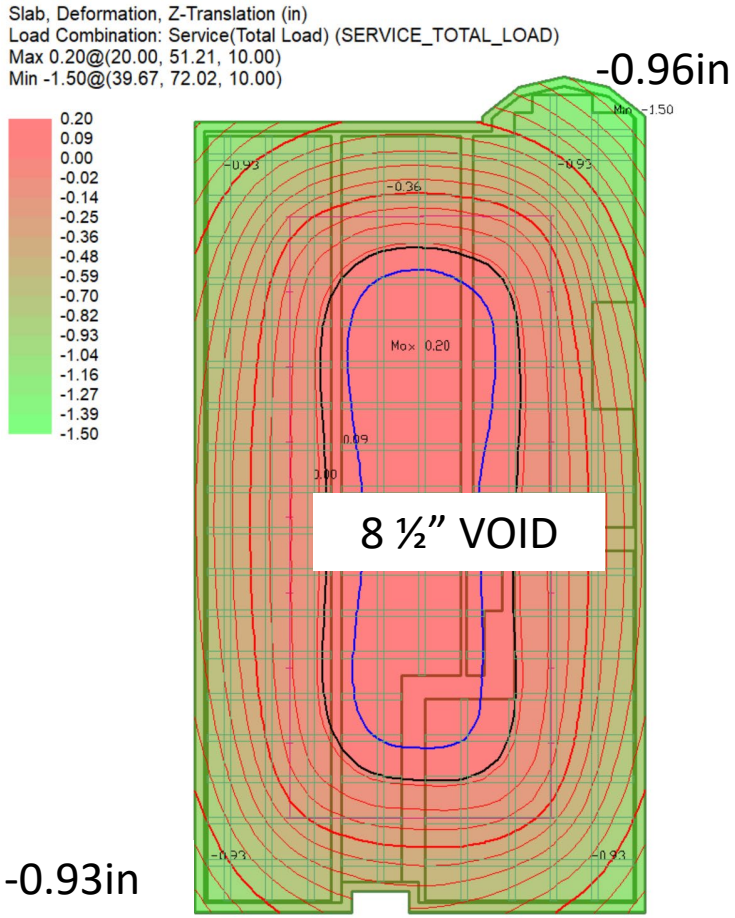


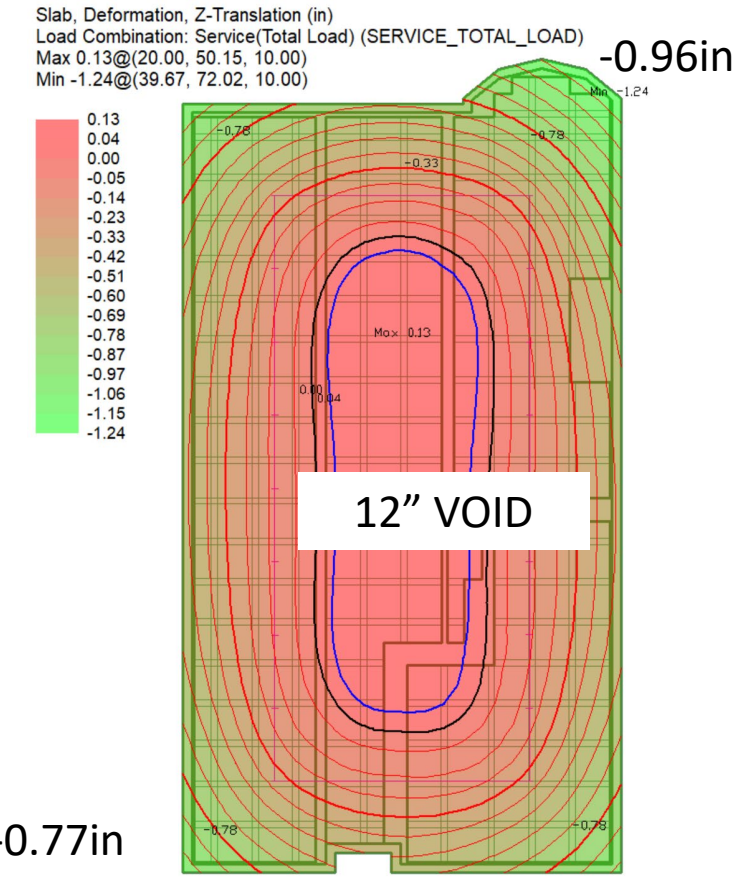




Edge Drop – 1 in – ym Bounded to 0.96in

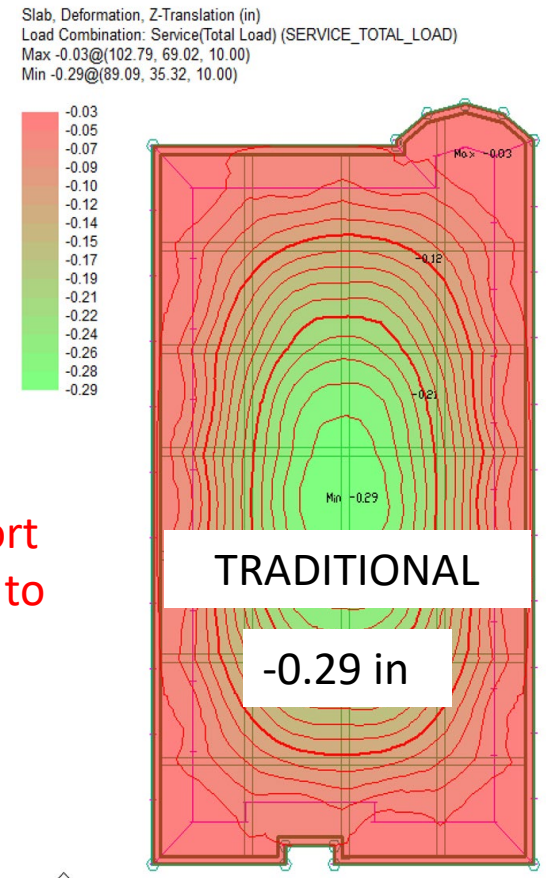






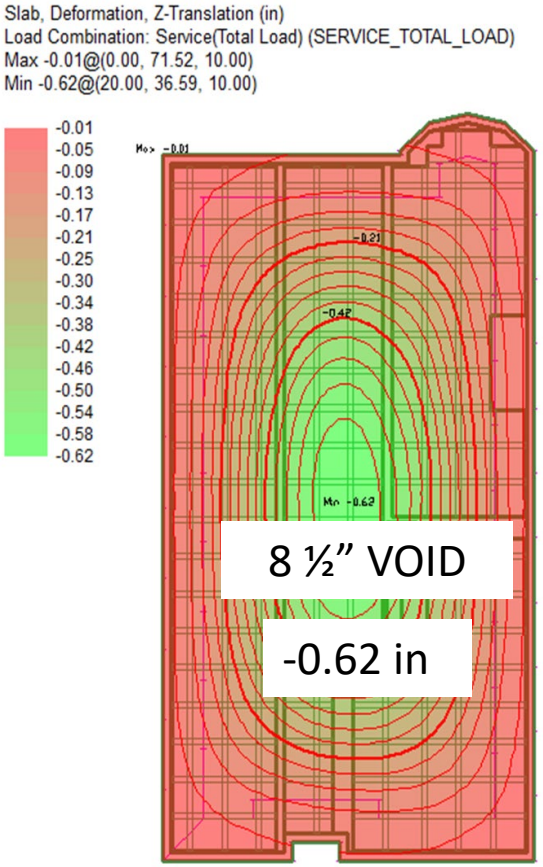
Void Forms Tendon Layout 1

Edge Lift – 1 in



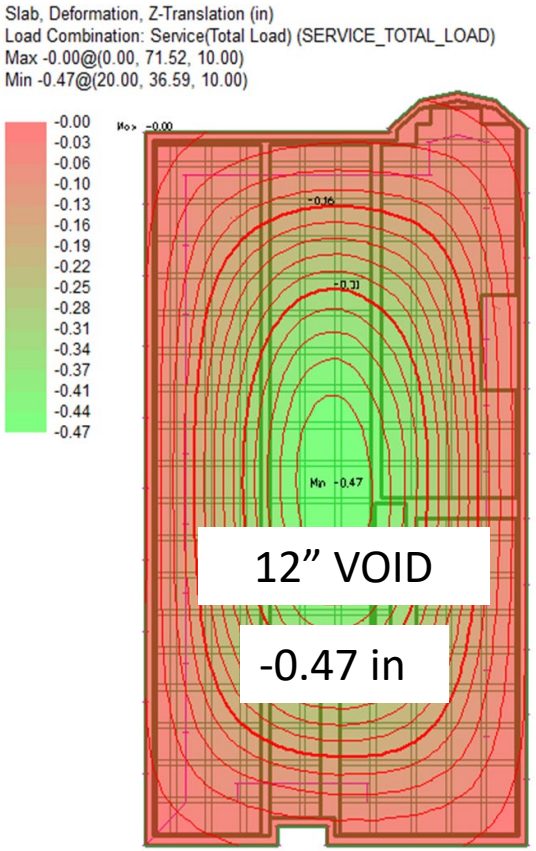
TRADITIONAL

-0.29 in



8 ½” VOID

-0.62 in



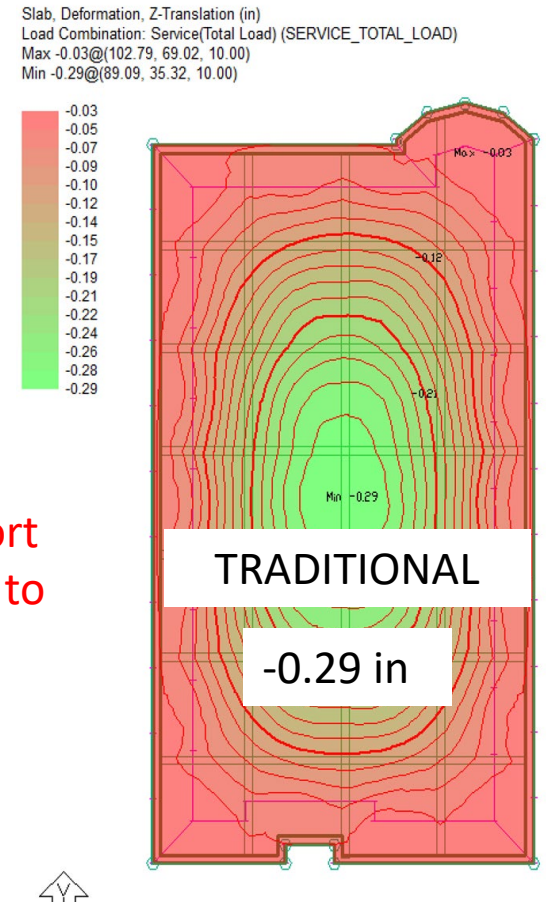
12” VOID

-0.47 in

Soils report limits ym to 1.33in

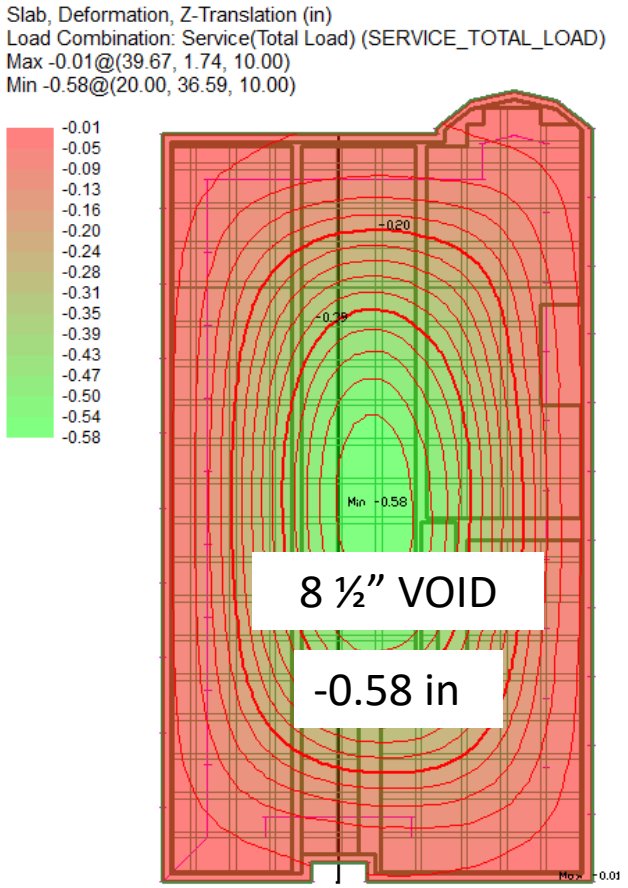
Void Forms Tendon Layout 2

Edge Lift – 1 in



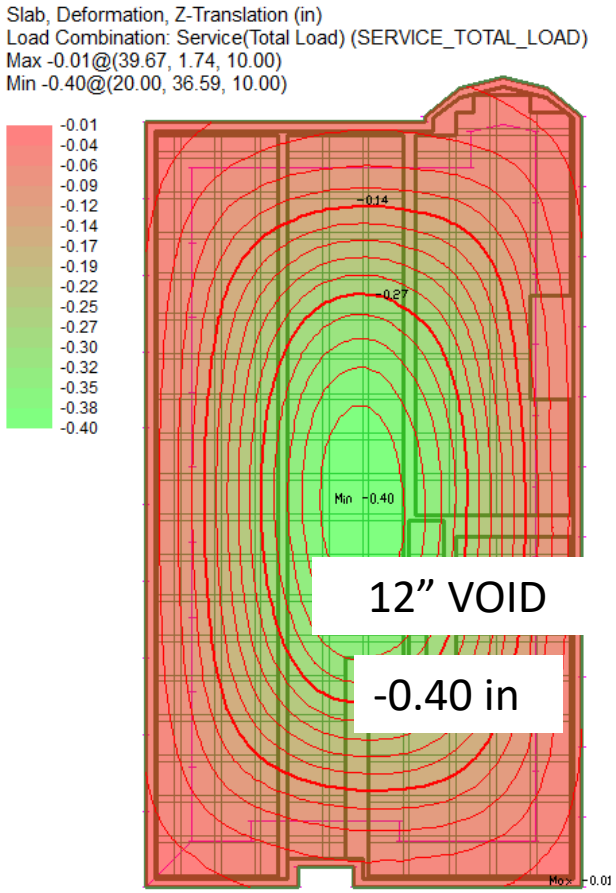
TRADITIONAL

-0.29 in



8 ½” VOID

-0.58 in



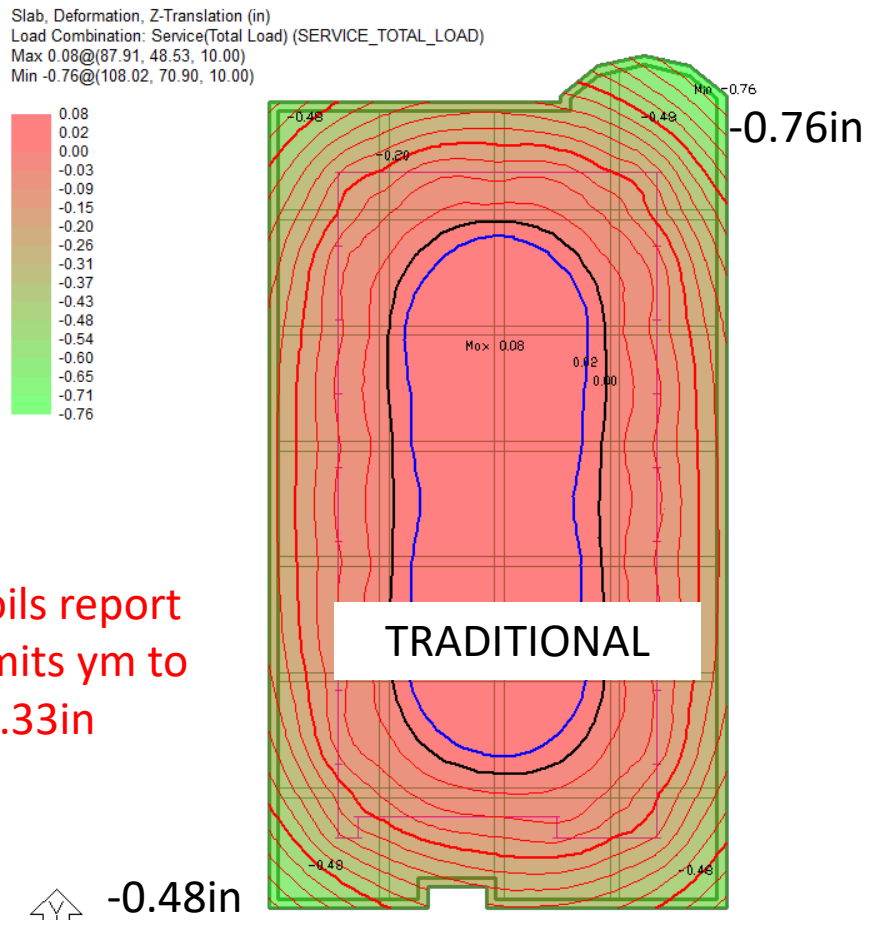
12” VOID

-0.40 in

Soils report limits ym to 1.33in

Void Forms Tendon Layout 1

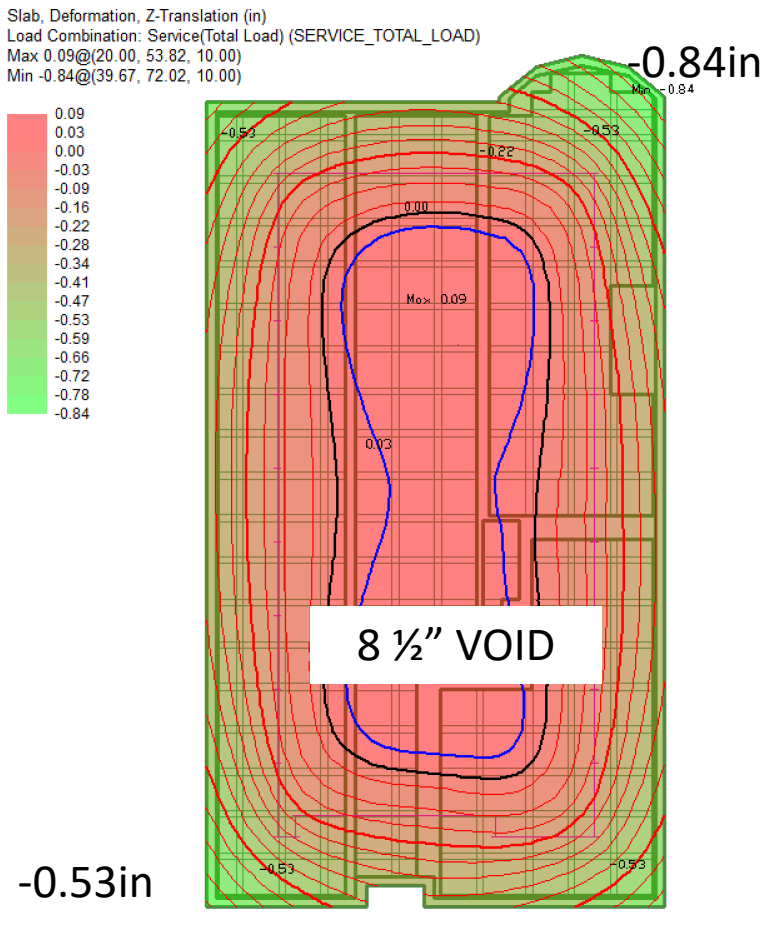
Edge Drop – 4 in



-0.76in

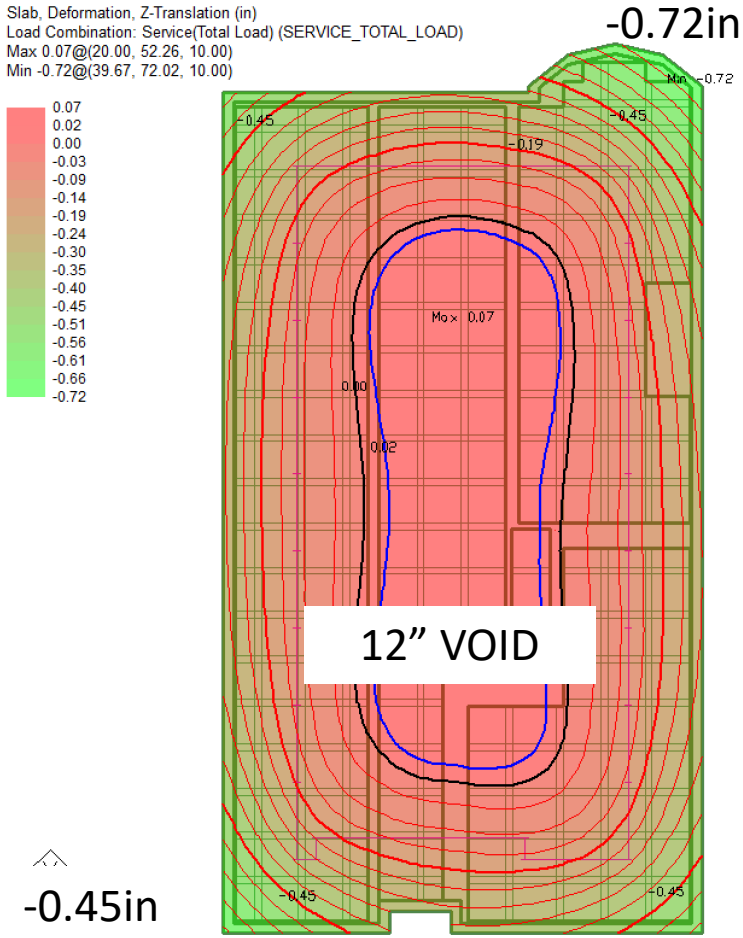
Soils report limits ym to -2.33in

-0.48in



-0.84in

-0.53in

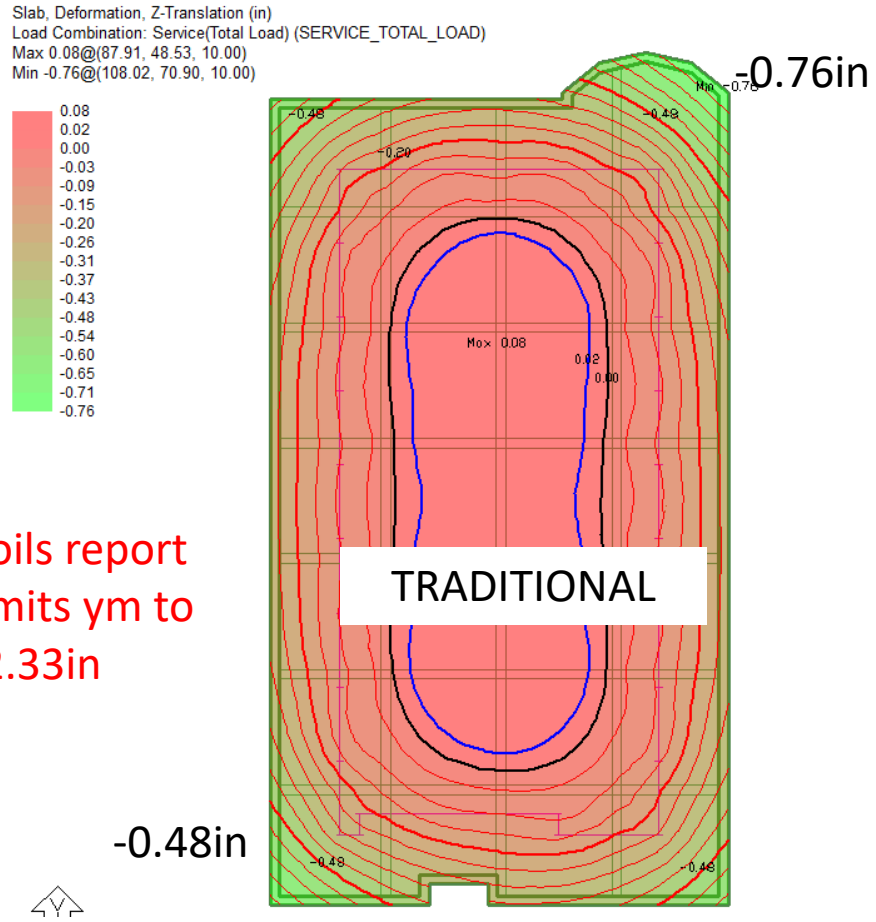


-0.72in

-0.45in

Void Forms Tendon Layout 2

Edge Drop – 4 in

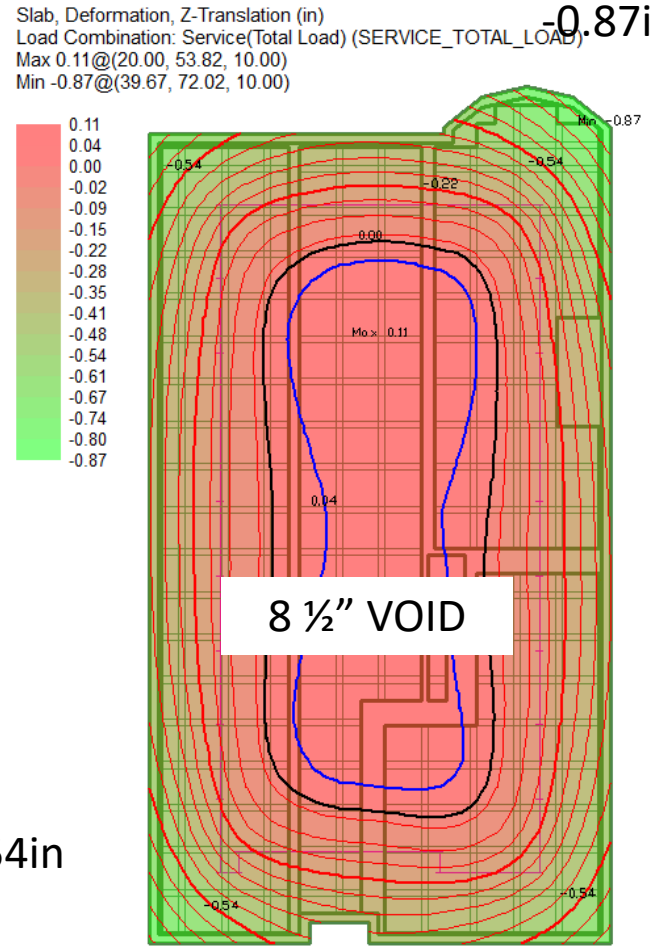


-0.76in

TRADITIONAL

Soils report limits ym to -2.33in

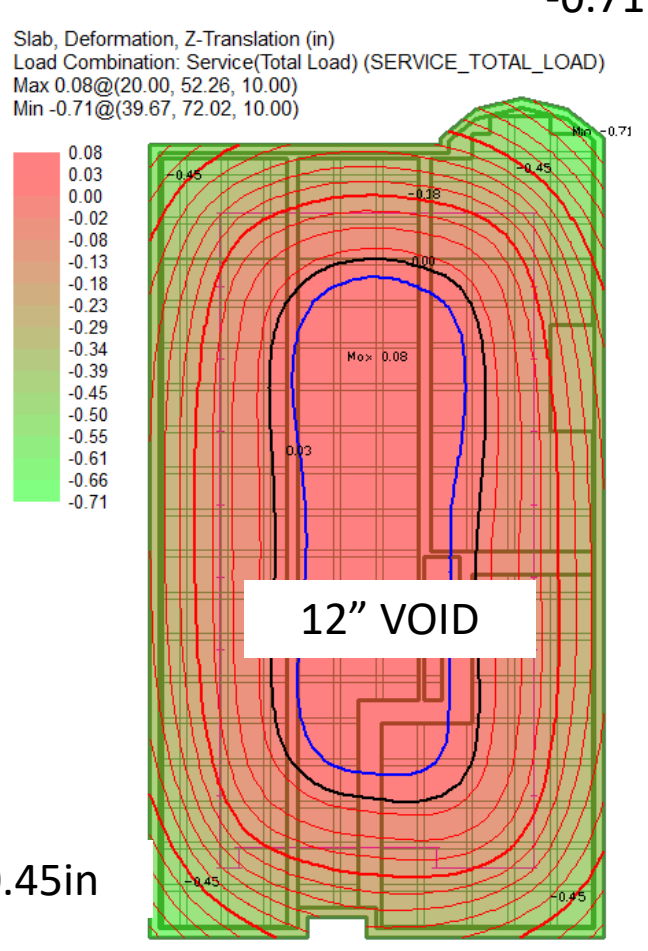
-0.48in



-0.87in

8 ½” VOID

-0.54in



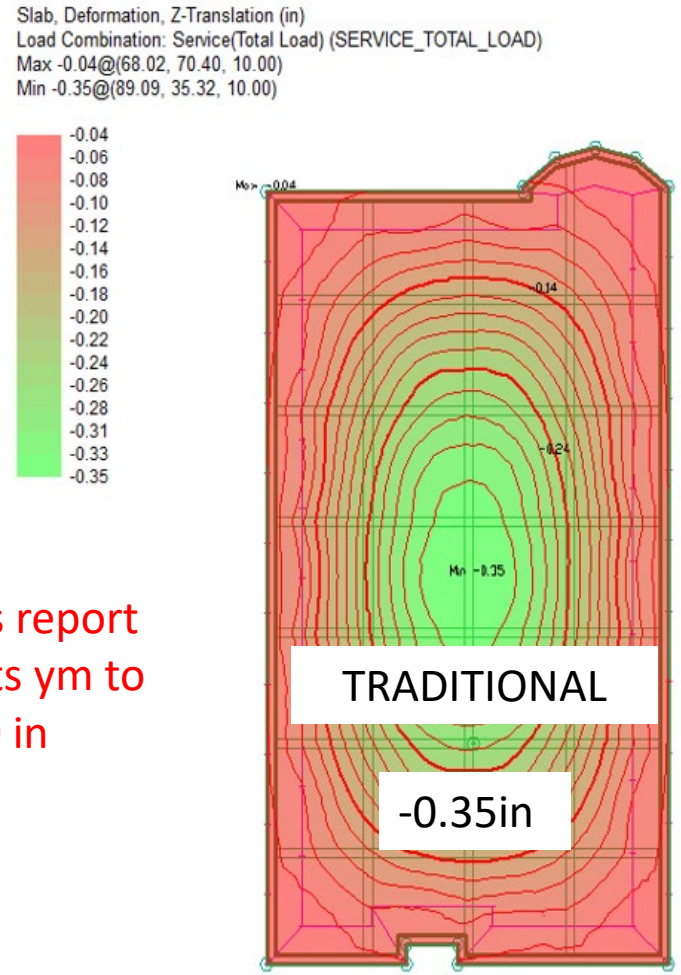
-0.71in

12” VOID

-0.45in

Void Forms Tendon Layout 1

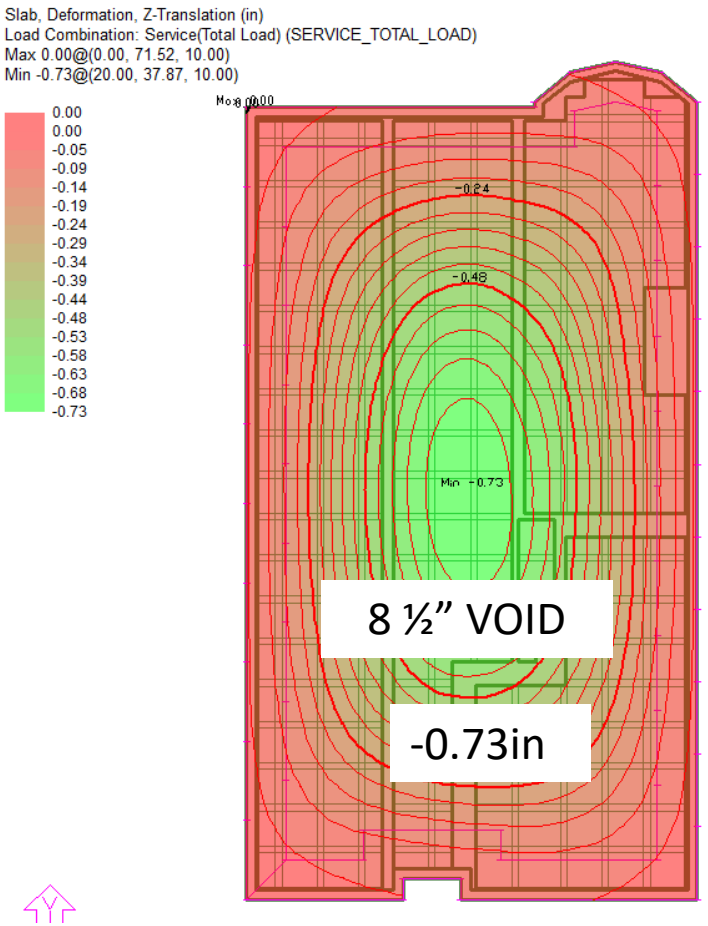
Edge Lift – 4 in



TRADITIONAL

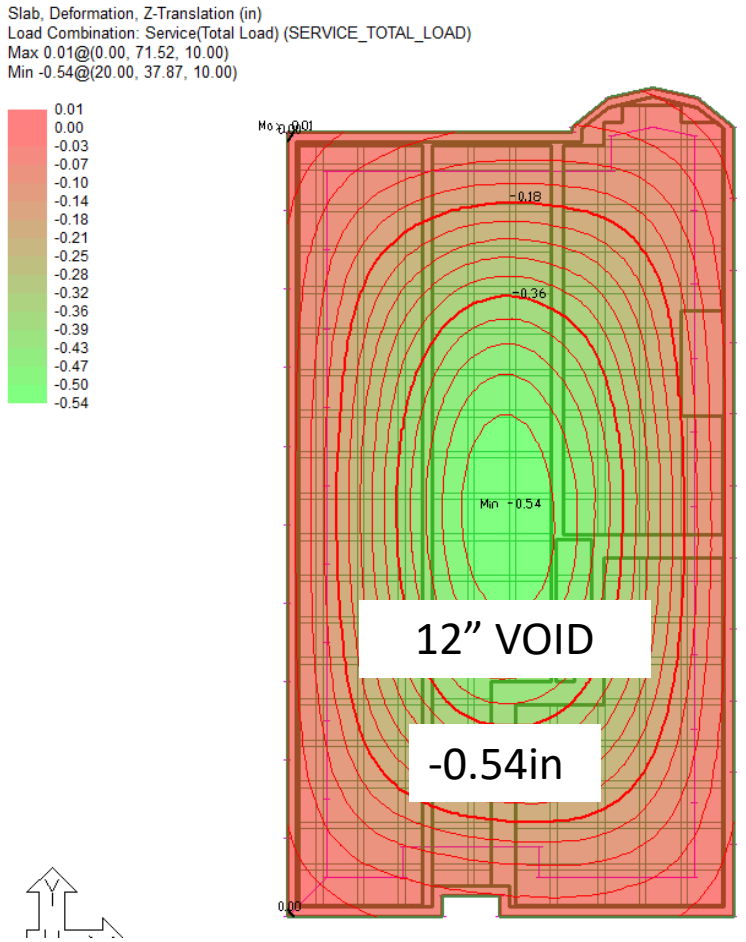
-0.35in

Soils report limits ym to 3.80 in



8 ½” VOID

-0.73in

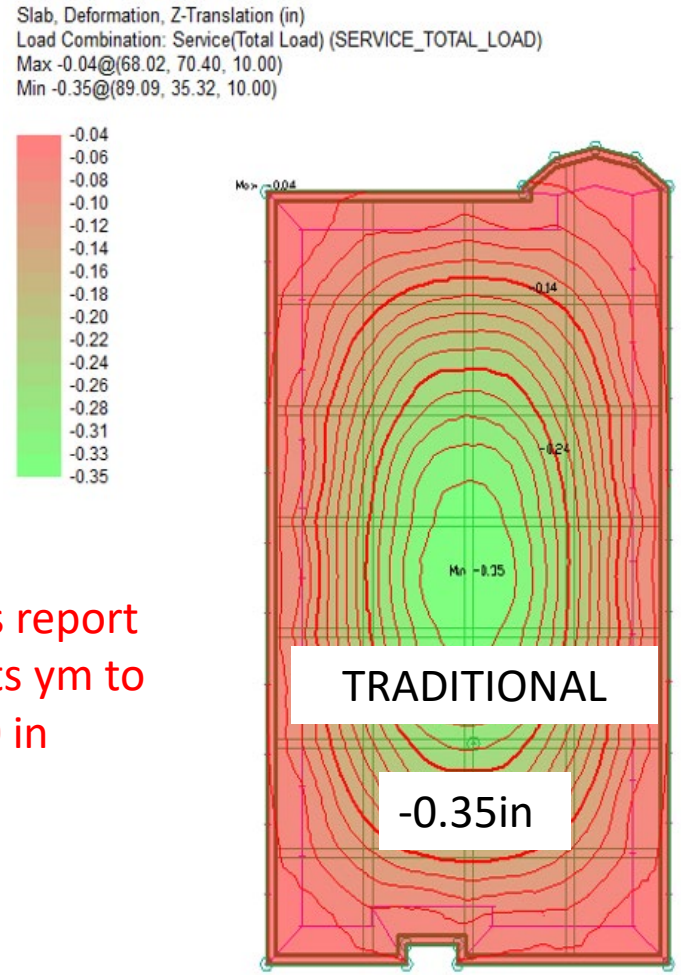


12” VOID

-0.54in

Void Forms Tendon Layout 2

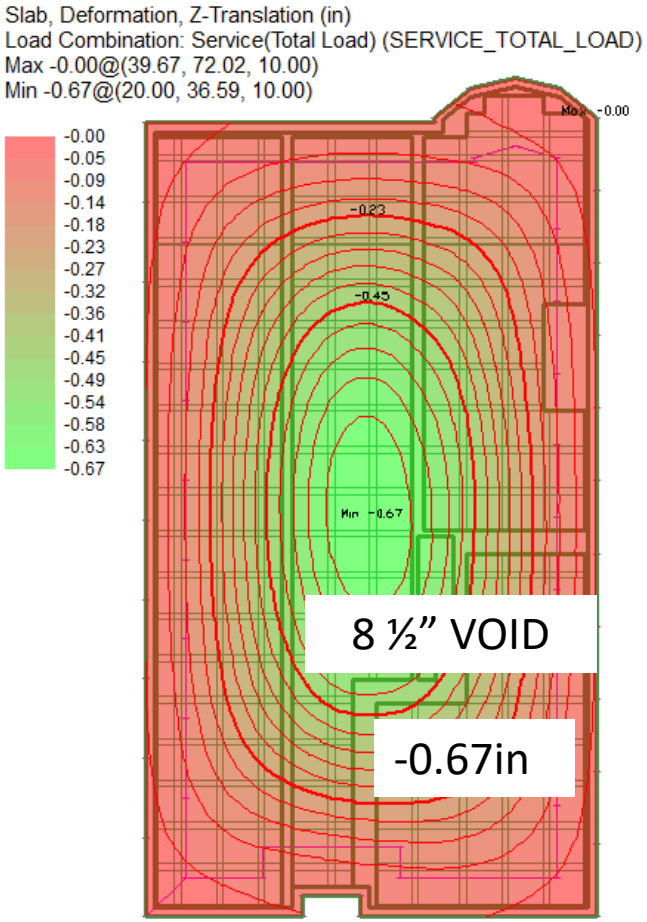
Edge Lift – 4 in



Soils report limits ym to 3.80 in

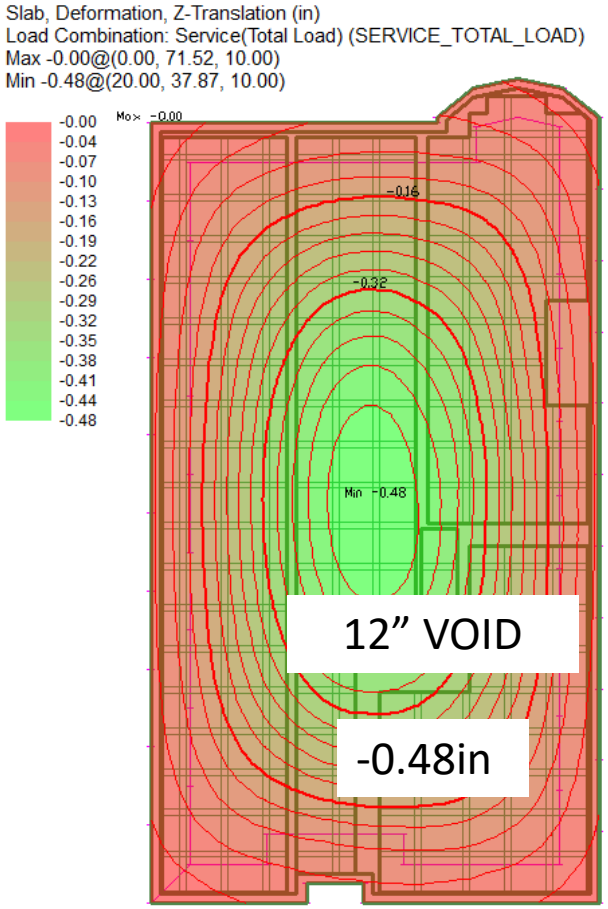
TRADITIONAL

-0.35in



8 ½” VOID

-0.67in



12” VOID

-0.48in

Traditional vs Void Form

Summary of Deflection Comparison

Void Forms Tendon Layout 1

1" PVR (in of max deflection)

	Traditional	8.5in Void	12in Void
Edge Drop	-0.74	-0.96*	-0.96*
Edge Lift	-0.29	-0.62	-0.47

4" PVR (in of max deflection)

	Traditional	8.5in Void	12in Void
Edge Drop	-0.76	-0.84	-0.72
Edge Lift	-0.35	-0.73	-0.55

Summary of Deflection Comparison

Void Forms Tendon Layout 2

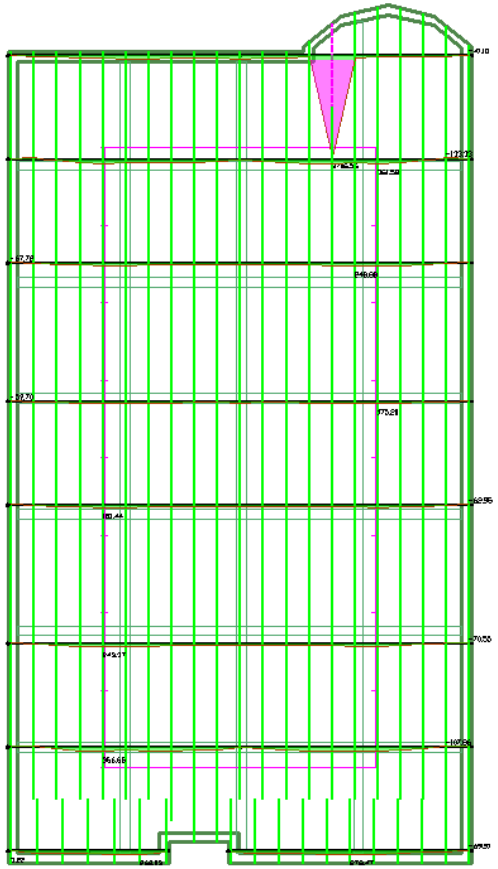
1" PVR (in of max deflection)

	Traditional	8.5in Void	12in Void
Edge Drop	-0.74	-0.96*	-0.96*
Edge Lift	-0.29	-0.58	-0.40

4" PVR (in of max deflection)

	Traditional	8.5in Void	12in Void
Edge Drop	-0.76	-0.84	-0.72
Edge Lift	-0.35	-0.67	-0.48

Top Fiber Stresses – Edge Drop – 1 in



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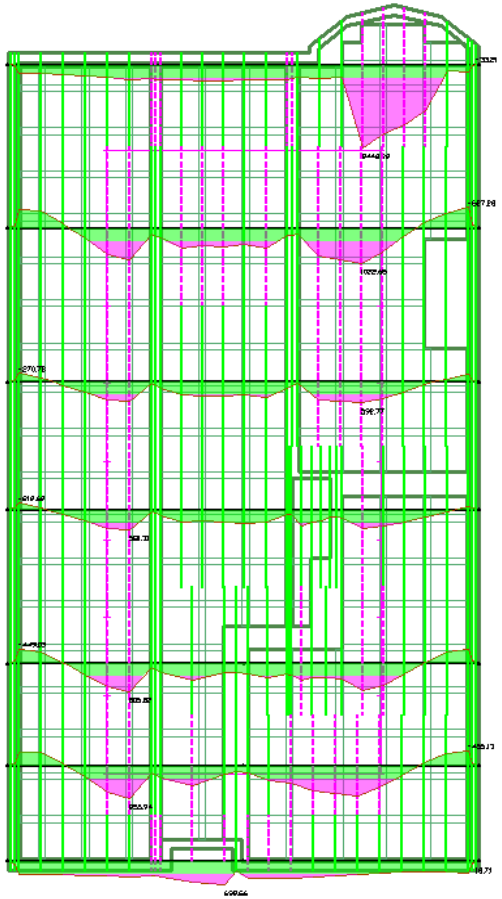
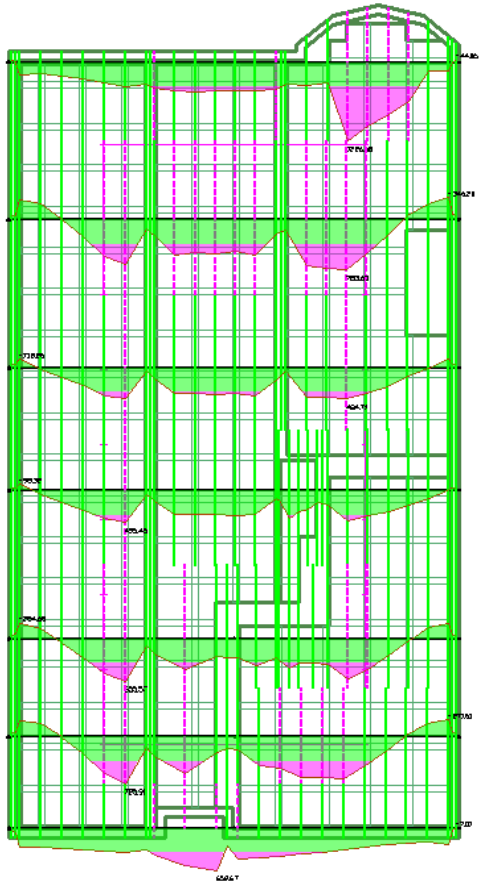
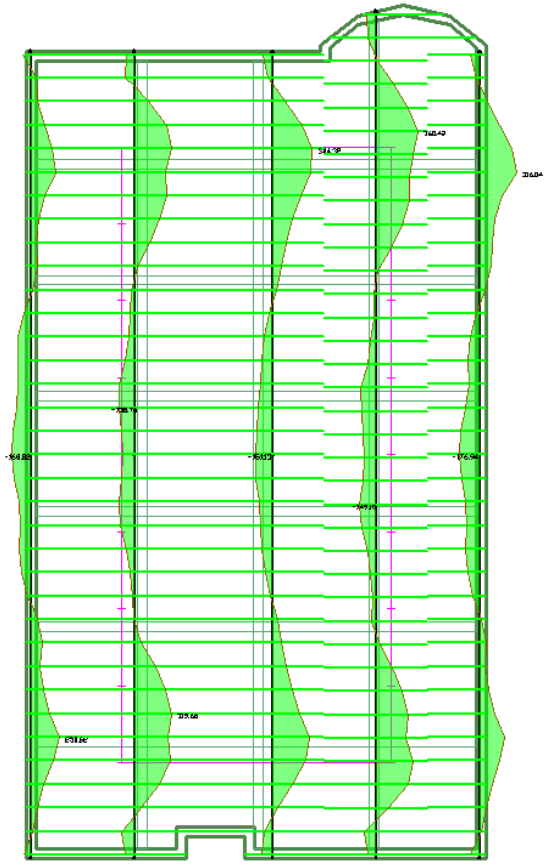


8 ½” VOID



12” VOID

Top Fiber Stresses – Edge Drop – 1 in



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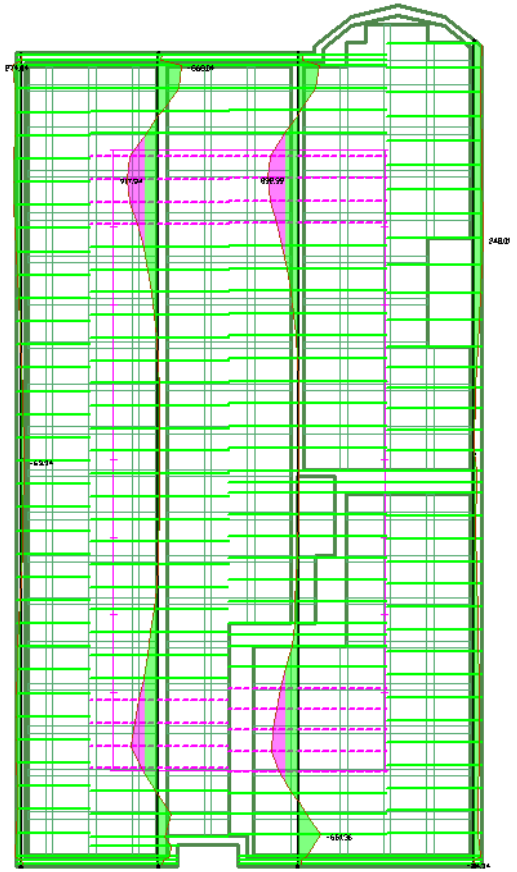
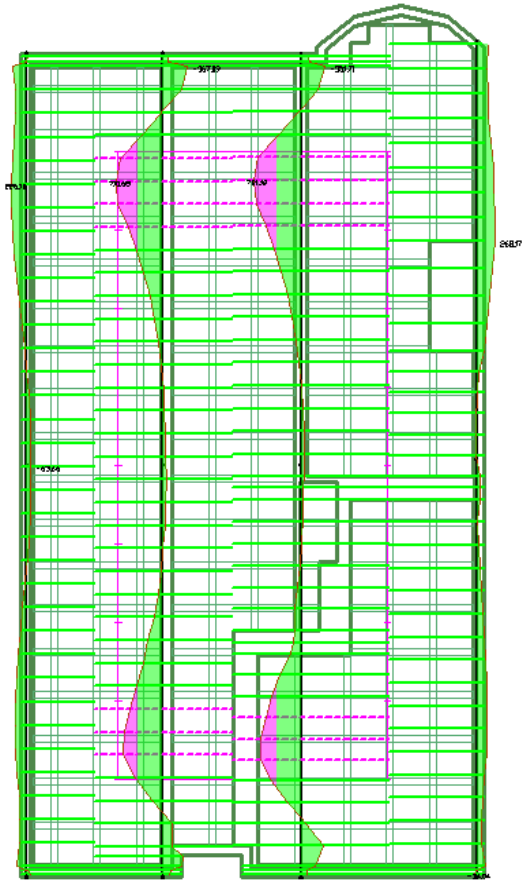
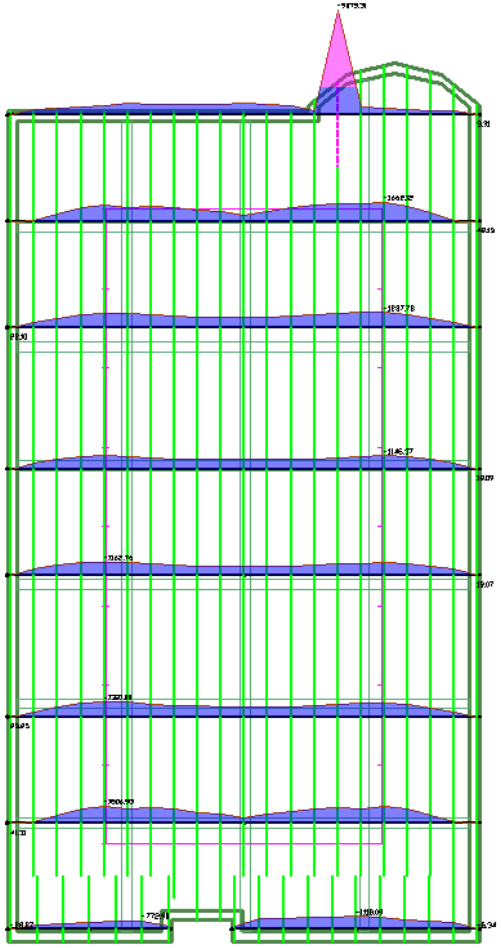


8 ½” VOID



12” VOID

Bottom Fiber Stresses – Edge Drop – 1 in



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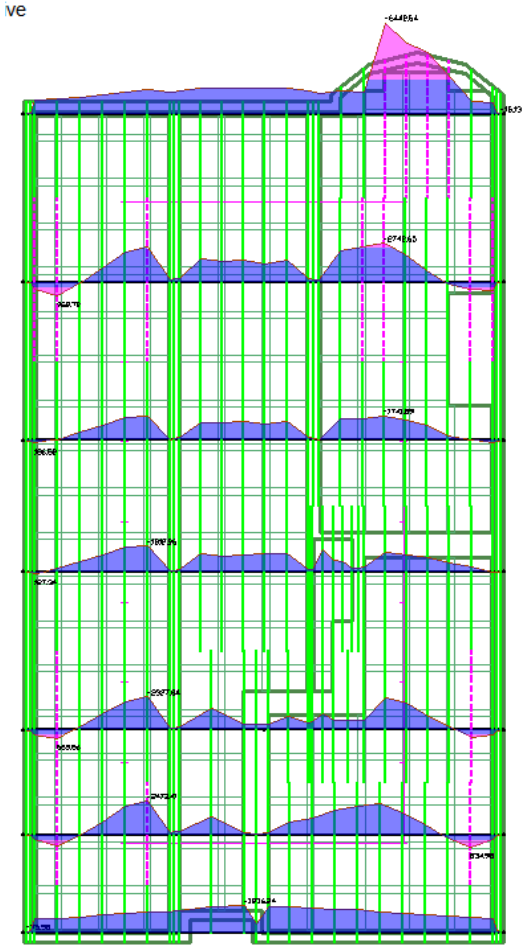
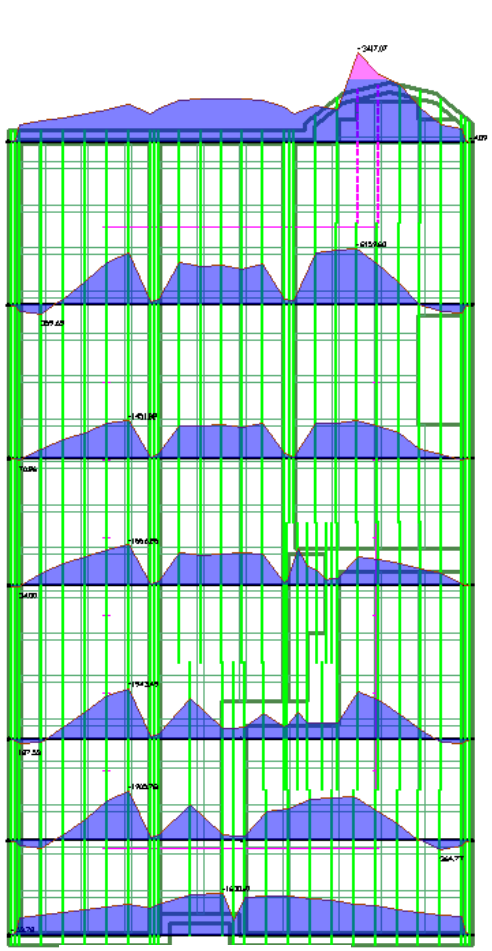
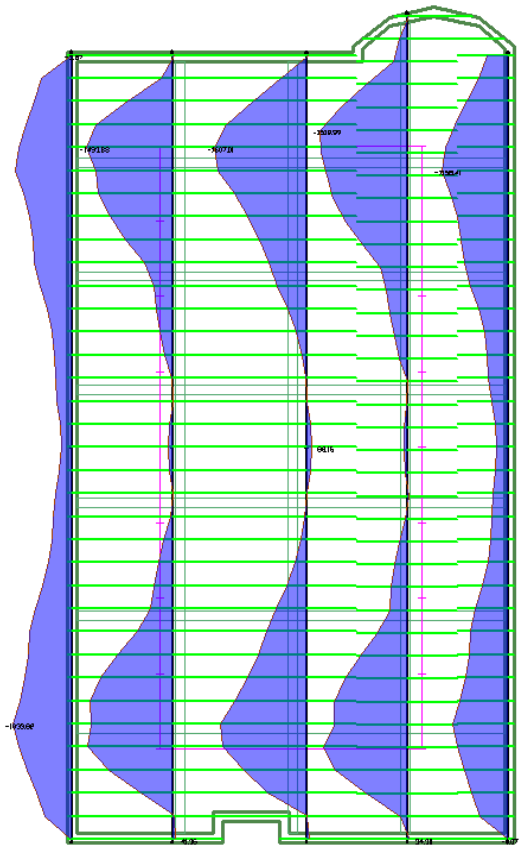


8 ½” VOID



12” VOID

Bottom Fiber Stresses – Edge Drop – 1 in



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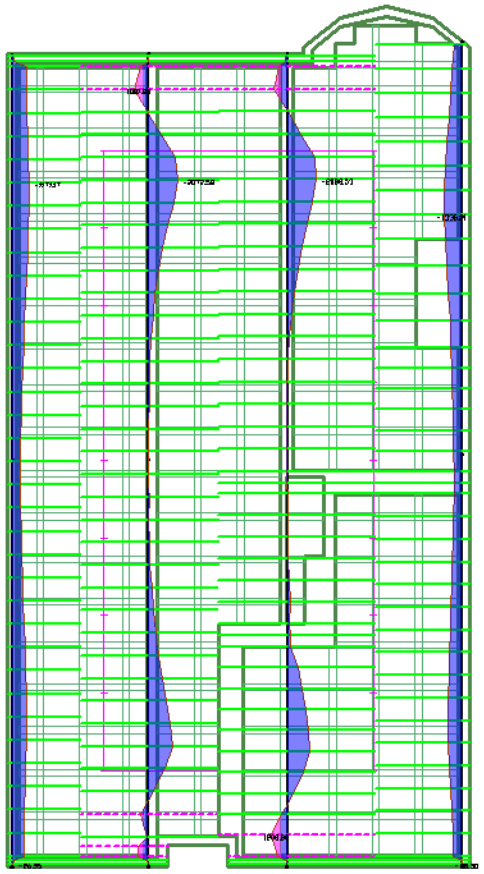

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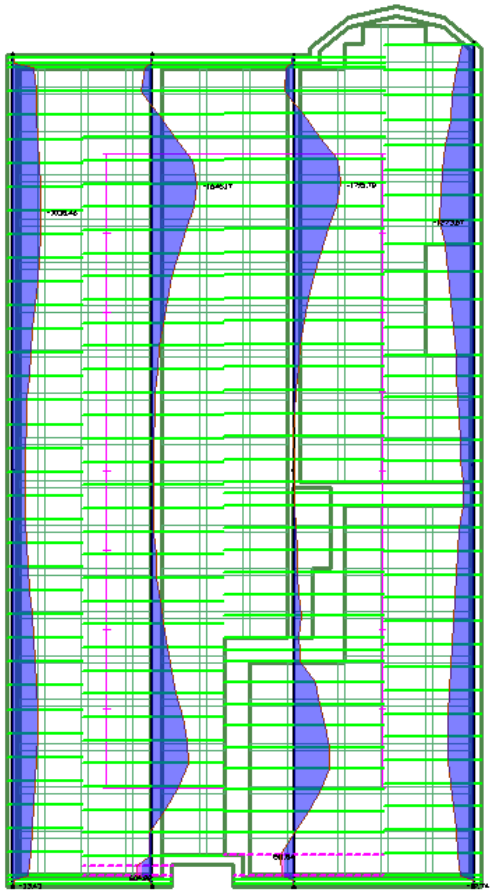
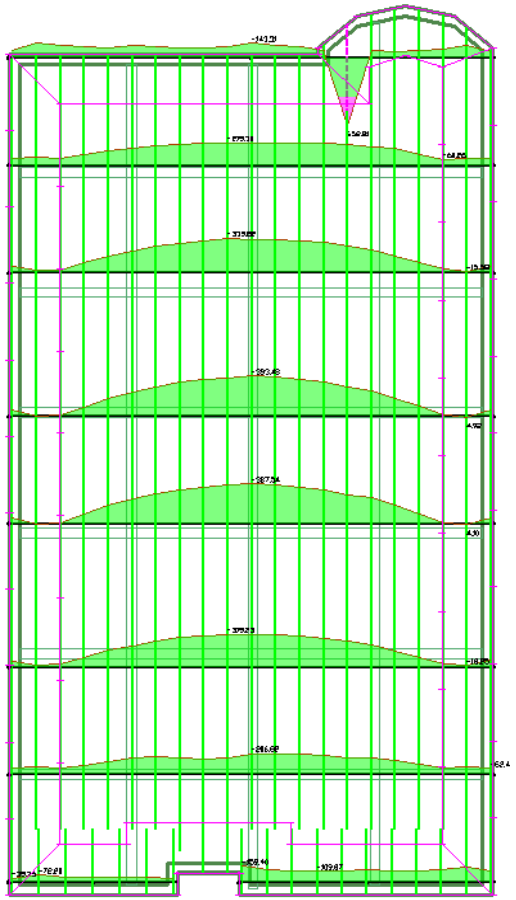
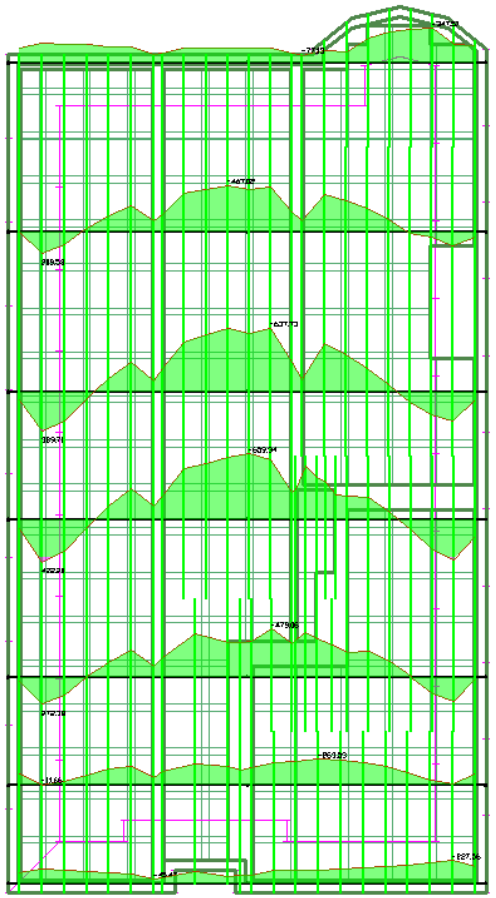


12” VOID

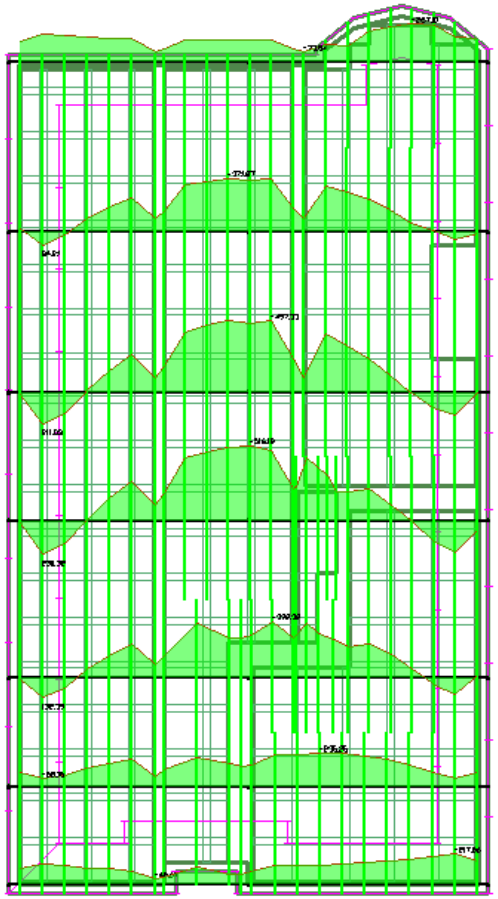
Top Fiber Stresses – Edge Lift – 1 in



TRADITIONAL

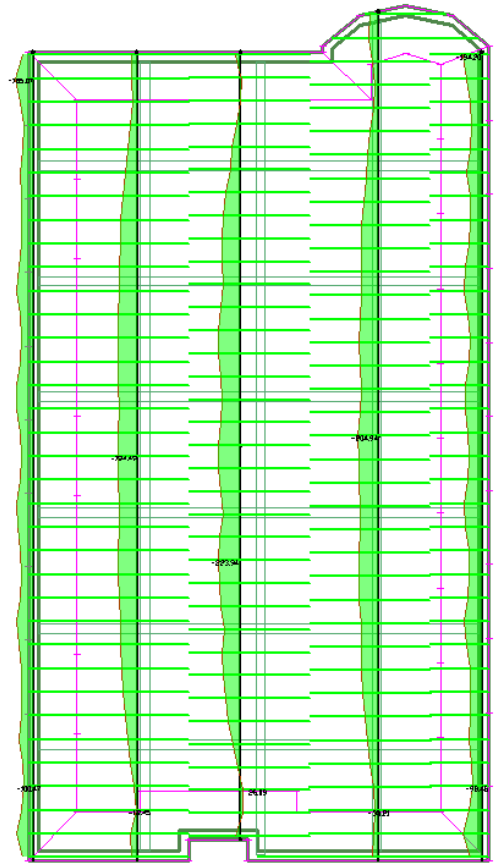


8 ½” VOID



12” VOID

Top Fiber Stresses – Edge Lift – 1 in

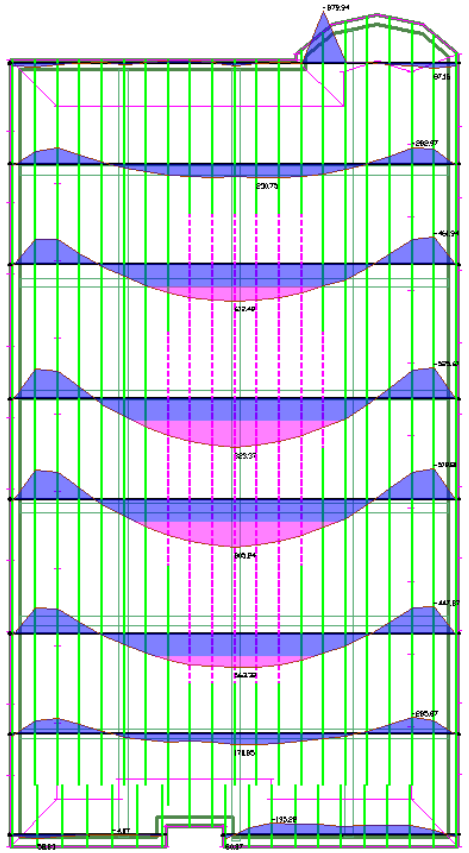


TRADITIONAL

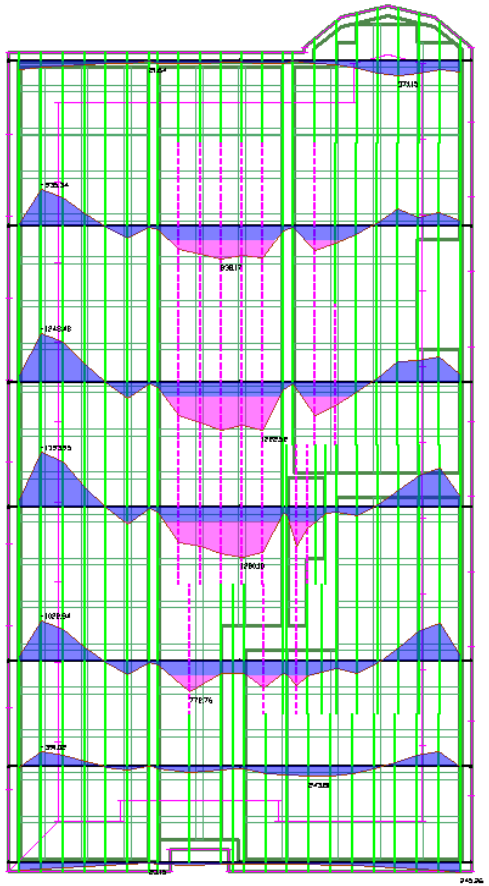
8 ½” VOID

12” VOID

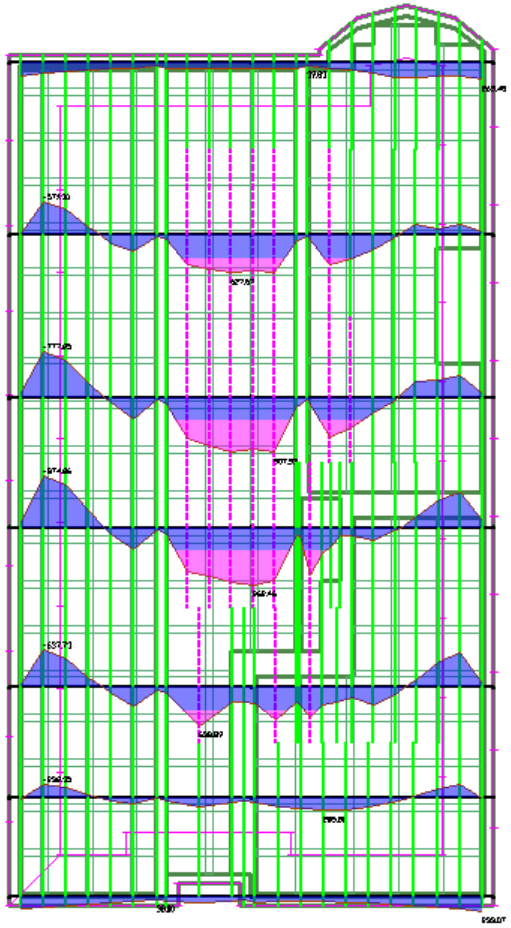
Bottom Fiber Stresses – Edge Lift – 1 in



TRADITIONAL

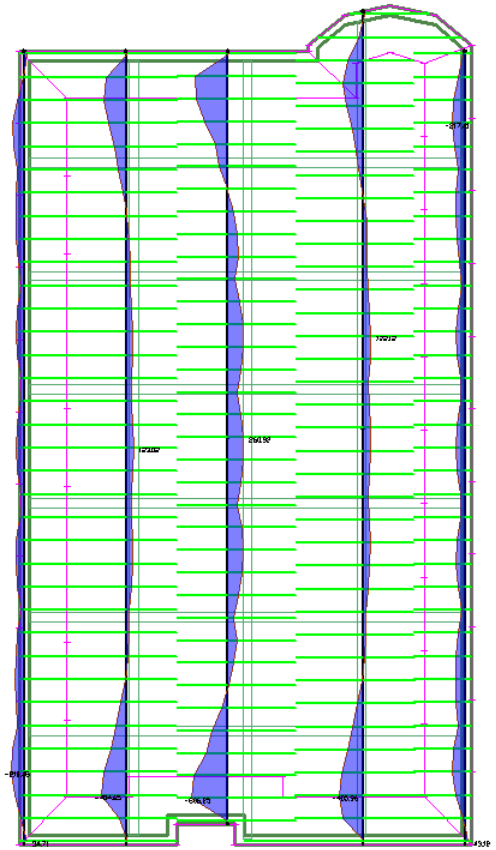


8 ½” VOID

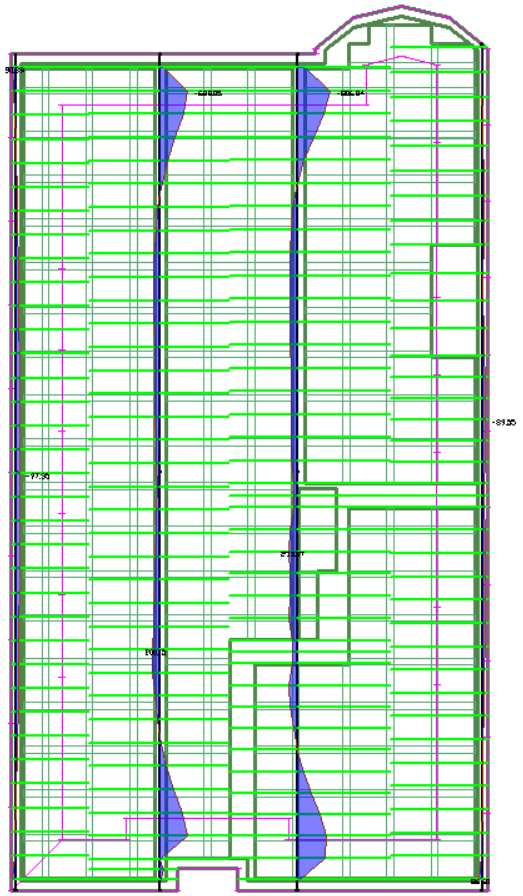


12” VOID

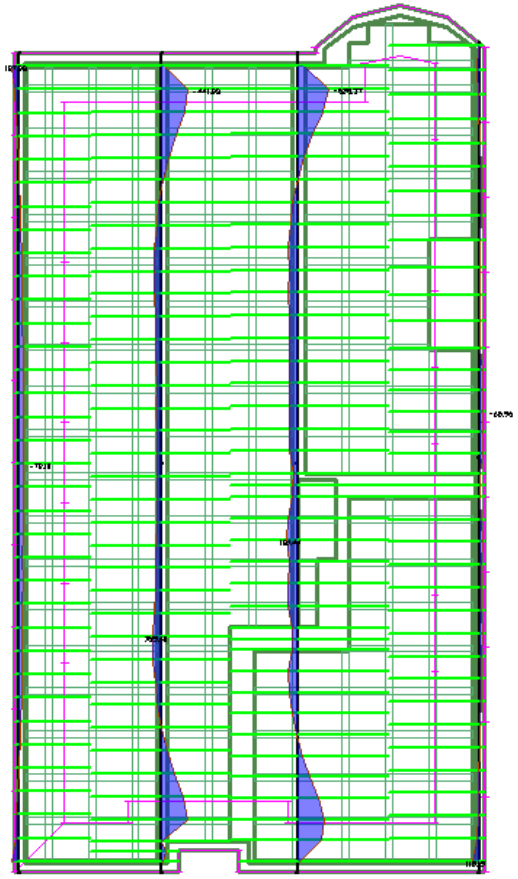
Bottom Fiber Stresses – Edge Lift – 1 in



TRADITIONAL



8 ½” VOID

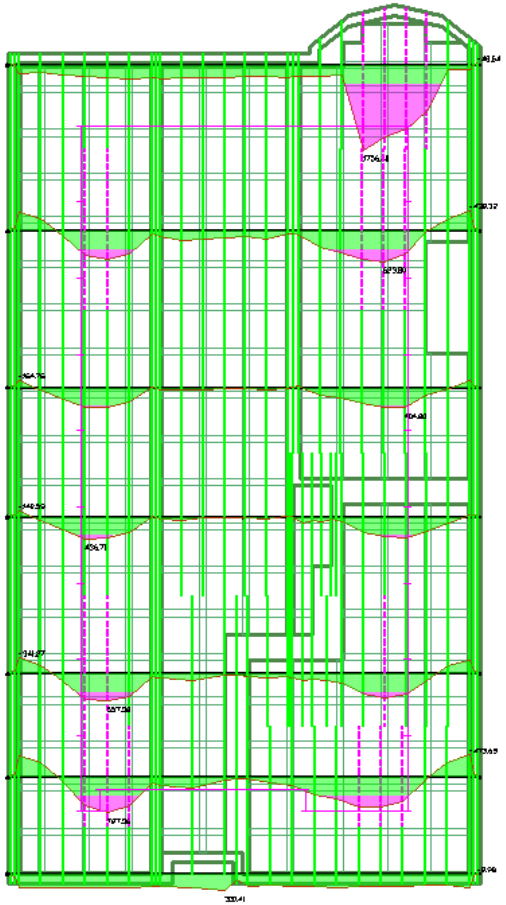


12” VOID

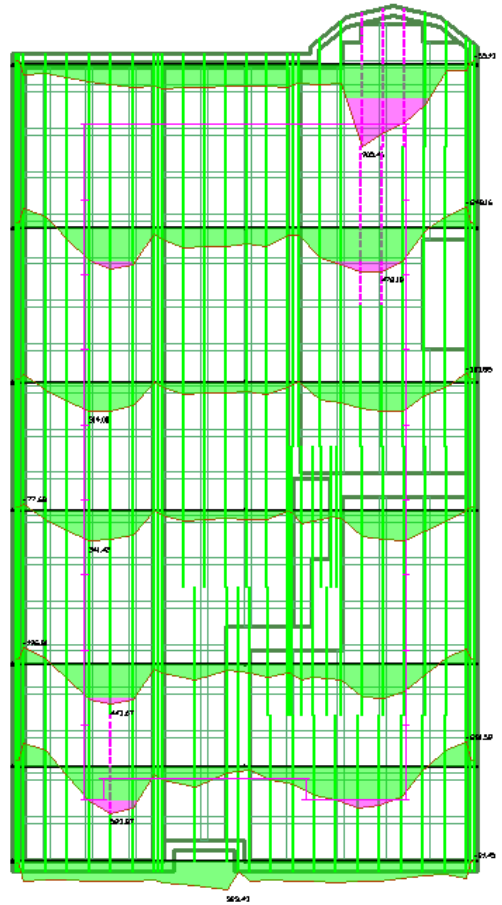
Void Forms Tendon Layout 1

Top Fiber Stresses – Edge Drop – 4 in

TRADITIONAL



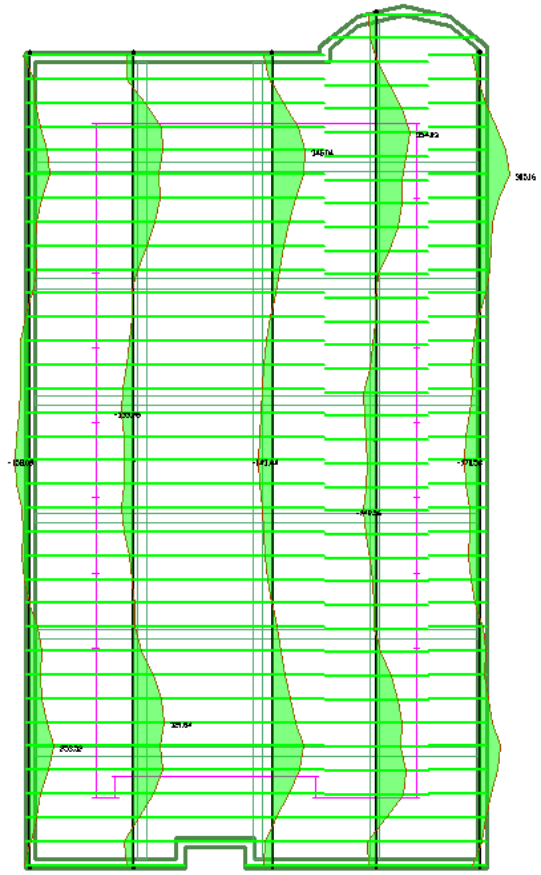
8 ½” VOID



12” VOID

Void Forms Tendon Layout 2

Top Fiber Stresses – Edge Drop – 4 in



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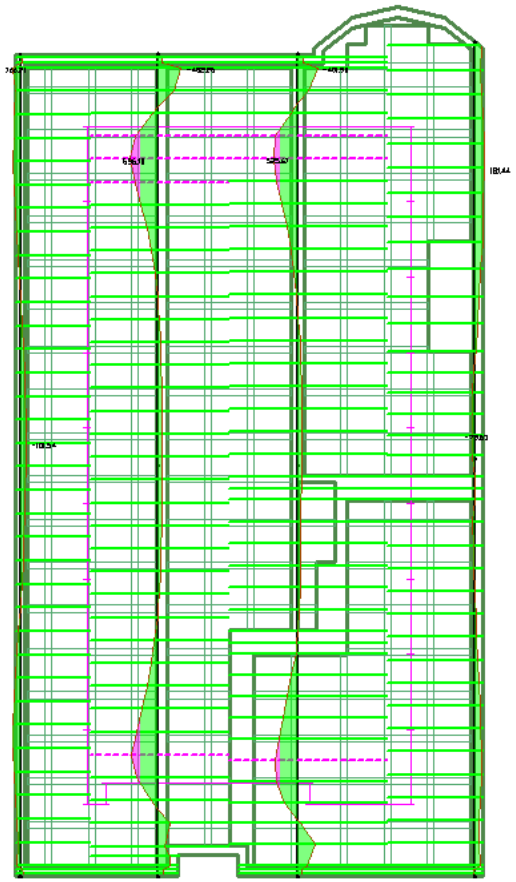

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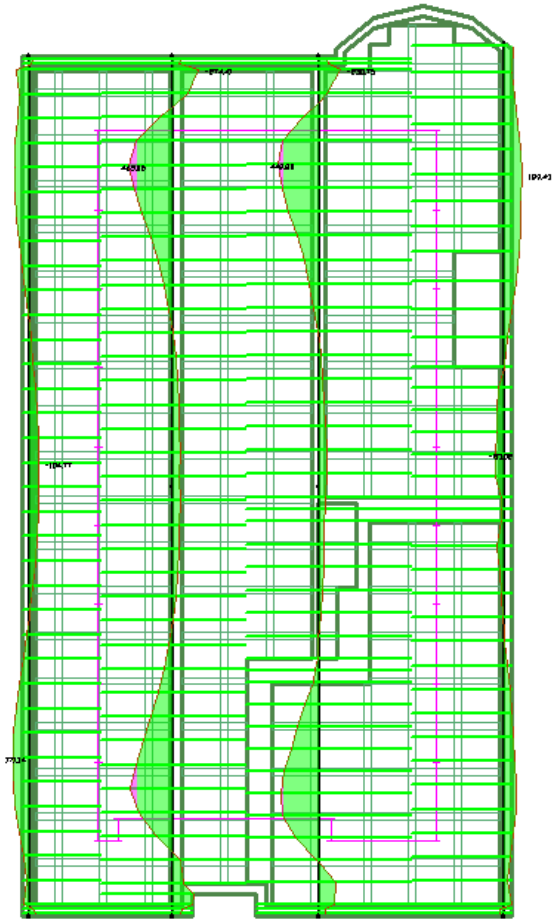
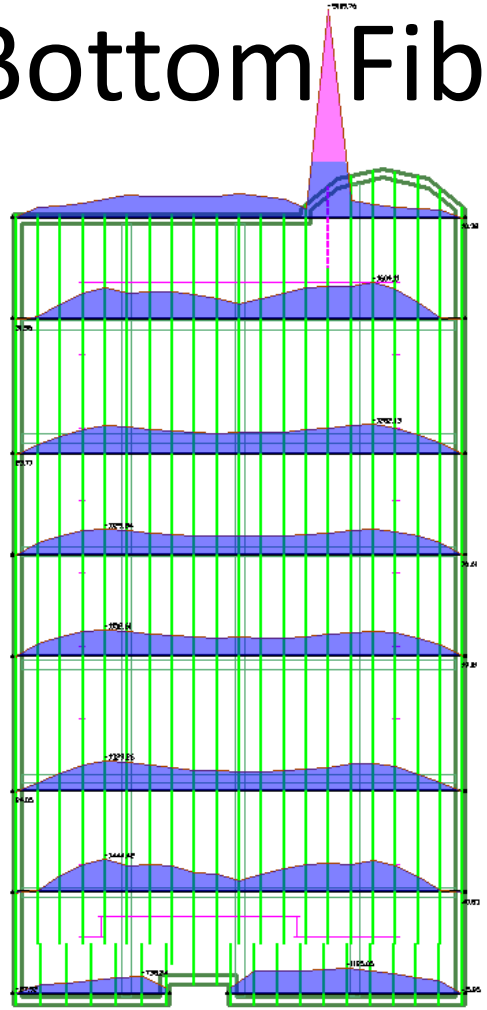


12” VOID

Bottom Fiber Stresses – Edge Drop – 4 in



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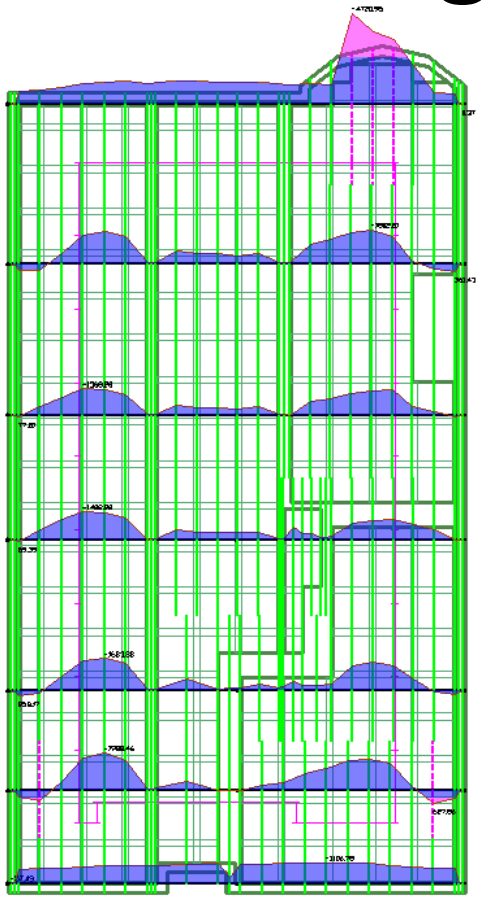
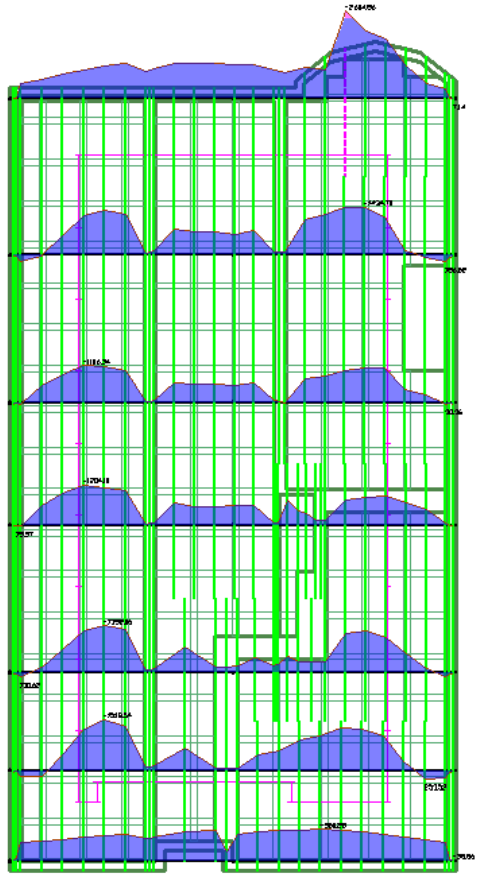
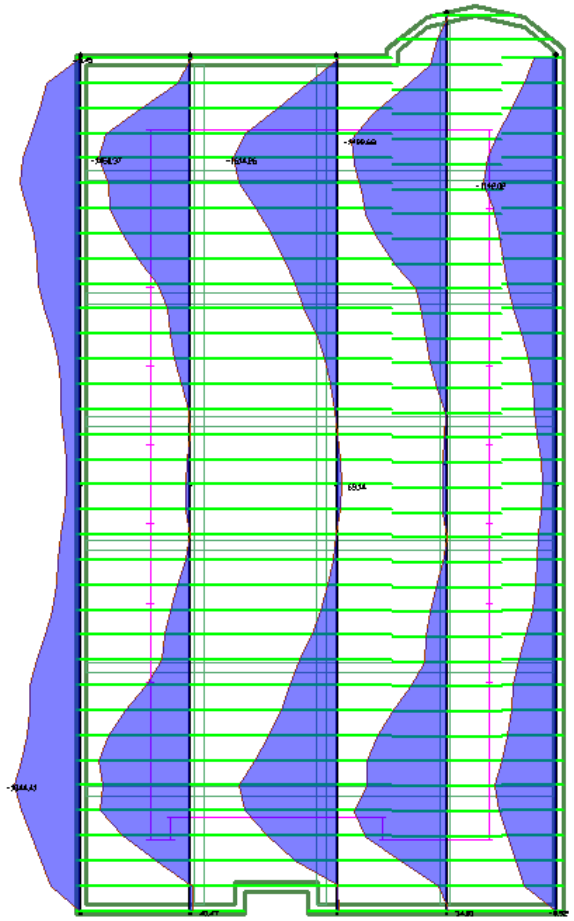


8 ½” VOID



12” VOID

Bottom Fiber Stresses – Edge Drop – 4 in



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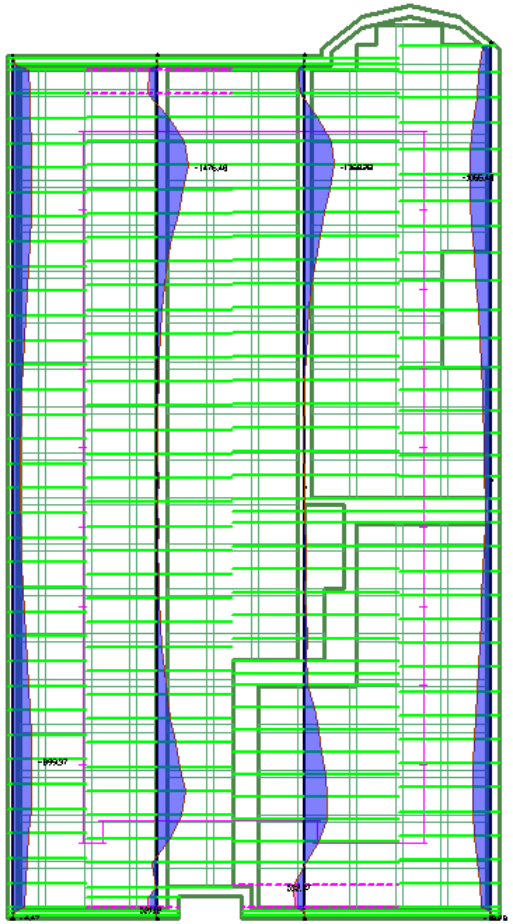
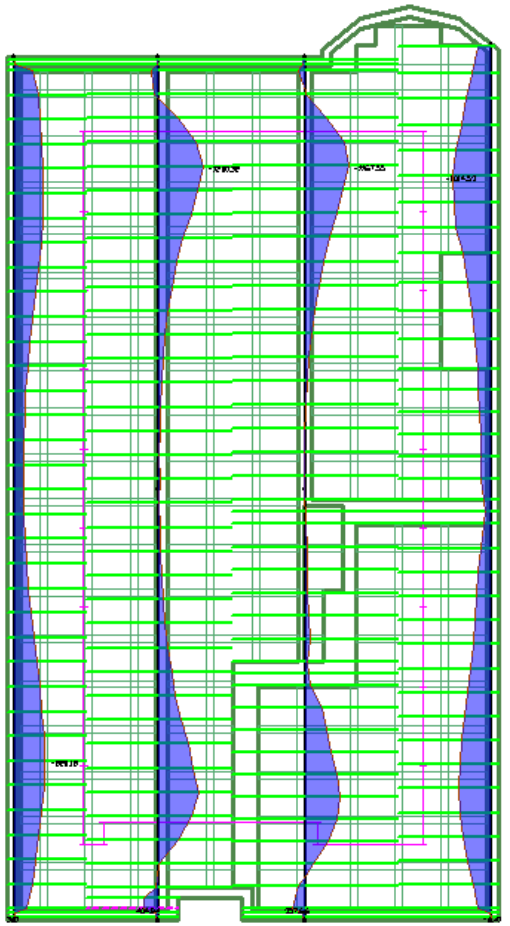
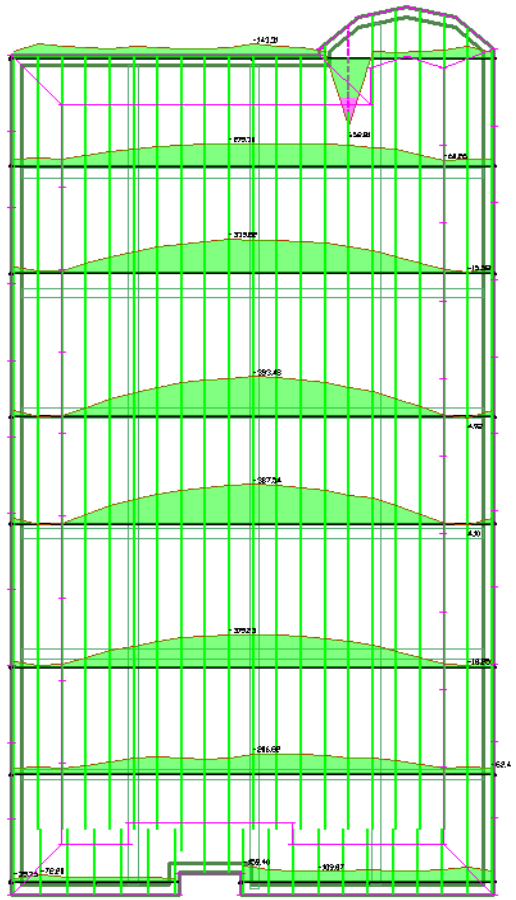


8 ½” VOID



12” VOID

Top Fiber Stresses – Edge Lift – 4 in



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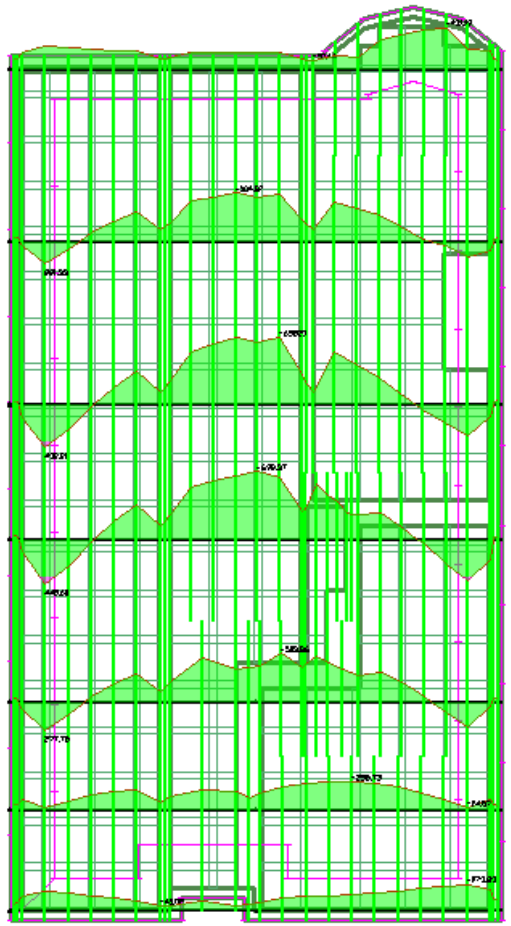
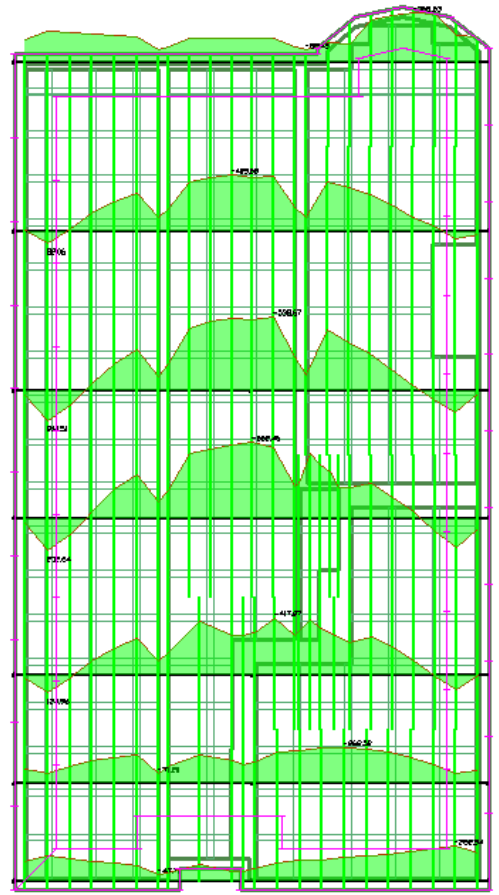
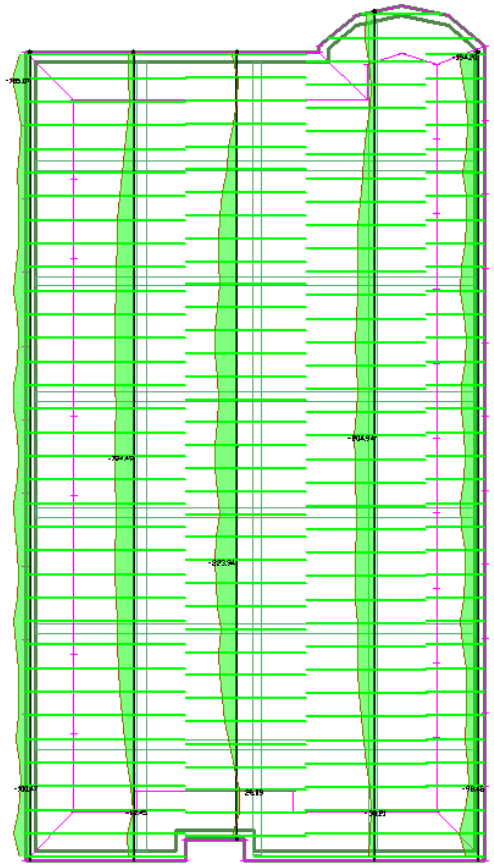


8 ½” VOID



12” VOID

Top Fiber Stresses – Edge Lift – 4 in



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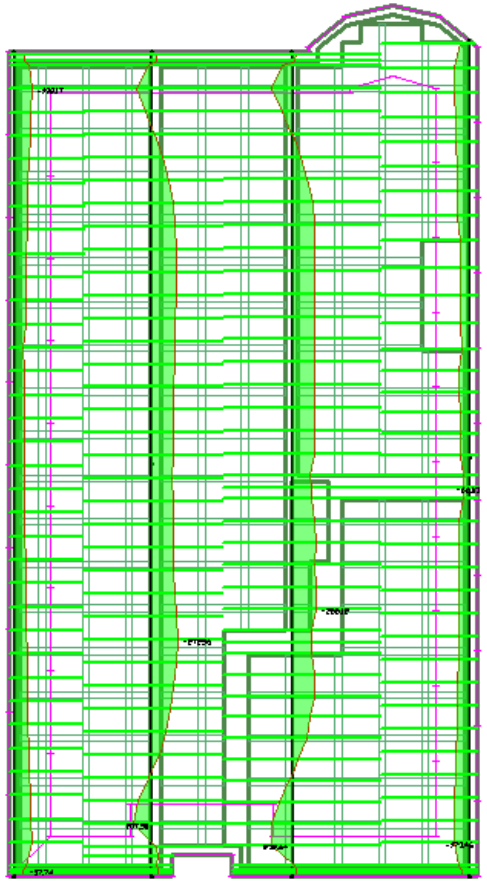
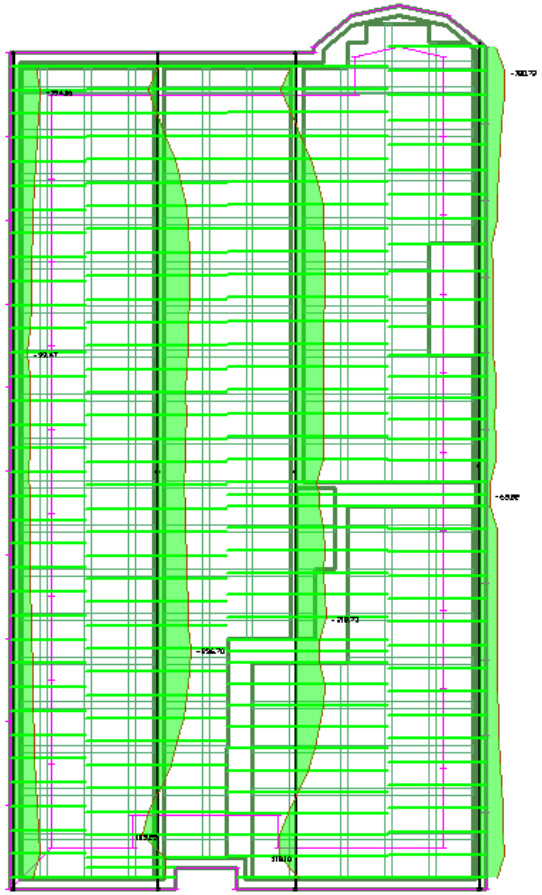
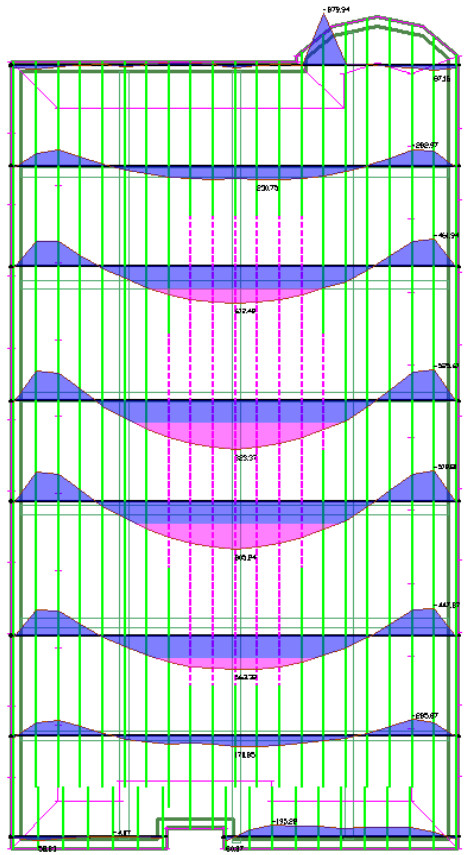


8 ½” VOID



12” VOID

Bottom Fiber Stresses – Edge Lift – 1 in



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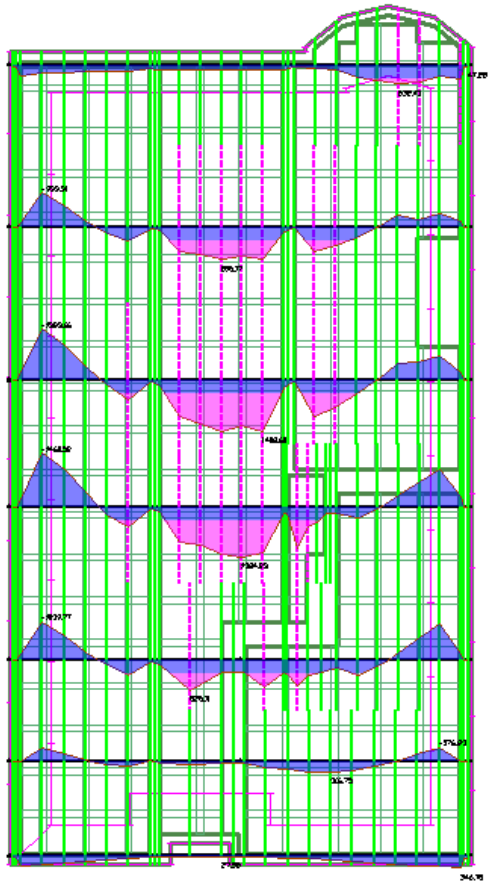
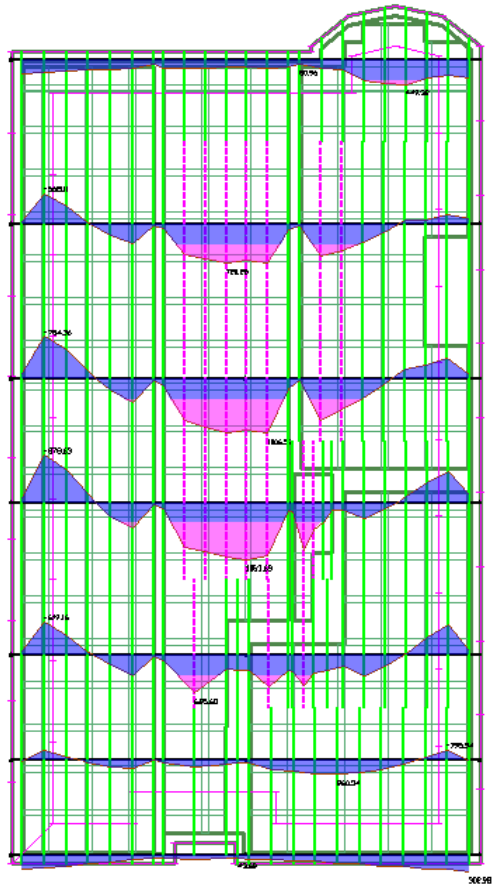
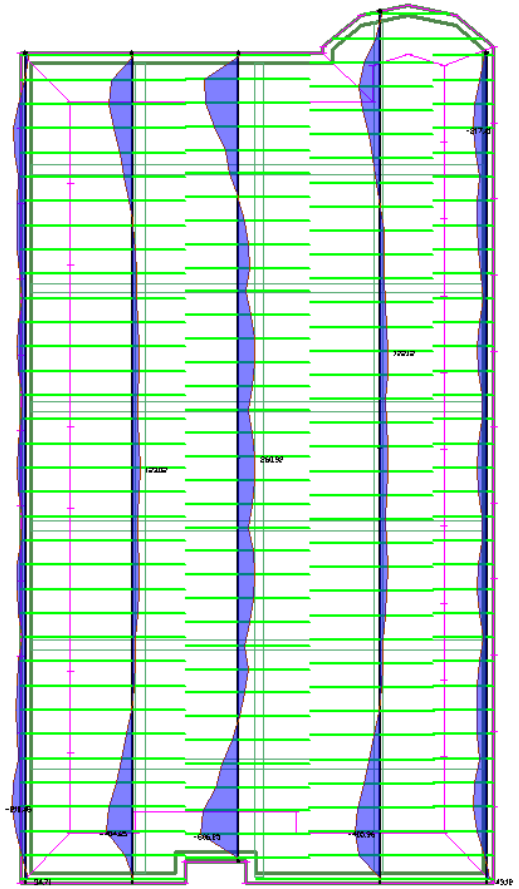


8 ½” VOID

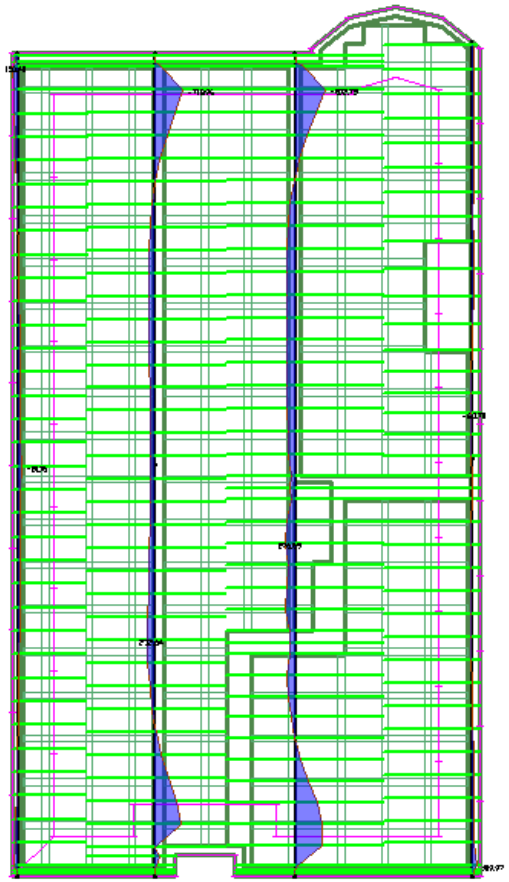


12” VOID

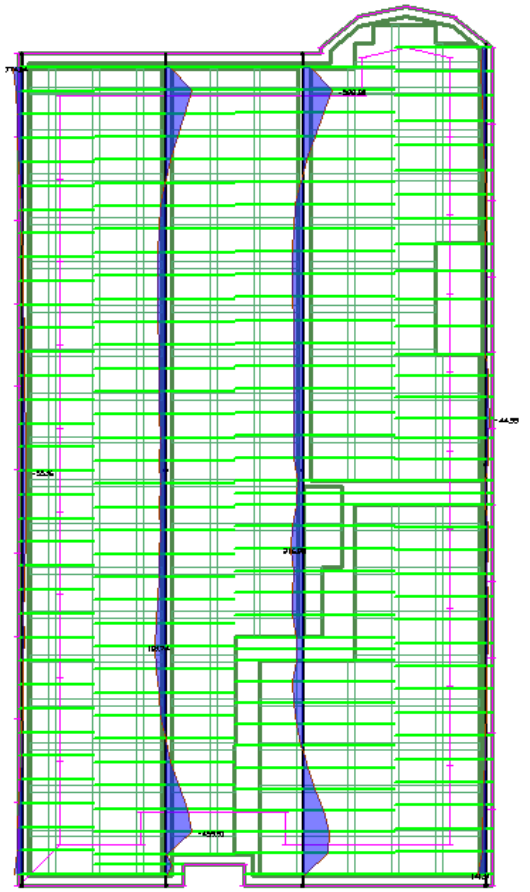
Bottom Fiber Stresses – Edge Lift – 4 in



TRADITIONAL



8 ½” VOID



12” VOID

Holistic Overview of Design Options

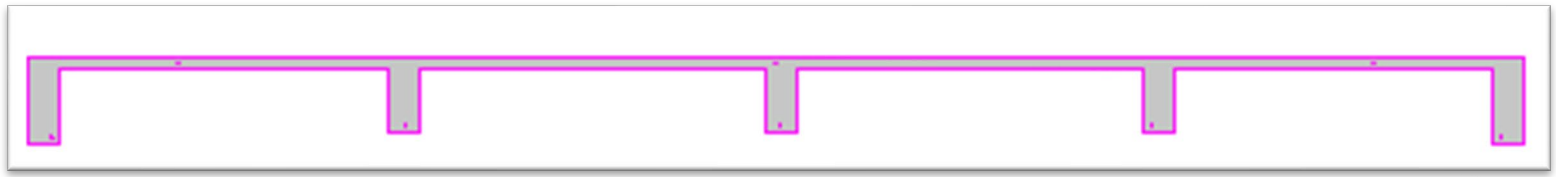
	THEORETICAL CONCRETE, FT^3	PT, LF	PERIMETER BEAM, LF	VOID FORM BOXES, Avg Cost/sq ft*	POTENTIAL CONCRETE WASTE & OVERAGES AT INTERIOR**	INTERIOR BEAMS EXCAVATION & MAINTENANCE	VAPOR BARRIER
TRADITIONAL	70	1,800	225.7	N/A	$$$	$$	$$
8 1/2" VOID FORM	77	1,800	225.7	$	N/A	N/A	$
12" VOID FORM	85.5	1,800	225.7	$	N/A	N/A	$

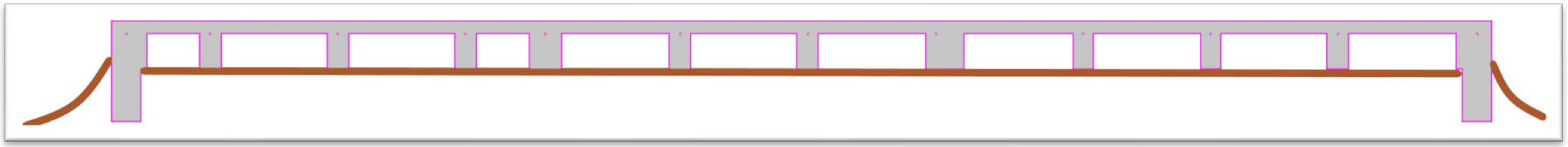
* Based on Market Prices, Prices may vary by region (8.5" boxes is approx $1.75/$ft^2$ & 12" boxes $2.25/$ft^2$)

**Theoretical volume is increased by waste factors of over excavating all trenched beams (Traditional ~ 95 ft^3, 8.5" box ~ 79 ft^3, 12" box ~ 87.5 ft^3)

Theoretical Concrete

THEORETICAL CONCRETE, FT^3
70
77
85.5





Post Tension Tendons

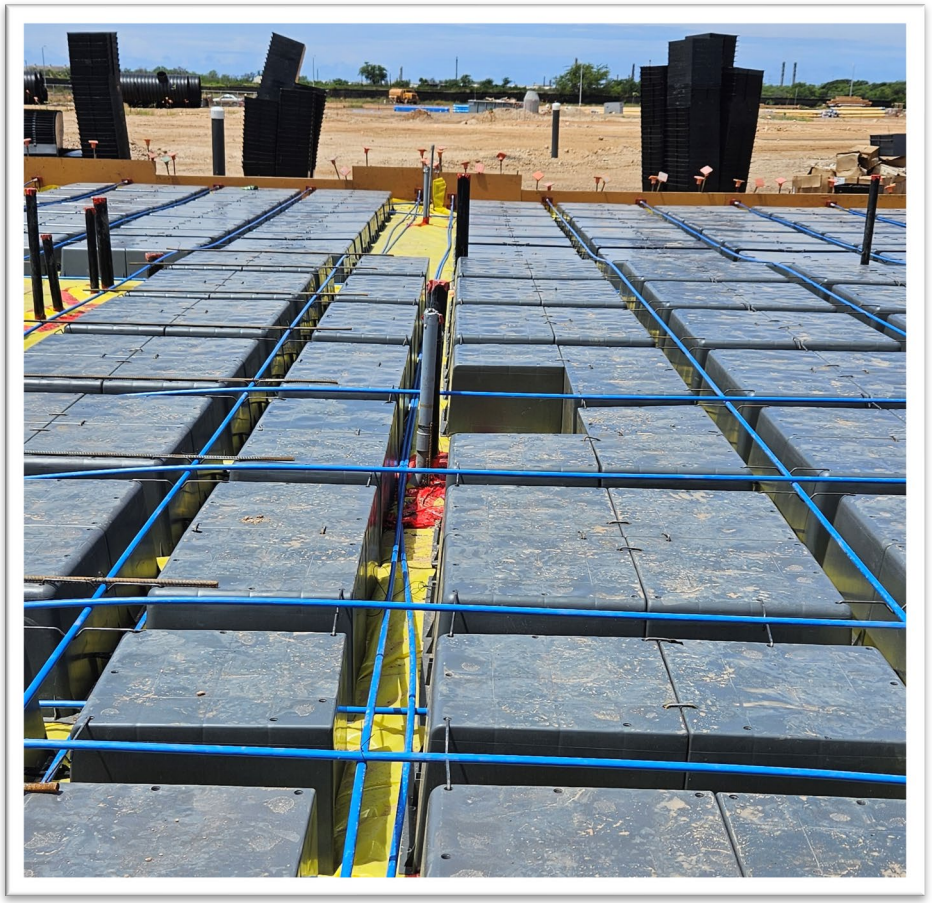
PT, LF
1,800
1,800
1,800

Perimeter Beam

PERIMETER BEAM, LF
225.7
225.7
225.7

Void Form Boxes

VOID FORM BOXES, Avg Cost/sq ft*
N/A
$
$



Potential Concrete Waste & Overages at Interior

POTENTIAL CONCRETE WASTE & OVERAGES AT INTERIOR**
$$$
N/A
N/A

Interior Beam Excavations & Maintenance

INTERIOR BEAMS EXCAVATION & MAINTENANCE
$$
N/A
N/A

Vapor Barrier

VAPOR BARRIER
$$
$
$

Observations

Even though the full cross-sectional moment of inertia was selected to be the same for all foundation models, their ultimate performance is impacted by their asymmetric geometry, precompression, tendon profiling and construction methods.

This concludes the Educational Content of this activity.

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Principal

Anna Olveda, MSCE (anna@wafflemat.com)
VP of Engineering