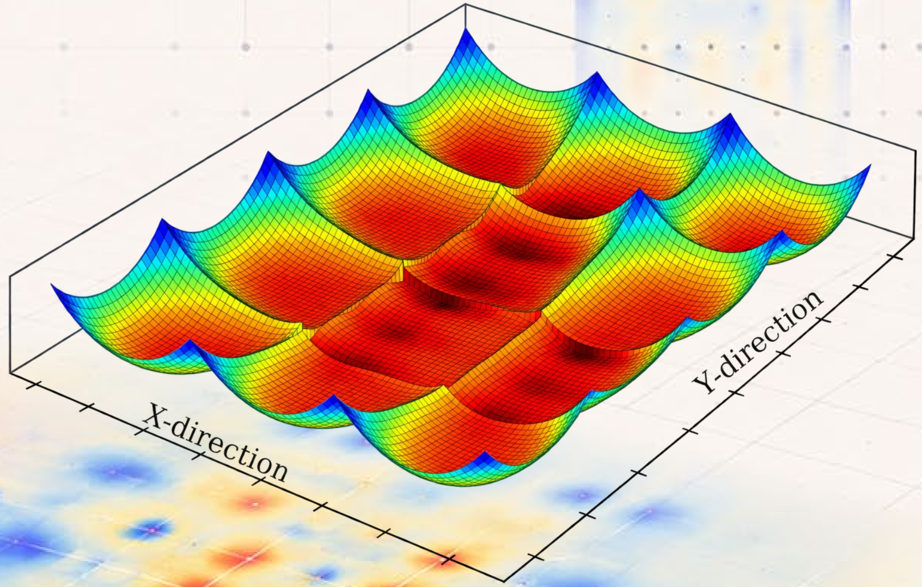
SLABS™

THE FUTURE OF SLAB-ON-GROUND DESIGN

The Curl Question



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Equivalent Built-in Temperature Differential (EBITD)

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ANALYSIS OF STRESSES IN CONCRETE PAVEMENTS DUE TO VARIATIONS OF TEMPERATURE

By H M WESTERGAARD

University of Illinois, Urbana, Ill

1926

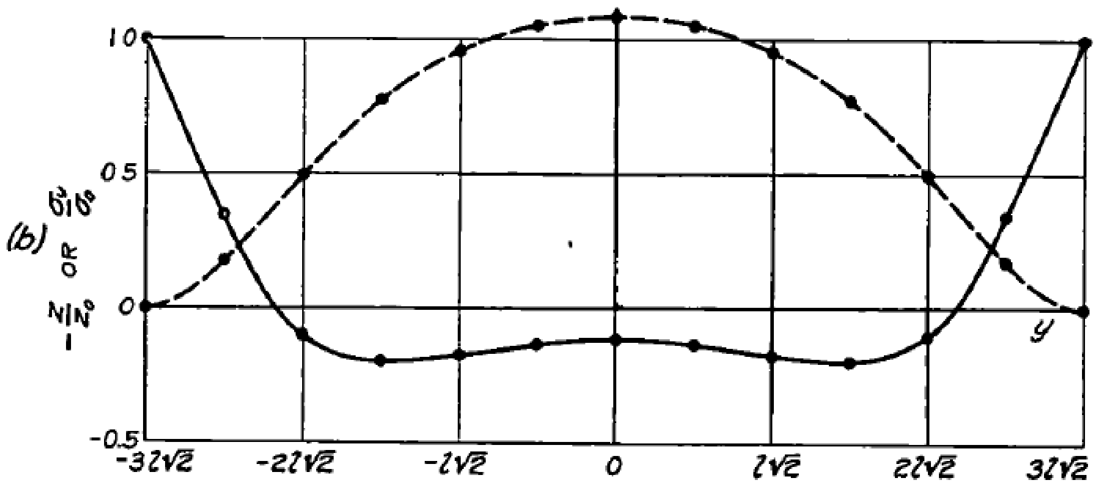

FIGURE 1 —Curling of pavements when the temperature is normal at the middle plane, and t degrees lower at the top than at the bottom

Thou Shalt Not Curl Nor Crack...(hopefully)

1999

Table 1 — Cumulative effect of adverse factors on shrinkage[2]

Poor practices that can cause increased shrinkage in floor slabs	Equivalent increase in shrinkage, percent	Cumulative effect
Temperature of concrete at discharge allowed to reach 80F (27C), whereas with reasonable precautions, a temperature of 60F (16C) could have been maintained	8	1.00 × 1.08 = 1.08
Use of 6 to 7 in. (150 to 180 mm) slump where 3 to 4 in. (75 to 100 mm) slump could have been used	10	1.08 × 1.10 = 1.19
Excessive haul in transit mixer, too long a waiting period at job site, or too many revolutions at mixing speed	10	1.19 × 1.10 = 1.31
Use of 3/4 in. (19 mm) maximum size aggregate under conditions where 1-1/2 in. (38 mm) aggregate could have been used	25	1.13 × 1.25 = 1.64
Use of cement having relatively high shrinkage characteristics	25	1.64 × 1.25 = 2.05
Excessive "dirt" in aggregate due to insufficient washing or contamination during handling	25	2.05 × 1.25 = 2.56
Use of aggregates of poor inherent quality with respect to shrinkage	50	2.56 × 1.50 = 3.84
Use of an admixture that produces high shrinkage	30	3.84 × 1.30 = 5.00
TOTAL INCREASE (percent)	Summation = 183	Cumulative = 400

EBITD is the measure of pavement (or slab) curvature

Curl Number Measurement

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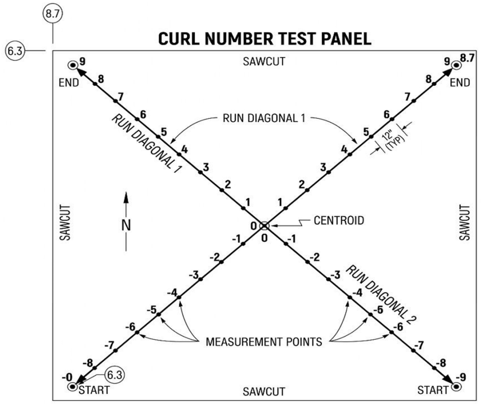
Addressing Concrete Slab Curl Numbers

What to know about collecting curl data to improve concrete slab designs.

By — Allen Face, Nigel Parkes
May 25, 2026
From The Slab Designer LLC

Layout and Measurement Procedure

Run diagonals are defined as the two lines connecting the test panel's opposite corners. The preferred run direction is from south to north, or east to west. Chalk lines are struck on both run diagonals, and the centroid and four corner intersection points are permanently marked. On each run diagonal, the start point and end point are located by measuring from the centroid to the whole foot nearest (but not beyond) the corner of the test panel. A sketch of each test panel should record its size, orientation, location, and run directions.



$$C = \frac{10{,}608{,}000\ S}{3L^5 + 15L^4 + 20L^3 - 8L}$$

Concrete Construction Magazine, 2010

For Construction Pros Magazine, 2026

SLABS Uses EBITD

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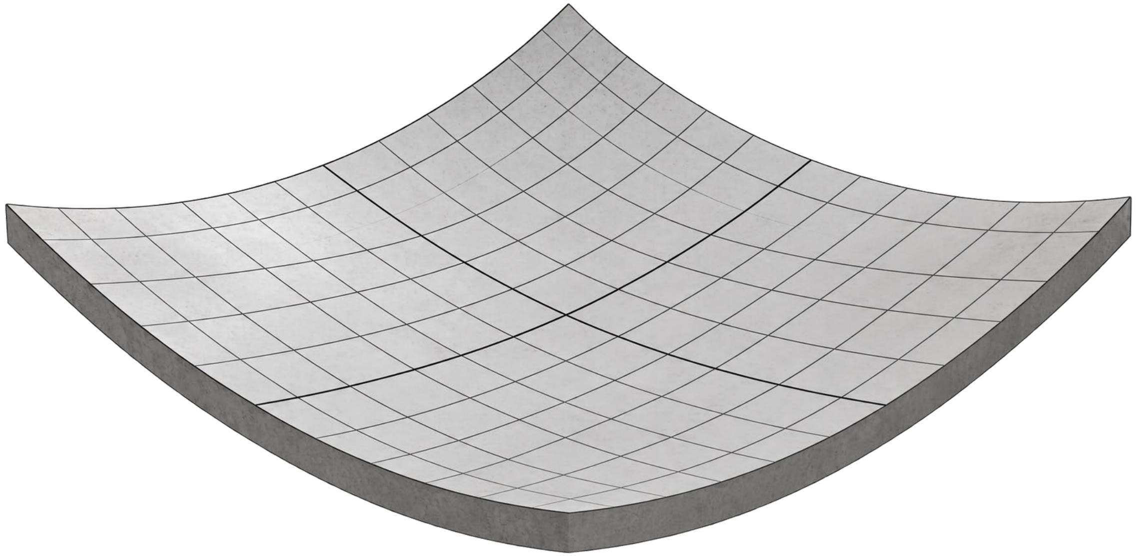
$$\text{EBITD} = \text{top/bottom temp difference (°F)} = \frac{C\,t}{a\,(C\,t + 3{,}182{,}400)}$$

where:

- a = concrete coefficient of thermal expansion (in./in./°F)
- t = slab thickness (in.)
- C = Curl Number

Curl Number can be converted to EBITD



For Construction Pros Magazine, 2026

Collection of Curl Numbers

Any Data is Better than "No Data," but it is best to have:

- Project location, date, and time of placement
- Design specifics:
  - Slab thickness, reinforcement, joint spacing, dowel details, vapor barrier or slip sheet
    - Note: contrary to beliefs, vapor barriers reduce curling by eliminating moisture migration
- Mixture proportions:
  - Cement type, lb / yd, and any additives or admixtures
    - Note: some admixtures can reduce curling, but some can increase it (significantly)
  - Aggregate & sand type gradation & proportions
  - Concrete design strength (compressive & flexural, if both are available)
- Ambient temperatures:
  - At time of placement
  - During the facilities use

Collecting this data + Curl Number will aid in design optimization

Why Measure Curl Numbers

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<u>Example (before F Numbers were measured):</u>

When asked "how do you know if you hit the slab tolerances" our good friend, Ross Martin answered…

"that's simple, you got paid your retainage"

Measurement of F Numbers produced vast improvement in floor flatness & levelness.

<u>The measurement of C Numbers will do the same for curl</u> and:

- Allow for design optimization:
  - Better slabs for less
- Reduce liability for the contractor
  - Specifications and/or mix designs that contribute to curl (<u>it's always the contractor's fault</u>)
  - Builds responsibility with the ready-mix producer, too
- Improve performance for the owner / tenant

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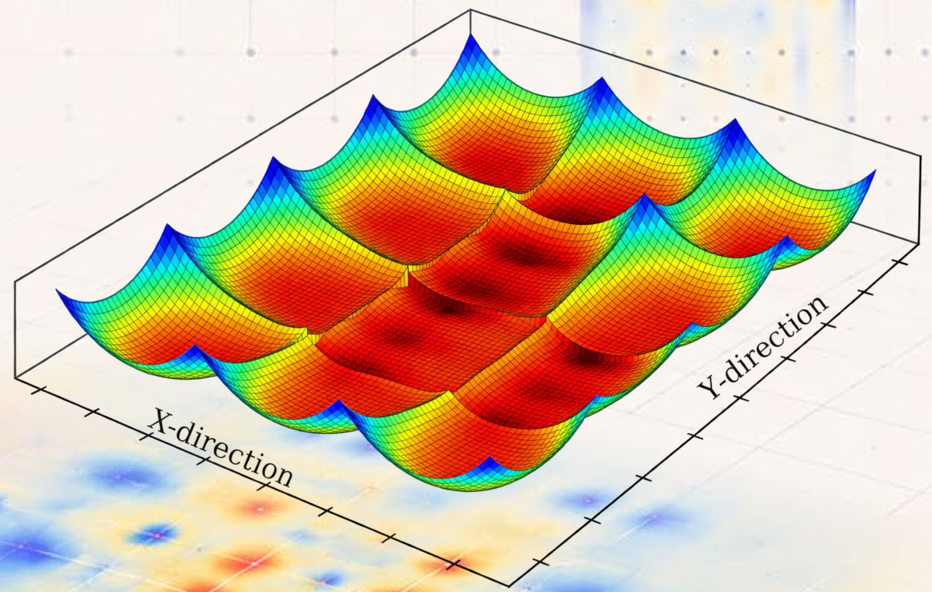
THE FUTURE OF SLAB-ON-GROUND DESIGN

Closing Remarks and Next Steps



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Comparison of Inputs Considered

Assumption	PCA	WRI	COE	SLABS™
Slab Shape	Flat Slabs	Flat slabs	Flat Slabs	Curled slabs
Subgrade Influence	Wrong	Wrong	Wrong	Analyzed Correctly
Stress location	Center of slab only	Center of slab only	Edge of slab only	Whole slab
Bottom-up cracking	Yes	Yes	Yes	Yes
Top-down cracking	No	No	No	Yes
Load transfer	Joint factor – 1.6	No	No	Yes - EIDM
Slab-to-beam ratio	No	No	No	Yes
Residual strength	No	No	No	Yes
Seismic	No	No	No	Yes

SLABS™ is more complete and accurate than PCA, WRI, or COE

Innovation for Construction

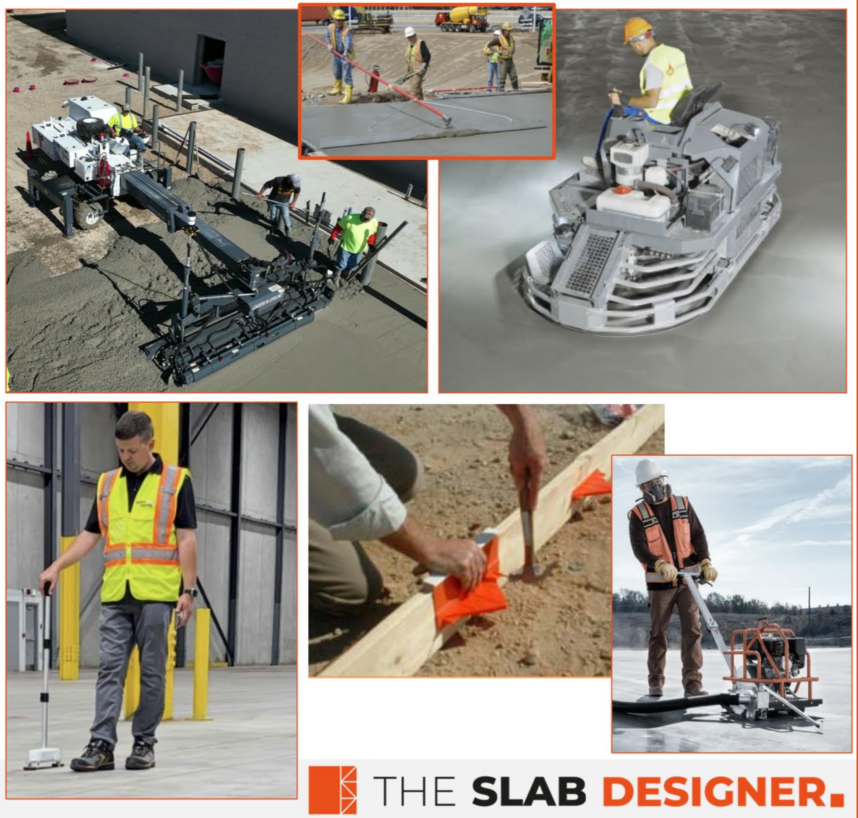
Top Innovations in Concrete Slabs…

Bill Palmer, Concrete Construction Magazine

- F Numbers
- Laser Screed & Bump-cutters
- Ride on Trowels with Pans
- Early Entry Saws
- Plate Dowels
- Armored Joints
- Vapor Barriers

Innovation in concrete slabs = construction methods & products…

Innovations in slab design has lagged behind pavements



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Innovation for Design

Design Build for Slabs - Curl Numbers for the life of the building.

General Assumptions

Loads:

- Racks: 6 high, first on floor (5 on racks)
- Pallet: 2000 lb. per
- Base Plate Size: 6”x6”
- Lift Truck: 2000 lb. load plus self weight

Support:

- Subgrade Resilient Modulus: 5,800 psi
- Subbase: 6” crushed stone

Concrete:

- Concrete Shrinkage: 550 micro-strains in 90 days
- Coefficient of Thermal Expansion: $4.5 \times 10^{-6}/° F$
- Concrete Strength: increases 10% from 28 to 90 days

Safety Factors:

- Static Safety Factor: 0.8
- Dynamic Safety Factor: 0.45

Slab Designs Considered

1. Unreinforced
2. Strategically Reinforced with Dowels
3. Enhanced Aggregate Interlock (0.1% Steel)
4. Extended Joint with Macro-Synthetic Fibers + Shrinkage Reducer
5. Crack Width Control with Steel Fibers
6. Shrinkage-Compensated Concrete (ShCC)
7. ShCC + Macro-Synthetic Fibers

1st in a series of 3

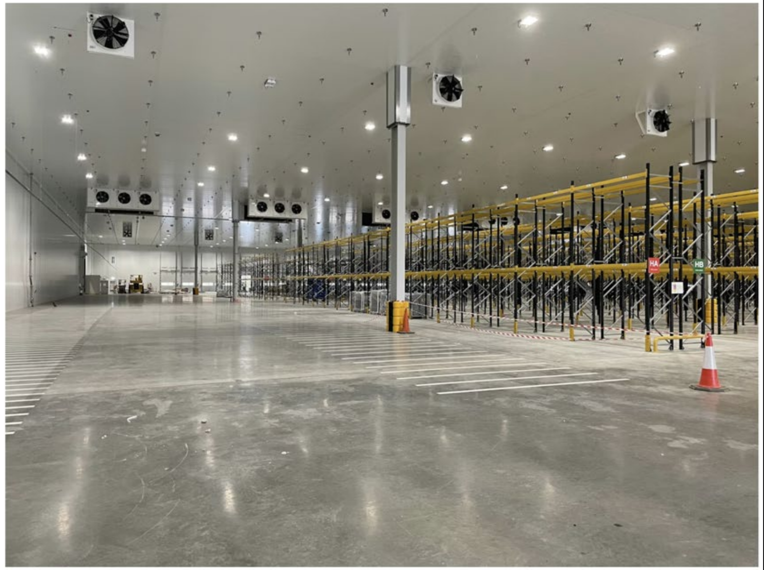
FOR Construction PROS.com®

CONCRETE | CONCRETE EQUIPMENT & PRODUCTS | TECHNOLOGY & SERVICES

Concrete Slab Design Options & Analysis

Concrete contractors have design options for concrete slabs. Here's what contractors needs to know.

By — Juan Pablo Covarrubias, P.E., Nigel Parkes, Bryan Birdwell, FACI
Jan 17, 2026
From The Slab Designer LLC



Some floor designs are better suited to specific applications than others. Understanding an owner's or tenant's requirements is critical to recommending a particular type of design.

Factors that determine the best solution are numerous and varied, and they interact to lead to a complex decision tree or matrix. These factors include, but are not limited to, facility use and conditions, construction conditions, load, floor tolerance, abrasion

Varying Design Parameters

2nd in a series of 3

#	Slab-on-Ground Type	Joint Spacing	Construction Joints	Sawcut Joints	EBITD	Concrete Strength	Concrete Shrinkage	Re3 from ASTM C1609
1	Unreinforced	15 ft (4.6 m)	Doweled	Undoweled	-25°F (-14°C)	3,500 psi (24 MPa)	600 με	-
2	Strategically Reinforced	15 ft (4.6 m)	Doweled	Dowels	-25°F (-14°C)	3,500 psi (24 MPa)	600 με	-
3	Enhanced Aggregate Interlock	15 ft (4.6 m)	Doweled	0.1% steel	-25°F (-14°C)	3,500 psi (24 MPa)	600 με	-
4	Extended Joint with Macro-Synthetic Fibers + Shrinkage Reducer	60 ft (18 m)	Doweled + Armored	N/A	-5.5°F (-3°C)	4,000 psi (27.5 MPa)	400 με	150 psi (1.0 MPa)
5	Crack Width Control with Steel Fibers	120 ft (36 m)	Doweled + Armored	N/A	-18°F (-10°C)	3,500 psi (24 MPa)	600 με	275 psi (1.9 MPa)
6	Shrinkage-Compensated Concrete (ShCC)	120 ft (36 m)	Doweled + Armored	N/A	-5.5°F (-3°C)	5,500 psi (38 MPa)	300 με	-
7	ShCC + Macro-Synthetic Fibers	120 ft (36 m)	Doweled + Armored	N/A	-5.5°F (-3°C)	5,500 psi (38 MPa)	300 με	150 psi (1.0 MPa)

Summary of Results

Dowels are for Structure and Serviceability

2^{nd} in a series of 3

#	Slab-on-Ground Type	Joint Spacing	Minimum Thickness	Serviceability Notes
1	Unreinforced	15 ft (4.6 m)	10 in. (25 cm)	Common serviceability issues include slab rocking, joint spalling, and cracking.
2	Strategically Reinforced	15 ft (4.6 m)	7 in. (18 cm)	Good performance under lift truck traffic with proper joint filling. Lower F_f & F_l tolerances than types 4 through 7.
3	Enhanced Aggregate Interlock	15 ft (4.6 m)	9.5 in. (24 cm)	Same as above but with a history of dominant joints, possibly accelerating joint spalling.
4	Extended Joint with Macro-Synthetic Fibers + Shrinkage Reducer	60 ft (18 m)	5.5 in. (14 cm)	25% of the joints to maintain. Higher F_f and F_l tolerances than types 1 through 3.
5	Crack Width Control with Steel Fibers	120 ft (36 m)	5.5 in. (14 cm)	13% of the joints to maintain versus types 1 through 3 and 50% of the joints of type 4.
6	Shrinkage-Compensated Concrete (ShCC)	120 ft (36 m)	5.5 in. (14 cm)	Fewer joints to maintain, like type 5. Higher F_f and F_l tolerances than types 1 through 3 and 5.
7	ShCC + Macro-Synthetic Fibers	120 ft (36 m)	5 in. (13 cm)	Fewer joints to maintain, like types 5 and 6. Highest F_f and F_l tolerances. Best overall performance.

Summary of Results

The Significance of Curling and Fibers

2^{nd} in a series of 3

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Slab Thickness Does Not Define Performance!

Relative Cost Survey Underway

Quality Need Not Cost More – Lower Capacity can Cost More!

3rd in a series of 3

#	Slab-on-Ground Type	Joint Spacing	Minimum Thickness	Relative Cost *
1	Unreinforced	15 ft (4.6 m)	10 in. (25 cm)	**100%**
2	Strategically Reinforced	15 ft (4.6 m)	7 in. (18 cm)	**(18% less)**
3	Enhanced Aggregate Interlock	15 ft (4.6 m)	9.5 in. (24 cm)	**(8% less)**
4	Extended Joint with Macro-Synthetic Fibers + Shrinkage Reducer	60 ft (18 m)	5.5 in. (14 cm)	**(22% less @ 7 lbs macro)**
5	Crack Width Control with Steel Fibers	120 ft (36 m)	5.5 in. (14 cm)	**(3% less)**
6	Shrinkage-Compensated Concrete (ShCC)	120 ft (36 m)	5.5 in. (14 cm)	n/a
7	ShCC + Macro-Synthetic Fibers	120 ft (36 m)	5 in. (13 cm)	n/a

All designs cost less than “unreinforced” IF the true capacity is equalized in the design

* *Data from one contractor, who does not construct shrinkage comp floors*

See slabs.design/workshop for:

1. **Concrete Slab-on-Ground Thickness Requirements From Modern Design**
   ForConstructionPros, Jul. 2026
2. **Mechanistic-Empirical Design of Concrete Slabs-on-Ground**
   Concrete International, Jul. 2026
3. **Addressing Concrete Slab Curl Numbers**
   ForConstructionPros, May 2026
4. **Concrete Slab Design Options & Analysis**
   ForConstructionPros, Jan. 2026
5. **Optimize Concrete Slab Dowel Design**
   ForConstructionPros, Oct. 2025

An Article Discussing TR34
Concrete, The Concrete Society — September 2026
By the presenters of today's workshop

AMERICAN SOCIETY OF
CONCRETE CONTRACTORS

LIVE WEBINAR

Why "Meets Design" Doesn't Always Stop Slab Cracking & Joint Spalling

Understanding the Real Drivers Behind Distress – and What We Can Do About Them

WEDNESDAY, SEPTEMBER 23, 2026
3:00 – 4:00 PM CDT
Live Online

PRESENTED BY
ROBERT RODDEN
The Slab Designer

REGISTER TODAY!
ascconlineinfo.org/event/why-meets-design-doesnt-always-stop-slab-cracking-joint-spalling-with-robert-rodden/

Next Steps

- **Complete the post-webinar survey** to request:
  - a CEU certificate (you are responsible for determining applicability to your individual licensing requirements.),
  - access to SLABS™,
  - a 1-on-1 meeting, or
  - to be notified when the team publishes new articles
- **Intermediate Workshops** around Fall **ACI**, at the Atlanta Hilton:
  - Sunday, October 11th
  - Tuesday, October 13th

  These include worked examples, deeper theory, open Q&A

Thank You

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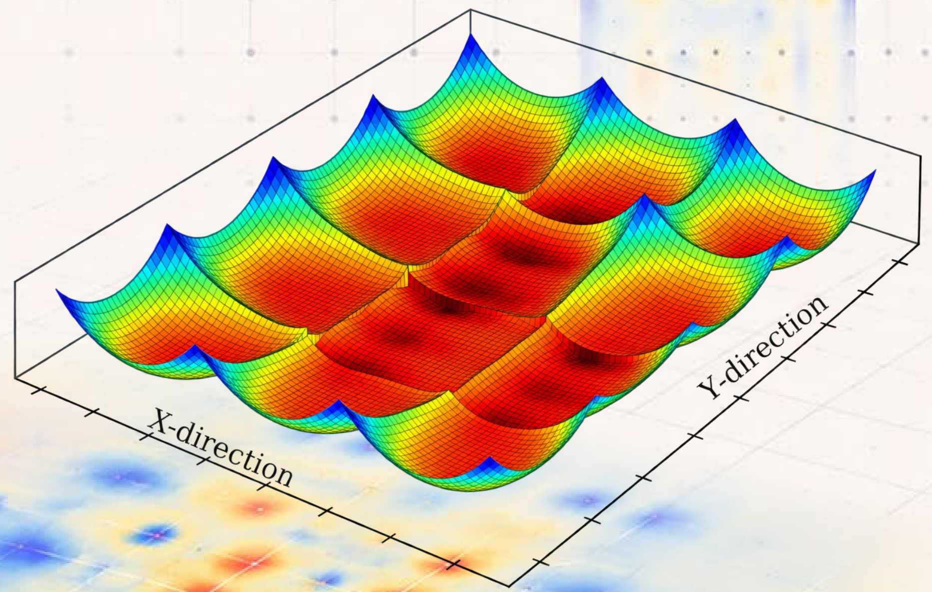
Questions & Answers



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