Roller Compacted Concrete Structural Design Methods

Review
of International Practice

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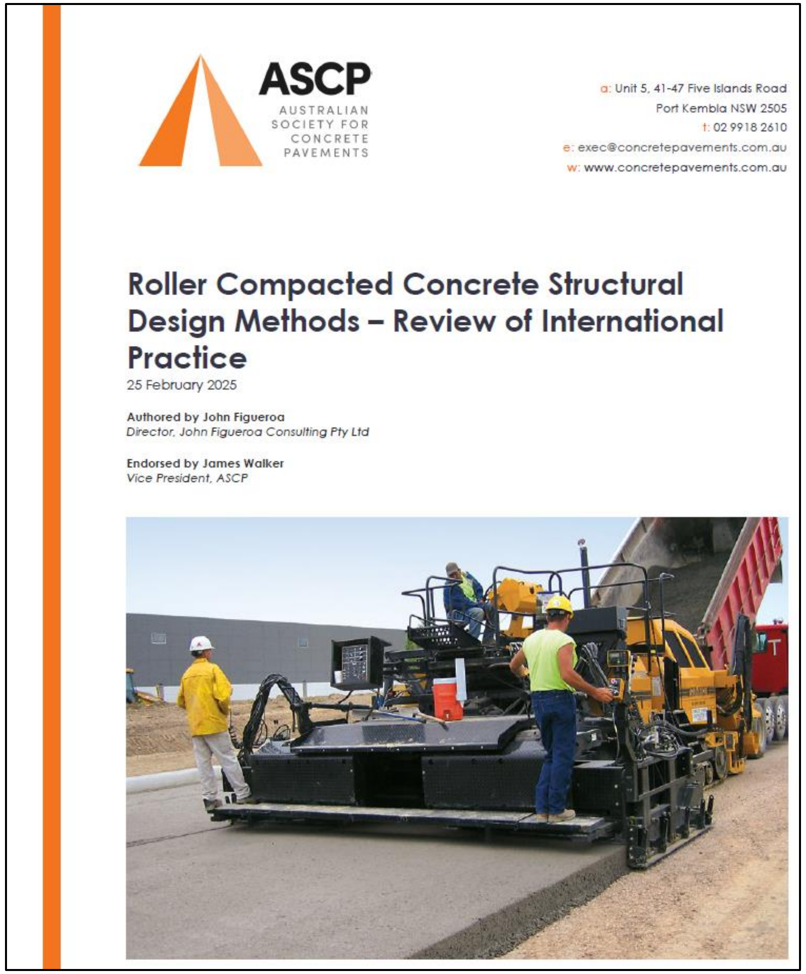
Work funded by ASCP Innovation Fund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Roller Compacted Concrete Structural Design Methods – Review of International Practice

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Today's content

1. What is RCC Pavement?
2. RCC Mixture Properties
3. Review of RCC Fatigue Models
4. Design Methods and Computer Programs
5. RCC Paving Practice
6. RCC Curing and Sawcutting of Joints
7. Summary and Acknowledgments

What is an RCC Pavement?

Like conventional concrete pavement

- Same basic ingredients
- Similar mechanical properties
- Curing is critical!

Like asphalt pavement

- Similar aggregate gradation
- Similar placement and compaction

RCC Pavement

- Stiffer than zero-slump concrete
- Plant mixed and transported in dump trucks
- Placed with a high-density asphalt paving machine
- Paved and rolled to ensure high compacted density
- Cured with water or curing compound

Source: TxDOT

Conventional concrete vs RCC

Material Proportions (% by weight)

Material	Conventional Concrete	RCC
Water	~7%	~5%
Cement	~15%	~12%
Fine Aggregate	~30%	~45
Coarse Aggregate	~50%	~35%

Workability, Paving, and Consolidation

- Conventional concrete for slip-form paving is:
  - Plastic and flowable
  - But stiff enough to maintain shape
  - Consolidated with internal and surface vibrators
  - Completed in one pass
- Roller compacted concrete:
  - Has the consistency of damp dirt
  - Is very stiff but fluid enough to distribute paste under vibratory rollers
  - Is laid in multiple lifts when total pavement thickness is greater than ~250 mm.

Reinforcement

- Conventional concrete pavement:
  - Always has some kind of reinforcement
- RCC pavement:
  - NONE

Finishing

- Conventional concrete pavement:
  - Tining
  - Hessian drag
- Roller compacted concrete pavement:
  - No finishing
  - Rolled surface is the riding surface
  - Broomed surface after the application of a finishing aid
  - Can be diamond ground to improve ride quality

Source: TxDOT

Conventional concrete vs RCC

Flexural Strength (MPa) = 0.79 $\sqrt{fc}$ (about 5% higher than that of conventional paving concrete)

Elastic Modulus (MPa)= 4,900 $\sqrt{fc}$ (slightly than that of conventional paving concrete)

Flexural and splitting tensile strength data from U.S. projects

Source: Rollings (1988)

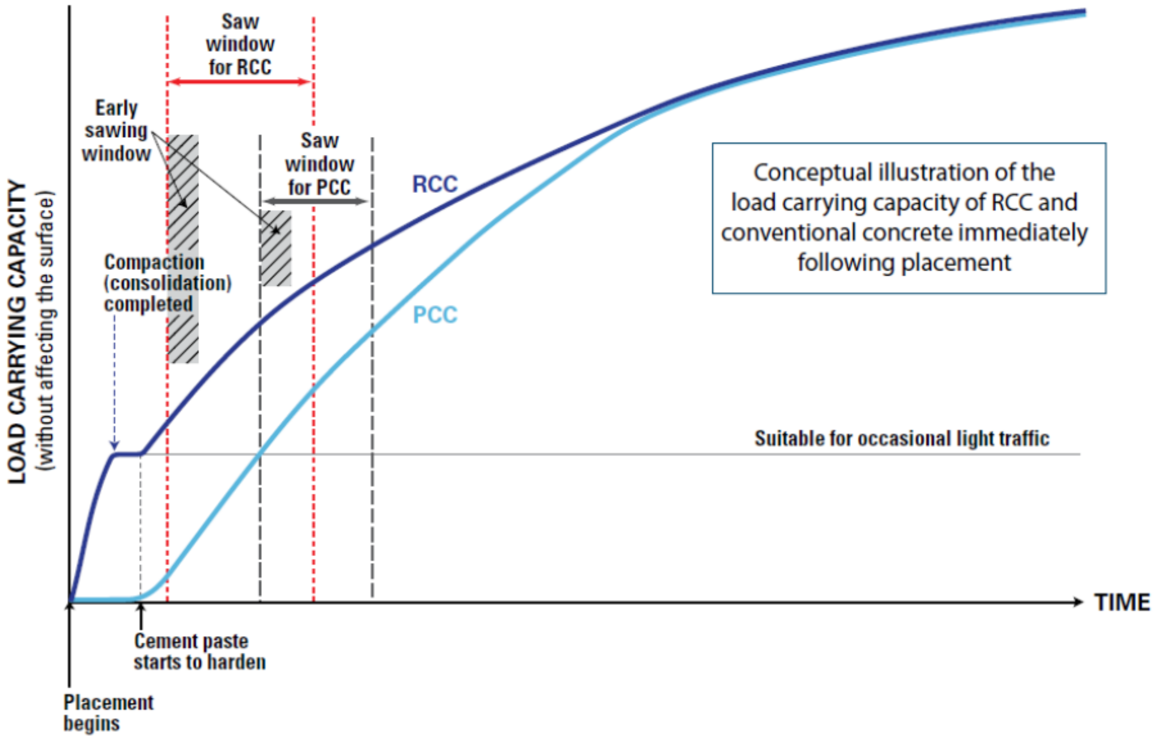
Project	Age, days	Sawed beam and core test results	
		Average flexural strength, MPa	Average splitting tensile strength, MPa
Ft. Stewart	90	7.0	—
Ft. Hood	7	4.6	—
	28	5.7	—
Harvey Barracks	7	—	2.3
	28	5.4	2.8
Ft. Campbell	7	4.5	2.7
	28	—	—
Aberdeen Proving Ground	7	3.8	2.6
	28	4.3	3.1

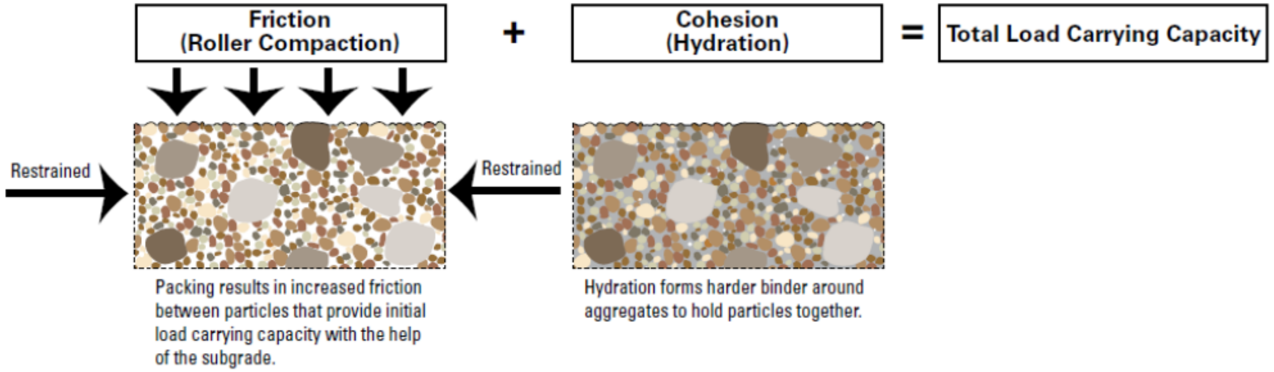
Flexural strength from sawn beams extracted from the pavement

Source: Rollings (1988)

Test	Flexural Strength (MPa)	Source of Data
Ft. Hood	5.78 5.72	Ft. Worth District US Army Corps of Engineers
Ft. Lewis	3.33 3.59 3.96	Seattle District US Army Corps of Engineers
Ft. Benning	4.90	Savannah District US Army Corps of Engineers
Kitzingen	5.40 6.43	Pittman 1988
Toole Army Depot	5.57	Hess 1987

RCC behaviour over the first few days after paving





Source: CP Tech Center (2010)

Advantages of RCC Pavements

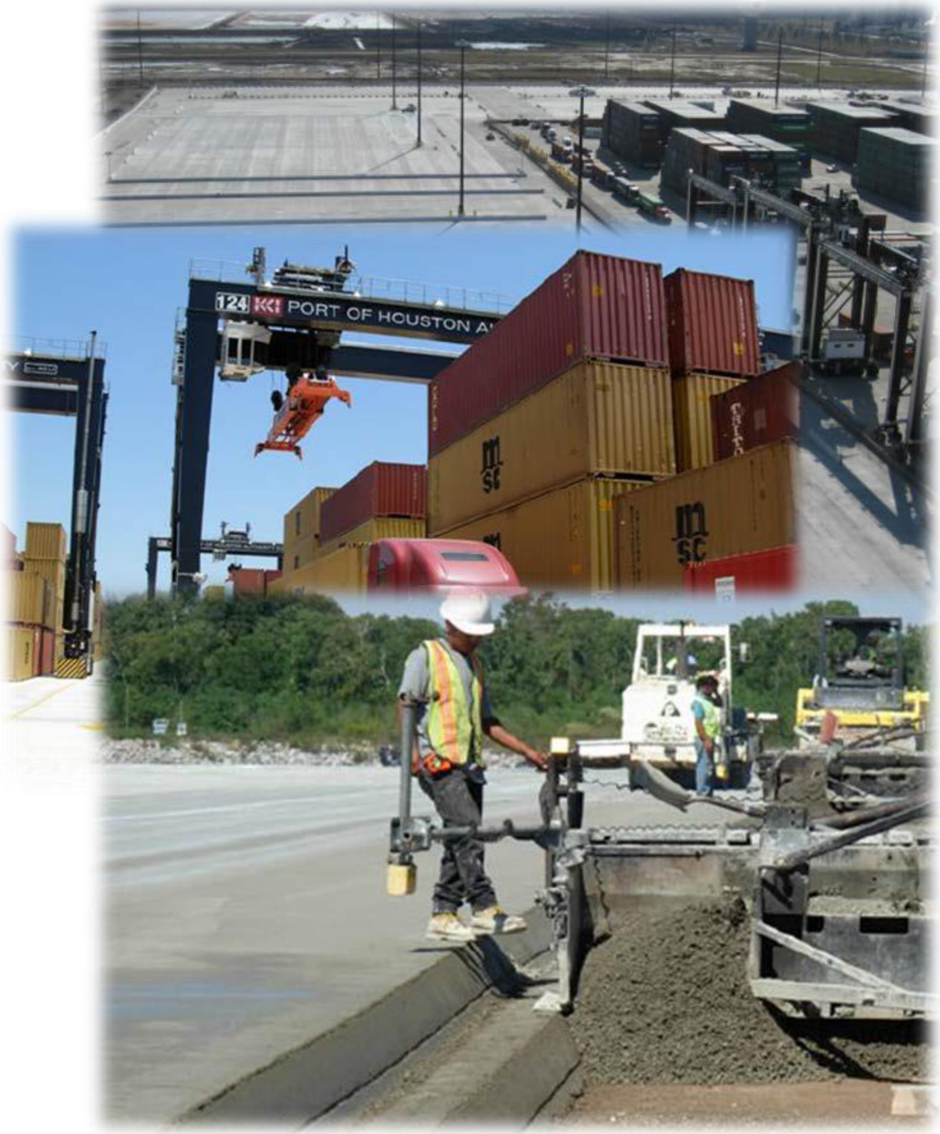
- Durability benefit of concrete
- Faster construction
- (Potential) cost savings
- Higher solar reflectance

Source: TxDOT

Where can RCC be used?

- Large open areas for easy construction
  - Ports
  - Industrial facilities
  - Carparks
  - Container yards

- Example: The Port of Houston
  - 3 different pavement designs
    - Thickness ranged from 350 – 460 mm
  - Port estimates RCC shortened construction by 4 months
  - 7-day compressive: 30 MPa
  - 7-day flexural: 3.9 MPa



Source: TxDOT

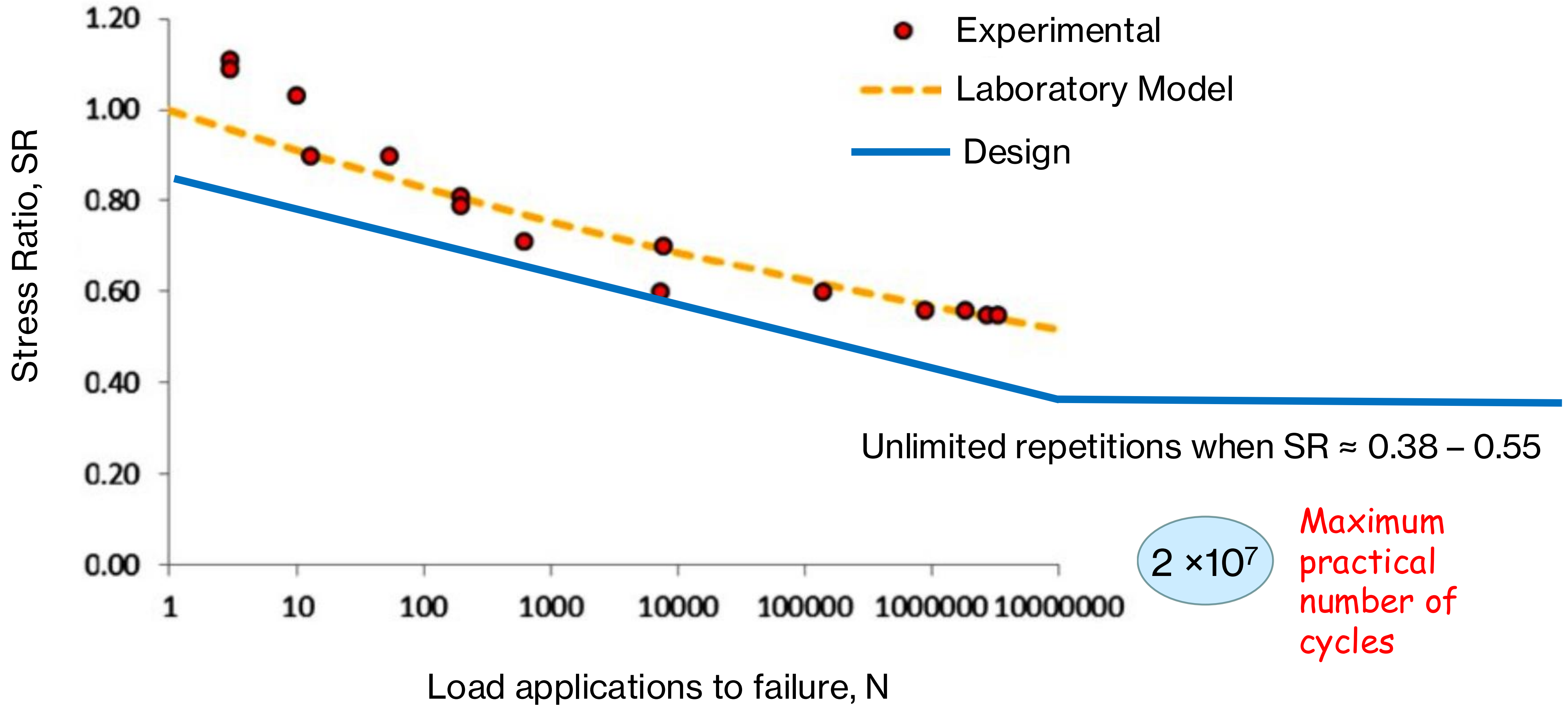
Can RCC be used in roads?

- Slow(er) speed traffic
  - Arterial and local streets
  - Shoulders

- Example: San Angelo, TX
  - TxDOT reconstructed a number a streets with RCC pavement
  - Diamond ground surface for smoothness
- Example: Georgia DOT
  - I-285 shoulder replacement
  - 150 – 200 mm thickness
  - Rumble strips ground into RCC

Source: TxDOT

Concept of Fatigue Endurance Limit



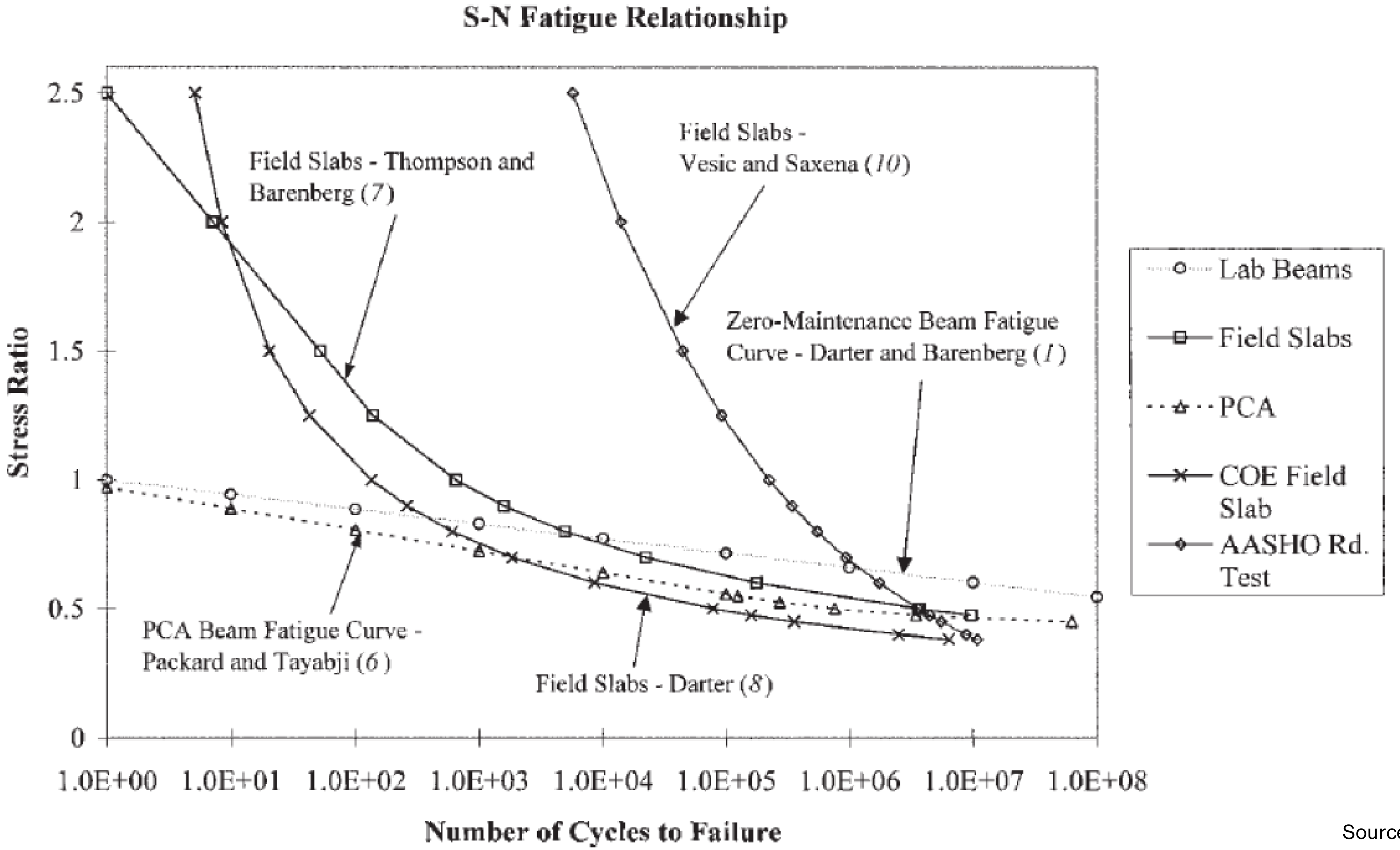
Unlimited repetitions when SR ≈ 0.38 – 0.55

2×10^7 Maximum practical number of cycles

Fatigue Endurance Limits used in Design

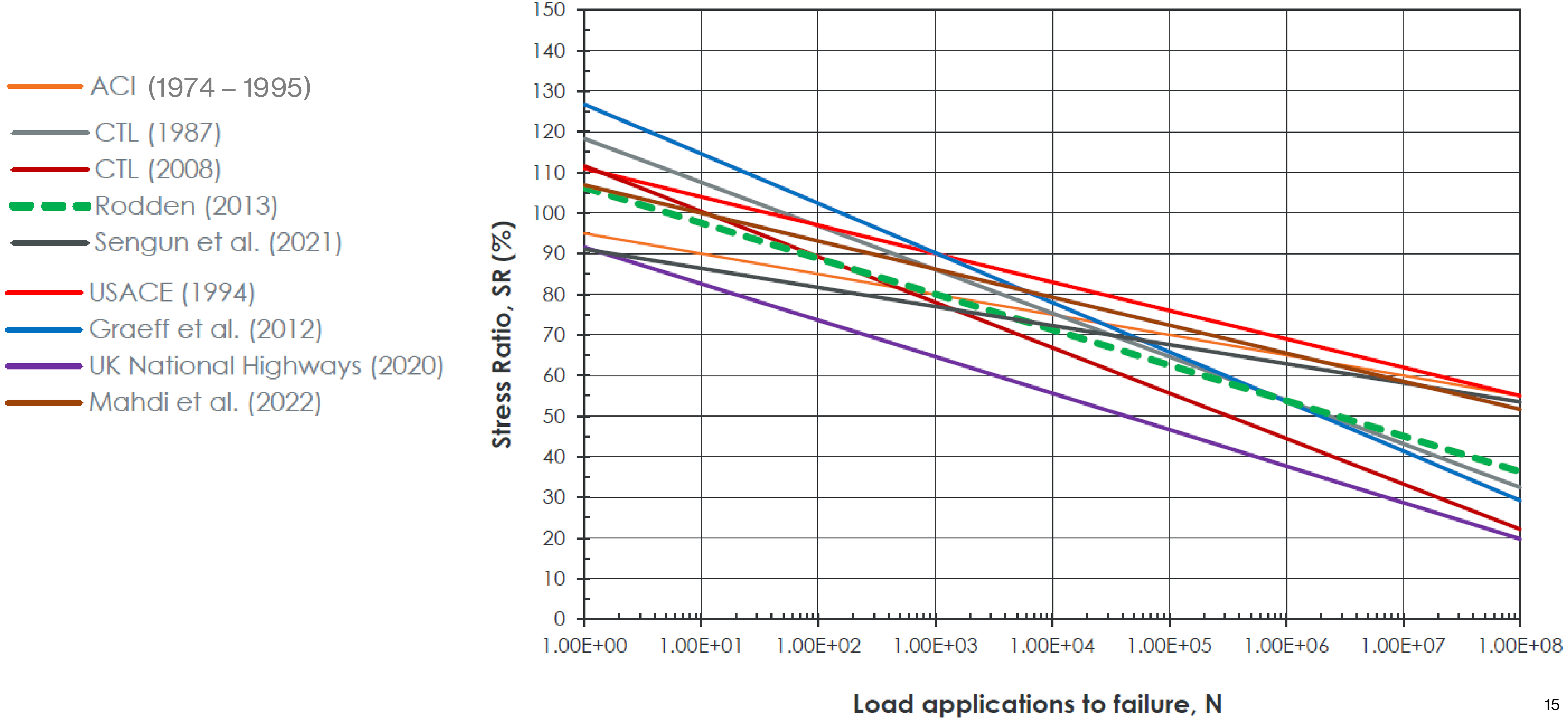
Use	**Fatigue endurance limit**	**Method**
Road pavements	45%	1984 PCA
Industrial / Intermodal	40%	1987 PCA
	38%	2002 PCA
	50%	2018 PavementDesigner.org
Airport pavements	50%	2011 AirPave

Flexural Behaviour of Concrete Slabs

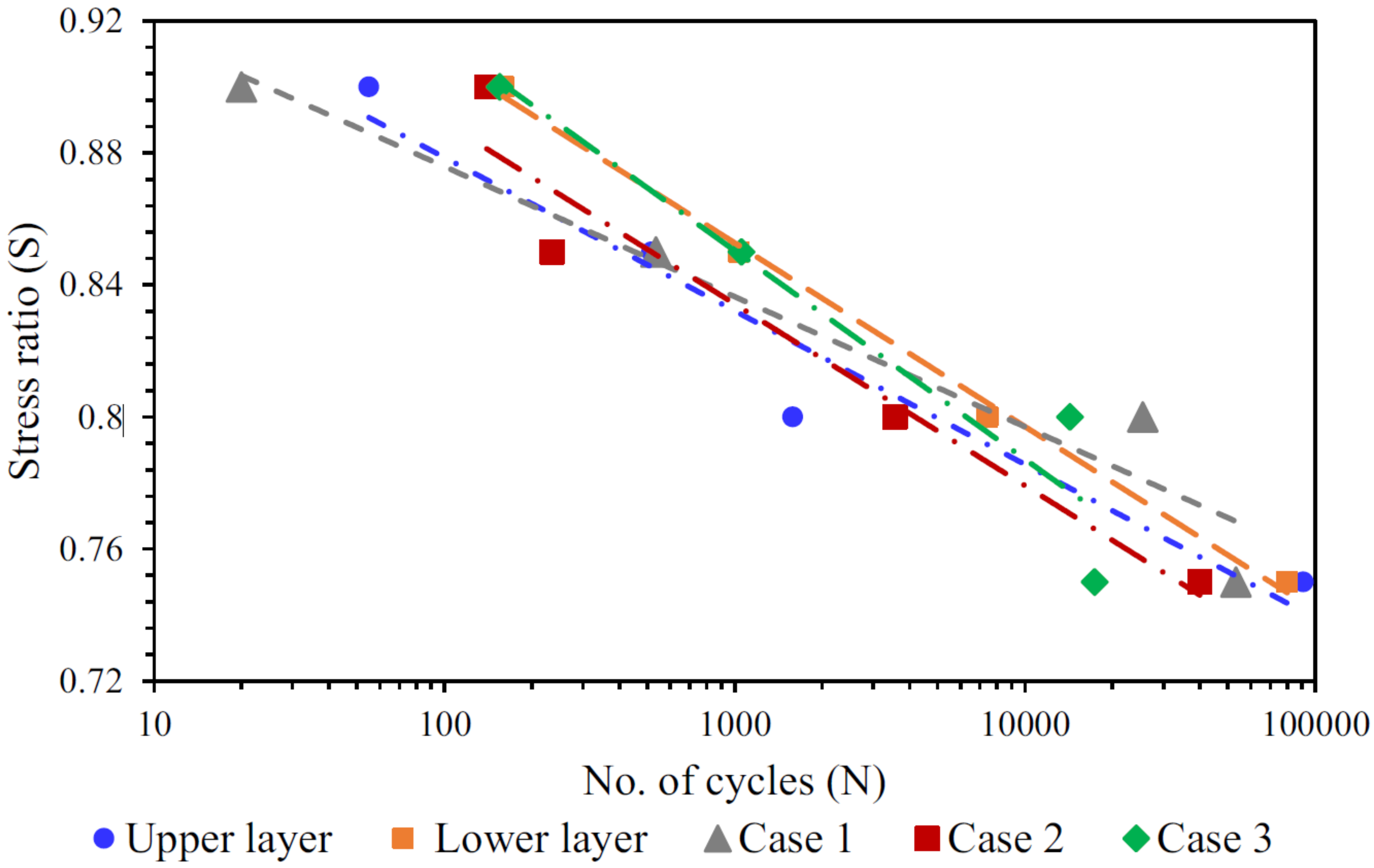


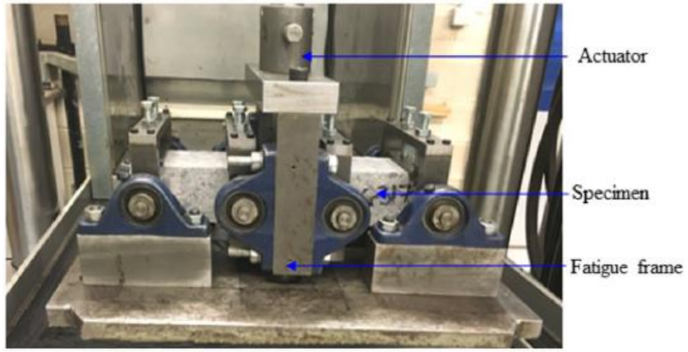
Source: Roesler (1999)

RCC Fatigue Curves from Laboratory Studies



Recent PhD work undertaken at Nottingham





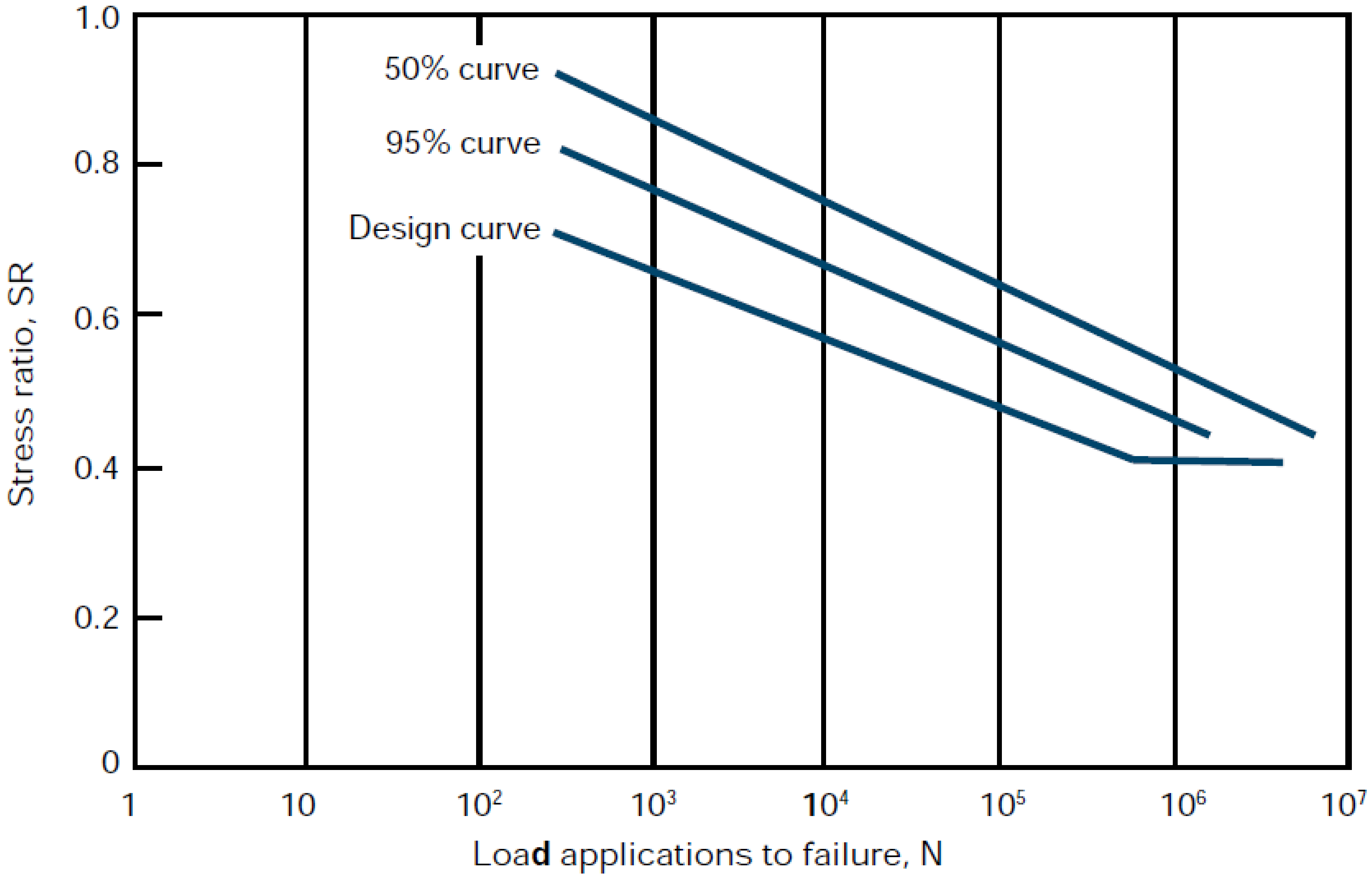
Four-point bending test setup

Source: Mohammed, Abed & Thom (2022)

Reliability in RCC Pavement Design

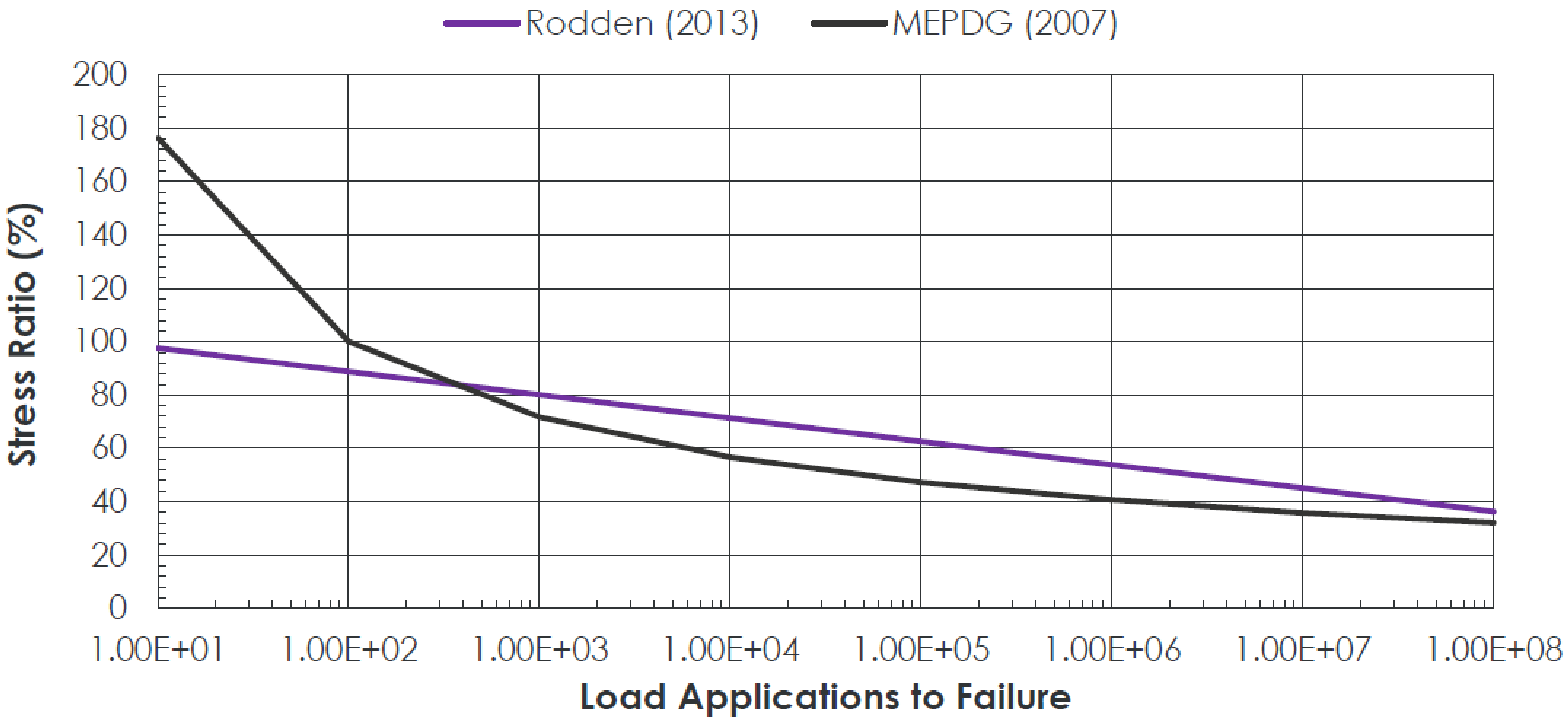
CTL / PCA Model (1987)

- 99% Reliability Level
- No Load Safety Factor
- Low Fatigue Endurance Limit

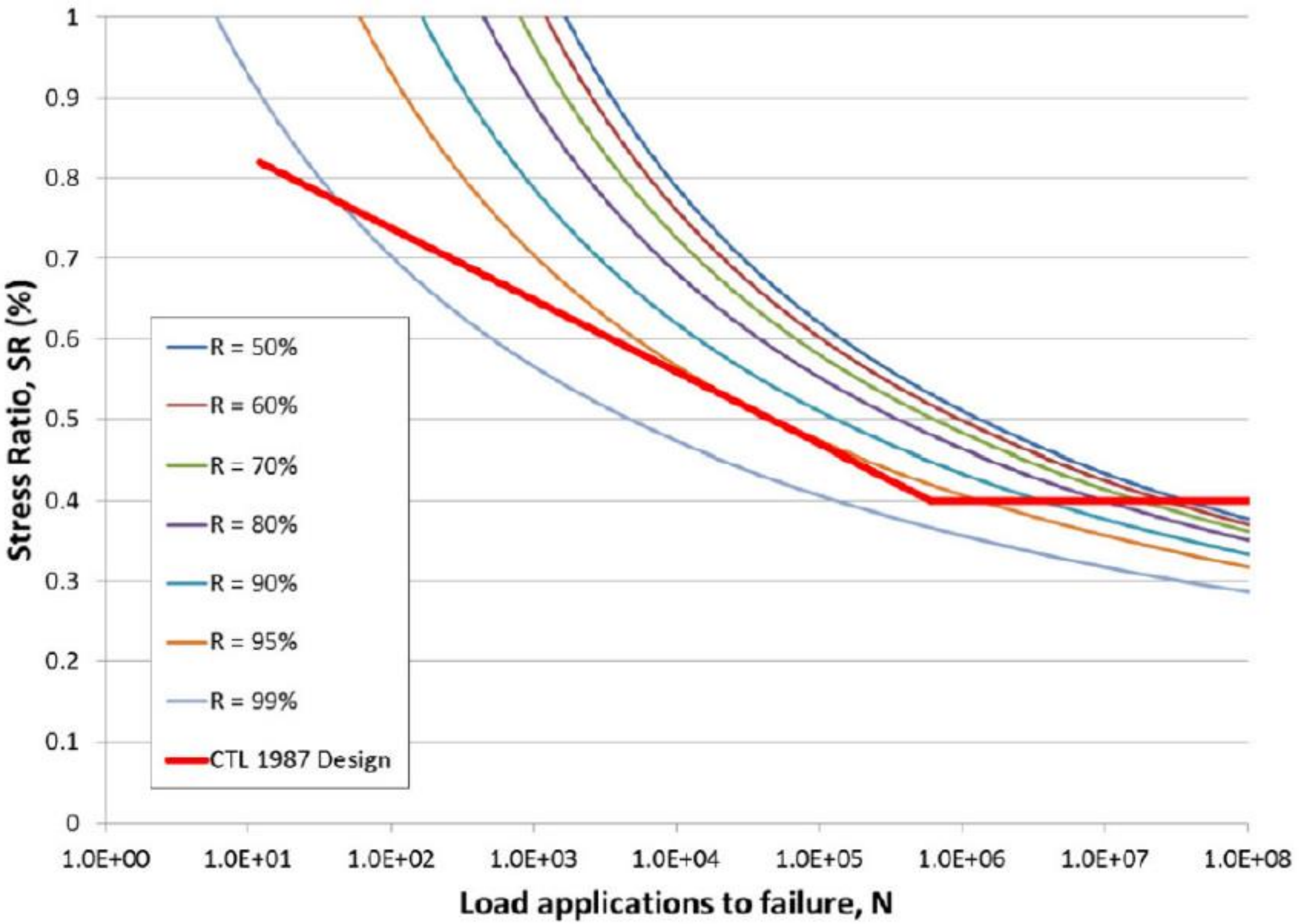


Source: CP Tech Center (2010)

Pavement ME Concrete Fatigue Model (MEPDG)



StreetPave Fatigue Model vs 1987 RCC PCA Model



StreetPave Fatigue Model

Design Reliability (%)

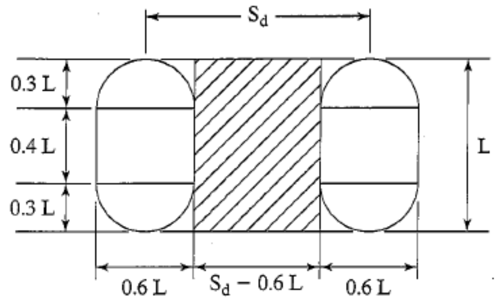
Slabs Cracked at end of life (e.g. 15%)

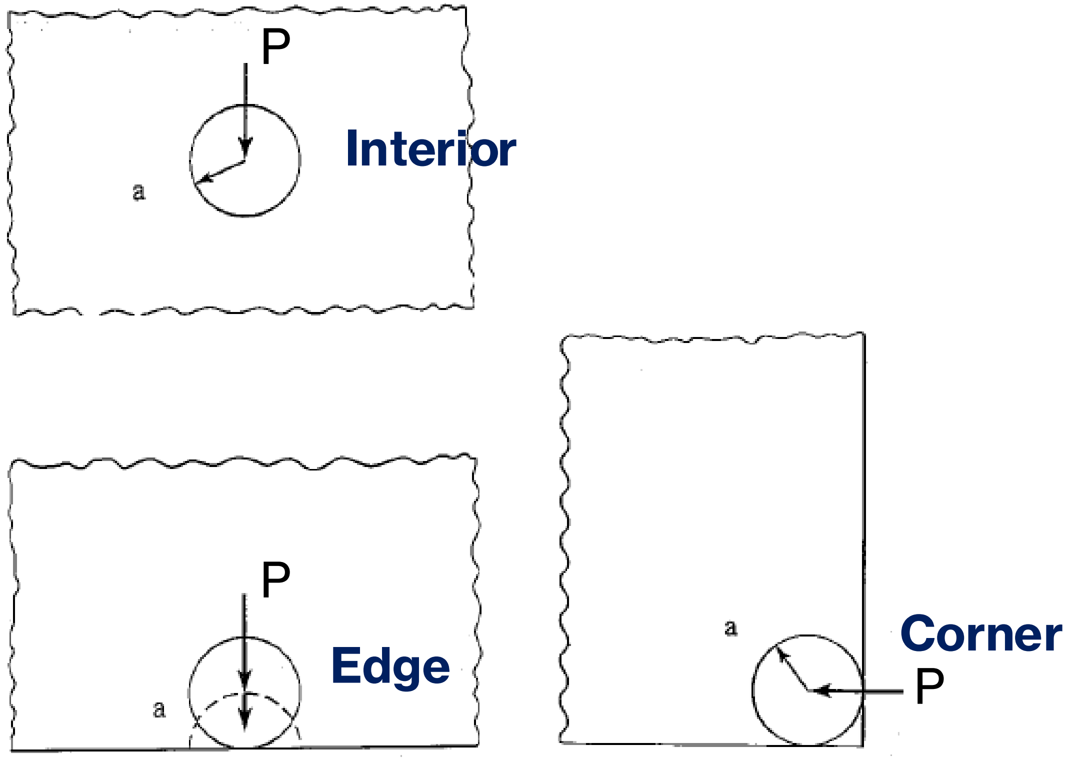
Source: Rodden (2013)

Typical Loading Case Scenarios

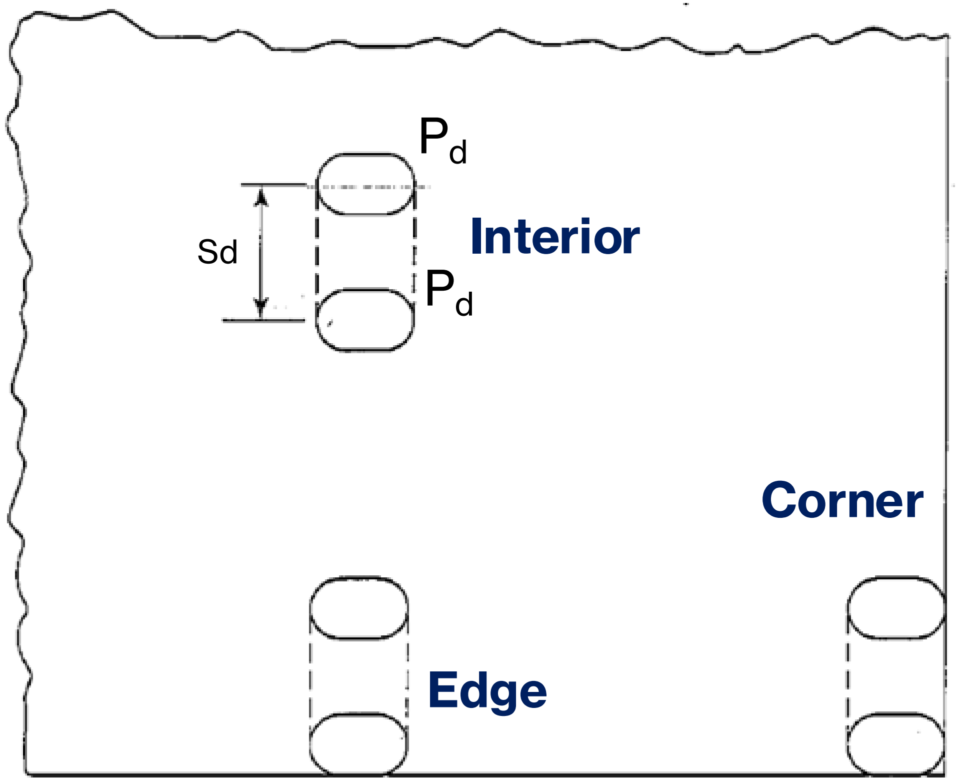
radius of contact area is

$$a = \sqrt{\frac{0.8521 P_d}{q\pi} + \frac{S_d}{\pi}\left(\frac{P_d}{0.5227q}\right)}^{1/2}$$





Single Wheel Load



Dual Wheel Load

Source: Huang (2004)

Load Transfer Efficiency at Construction Joint

Source: Gomaco RTP-500 -Ohio Industrial Loop Road (2011)

Source: Kemper Construction

There is little or no aggregate interlock at construction joints

For design purposes, assume LTE ≈ 0%

RCC Thickness Design Methods

Portland Cement Association

CONCRETE

INFORMATION

Structural Design of Roller-Compacted Concrete for Industrial Pavements

PCA Publication No IS233.01

Design for Interior Loading, but …

… Unlike highways where all wheel loads run very close to the pavement edge, the critical wheel-load placement for industrial facilities is considered to be at the interior of the pavement, away from pavement edges. **Where vehicles will be expected to travel at or on and off pavement edges the edge thickness should be increased 20%.**

Source: PCA (1987)

RCCPave

SOFTWARE FOR THE THICKNESS DESIGN OF ROLLER-COMPACTED CONCRETE PAVEMENT

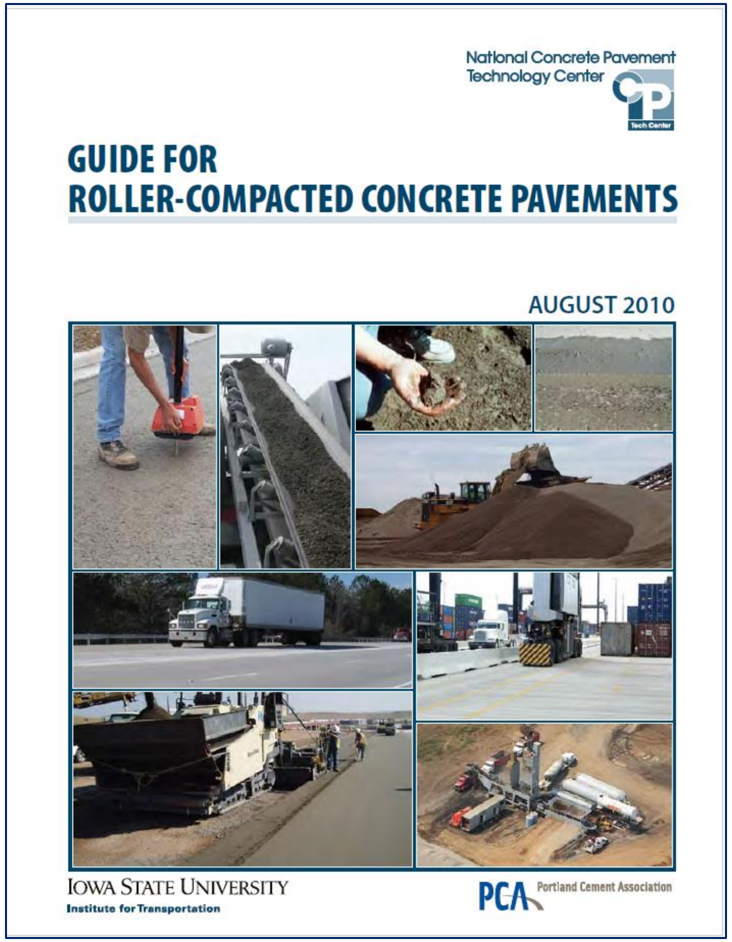
CTL – PCA Fatigue Model

Design for:

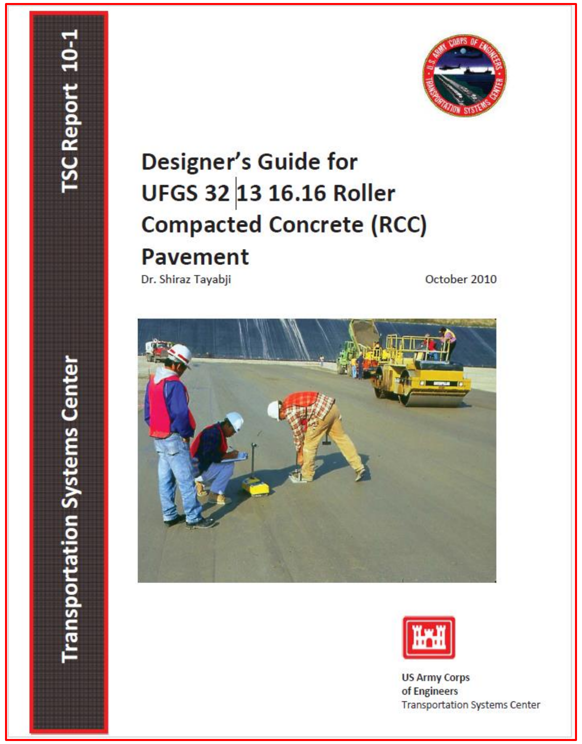
- Interior Loading
- Edge Loading

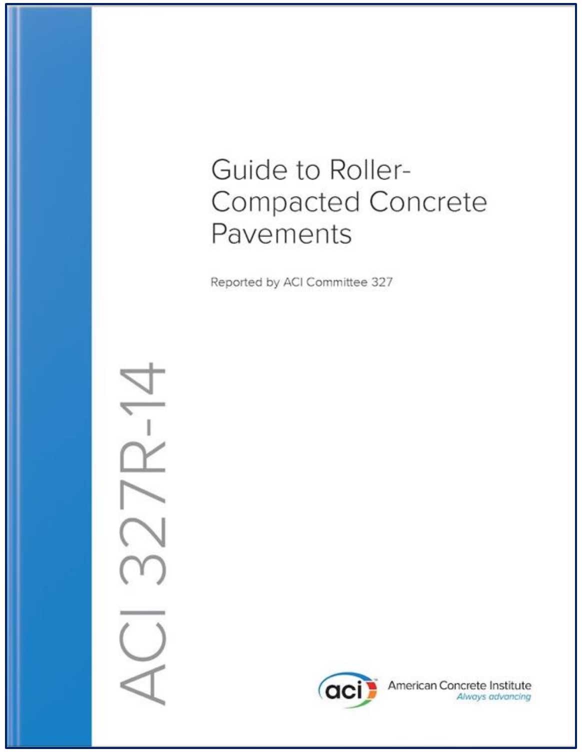
Source: CTL (2008)

RCC Design Guides

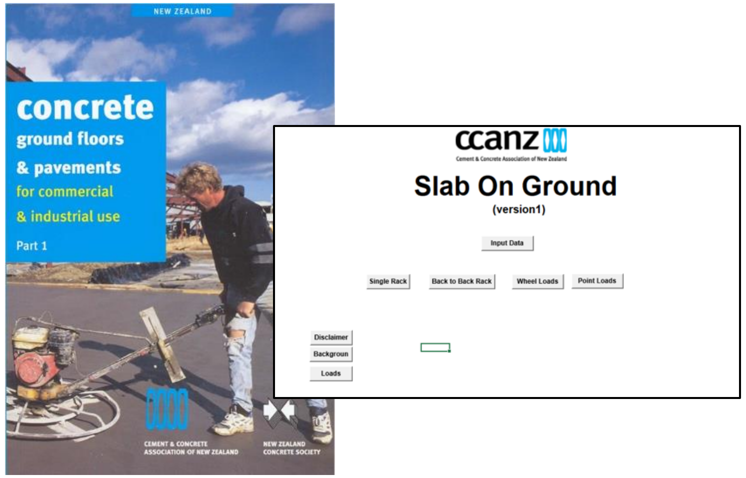


The fatigue curve traditionally used in RCC pavement design is more conservative than the fatigue curve traditionally used in conventional concrete pavement design. When designing RCC pavements using conventional pavement design software (such as WinPAS or Street-Pave), it is recommended to that the default reliability level be increased by 5 percent to achieve results comparable to those of traditional RCC pavement design software (such as RCC-PAVE).



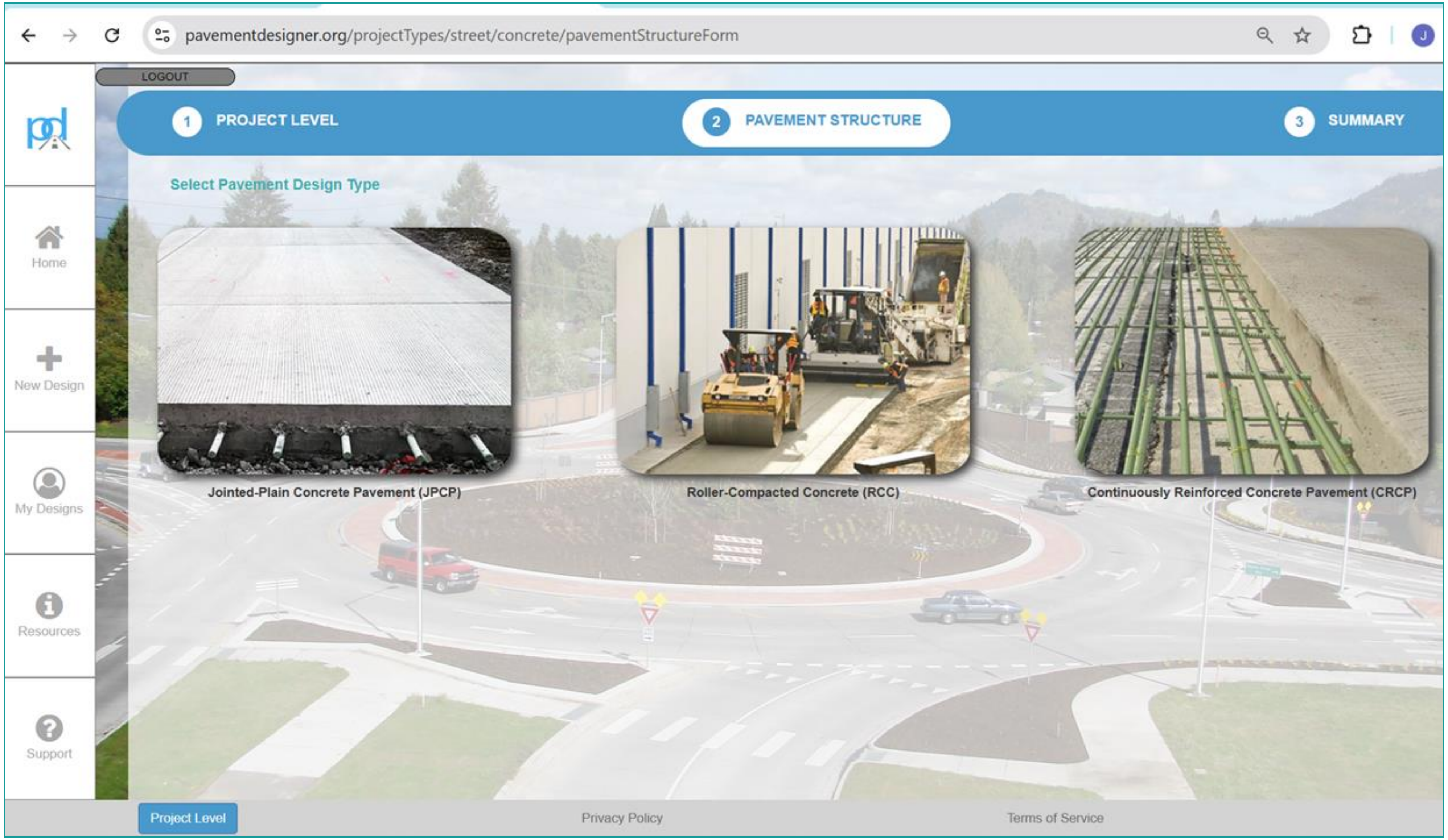


General Concrete Pavement Design Software



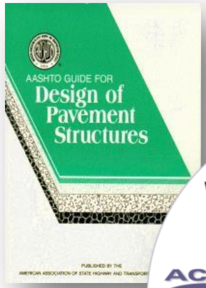
PavementDesigner.org

Street Module in PavementDesigner.org



Other Programs (not used in Australia)

AASHTOWare Pavement ME
(previously known as
DARWin-ME and MEPDG)



AASHTO 93
(ACPA WinPAS)

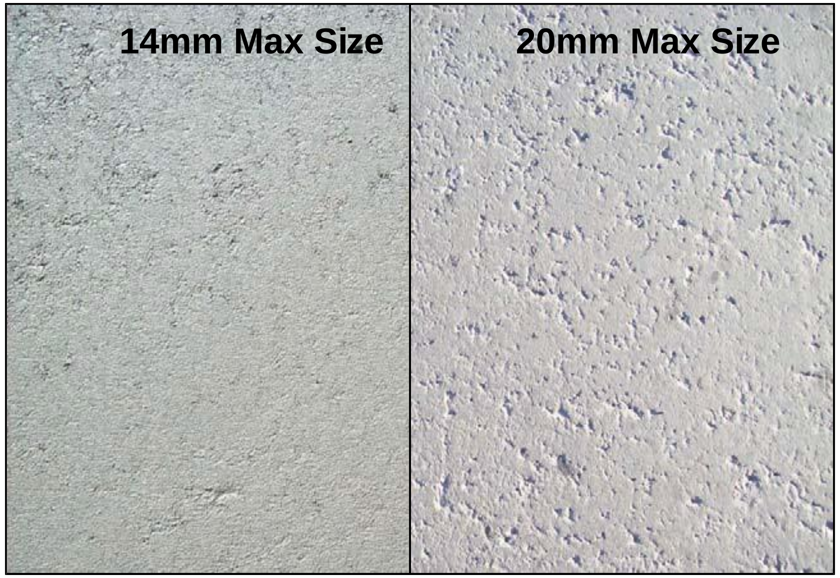
Source: Rodden (2014)

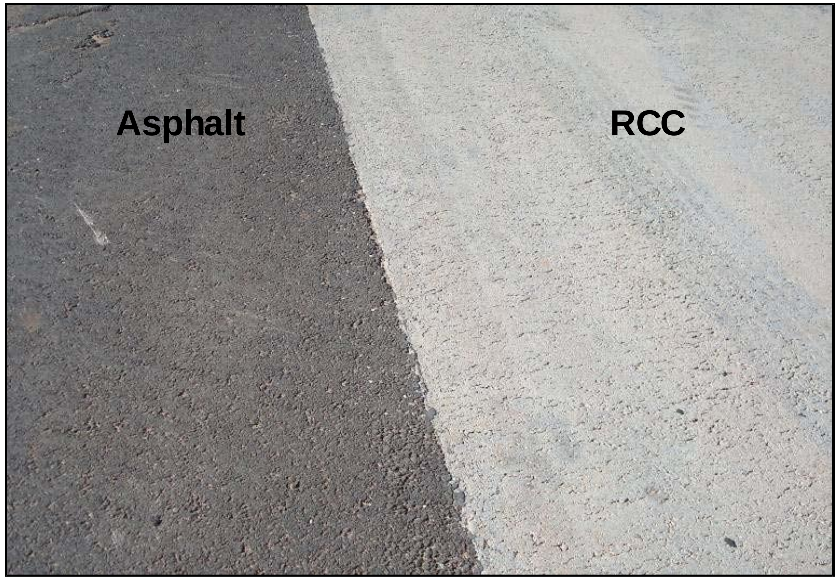
RCC Paving Practice

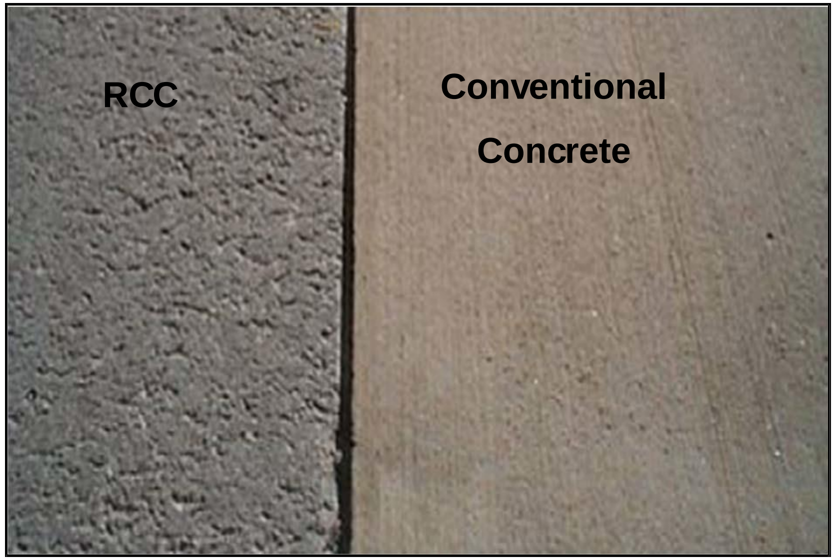
- High density screed (Vogele or ABG Titan)
- High initial density from paver (90% - 96%)
- Availability is increasing, but still limited
- Smoother surface due to higher initial density
- Less “roll down” to achieve final density
- High-production (1.8 to 2.4 m/min)
- Lift thick range: 100 mm to 230 mm
- Strongly RECOMMENDED

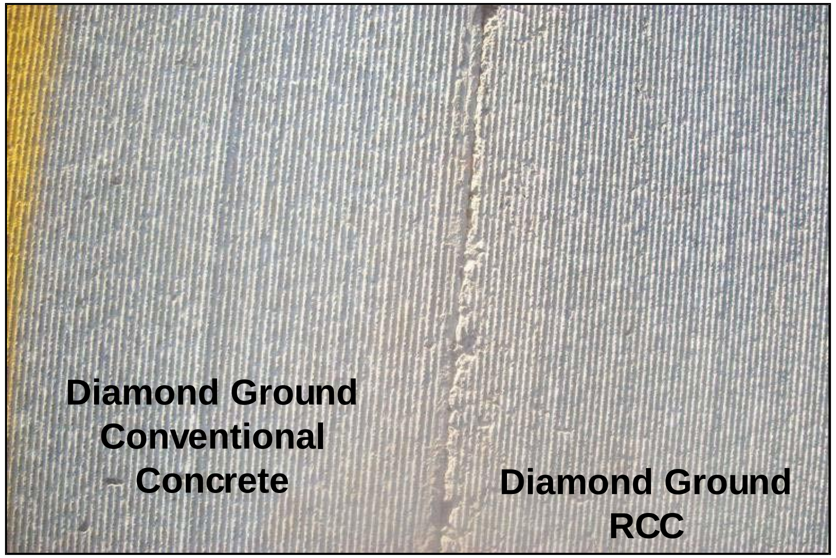
Source: A.G. Peltz – Bayport Container Yard , Port of Houston (2018)

RCC Surface Characteristics



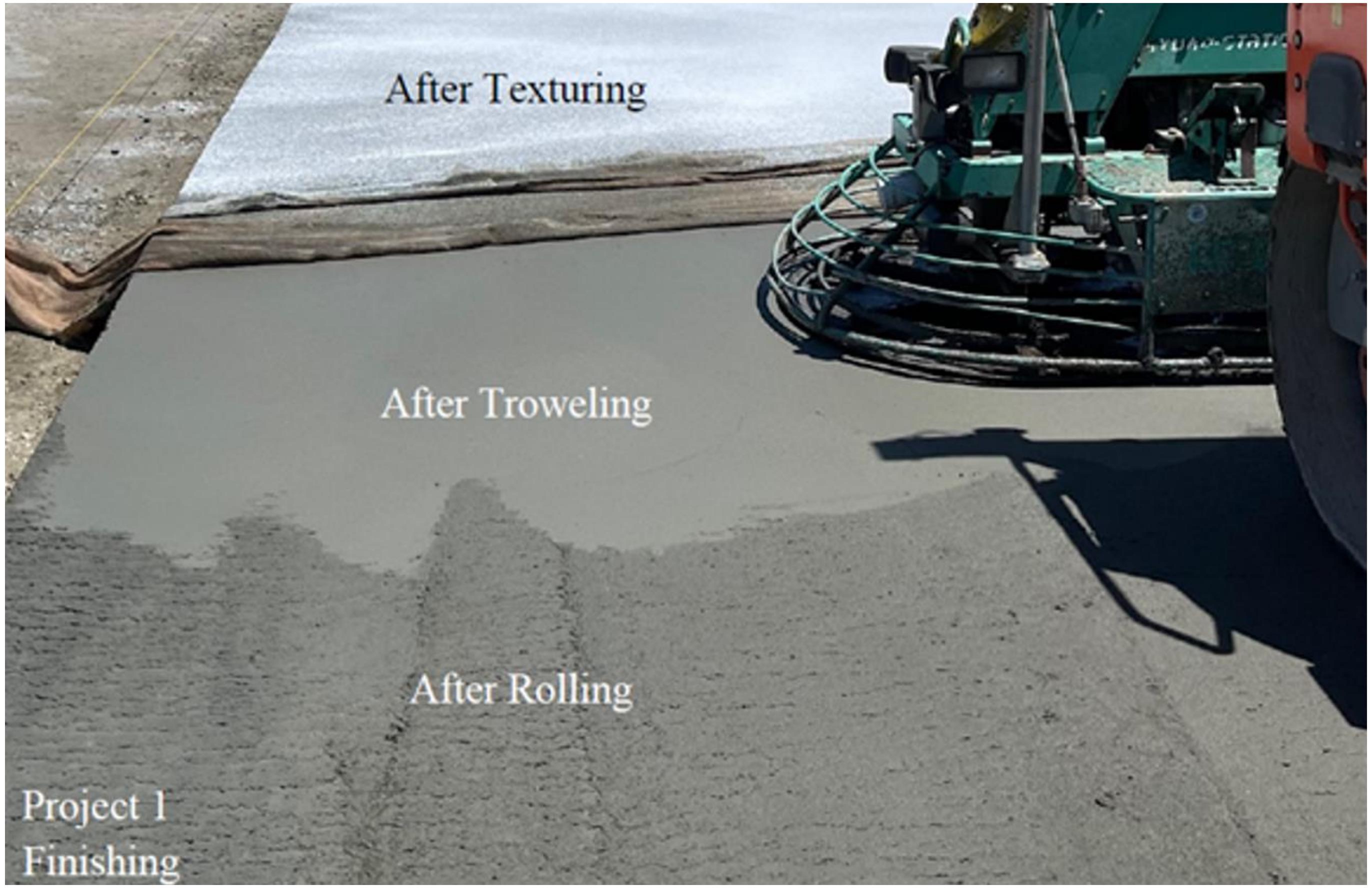




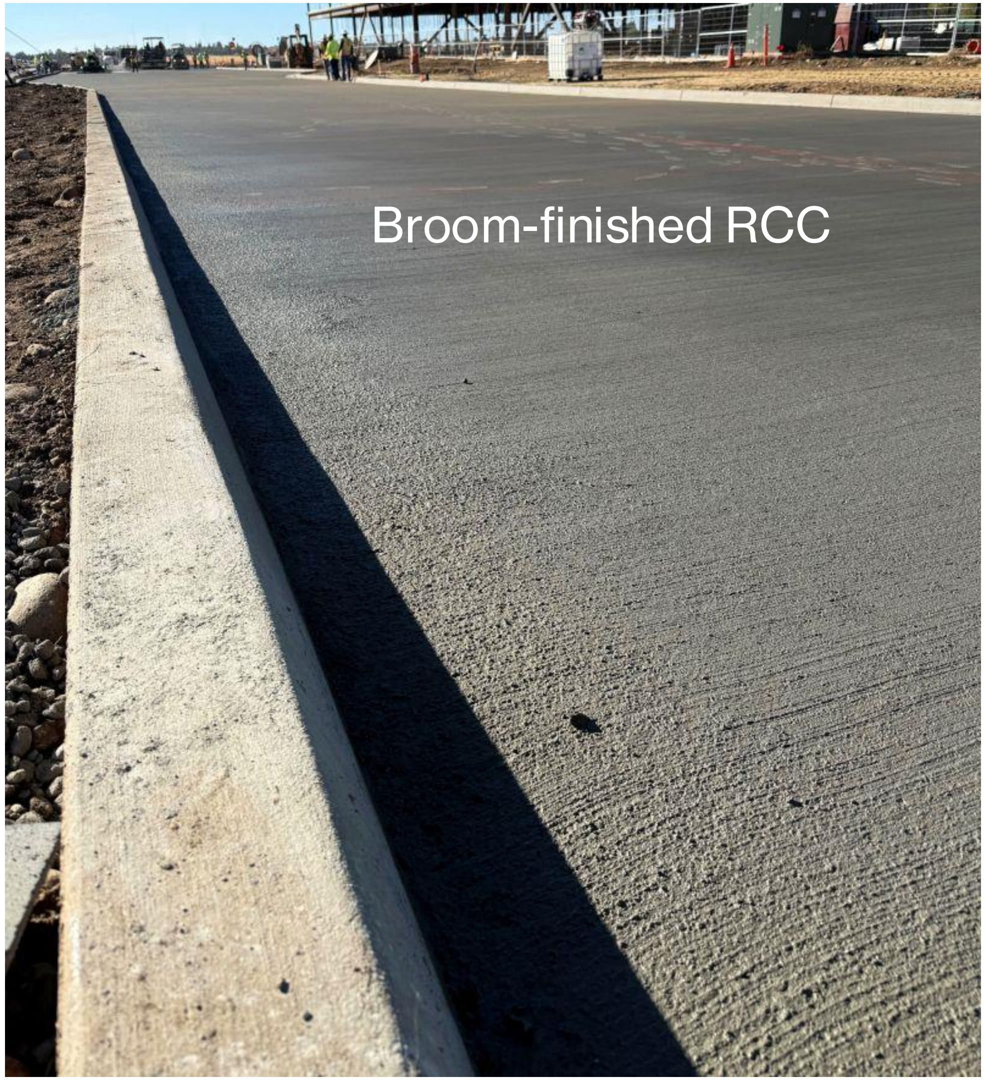


Source: Zollinger, LTRC (2014)

Finishing Techniques



Source: Ouellet & Roesler (2024)



Source: California Nevada Cement Association (2025)

Curing & Sawcutting of Joints

Curing

- Applied at same rate or slightly higher than conventional concrete
- Ensure uniformity with application process
- Apply as soon as possible behind roller operation
- Recommend water-based, resin-based, white-pigmented curing compounds
- Ensures durable surface

Sawcut & Sealing of Joints

- More aesthetically pleasing
- Early entry saw very effective, shortly following placement
- Recommend sawing within 2 - 6 hours to avoid uncontrolled cracking
- Depth: D/4 to D/3
- Spacing: Maximum 36 times thickness

Source: Zollinger, LTRC (2014)

Summary

- RCC pavement:
  - Provides the long-term durability of conventional concrete with diamond grinding an option for a smooth finish
  - Can be constructed relatively fast
- Successful and proven applications include:
  - Heavy industrial areas
  - Collector roads
  - Local streets
  - Shoulders
- Need to develop a Technical Guide for the design and construction of RCC pavements.
- Need to adapt a design methodology for Australian design and construction practice.
- Need to develop material and roadworks specification for RCC surface exposed pavements.

Acknowledgements

Thank you to ASCP Innovation Fund for preparing the literature review report and to ERDC for allowing me to visit their facilities and engage with their team".

Appreciate the partnership very much!

Jeb Tingle, Dr Ray Rollings & Dr Marian Rollings

US Army Corps of Engineers®

Dr David Pittman

Source: Tingle & Pittman

Thank you!

NO TIME FOR QUESTIONS

Source: RCC Pavement Council

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