Design Catalog Based on AASHTO Pavement ME Design

Image Source: FHWA

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Office of Infrastructure

Content

- Background
- Content of the Design Catalog
- Status
- Related work

Rationale for the Design Catalog

- Promote best practices in pavement design
- Provide a tool for design checks
- Facilitate structural design
- Possible application in pavement-type selection evaluation

Recommendations from Scan Tour
High Payoff Items for Implementation

- Two-Lift Construction (as per 1992 SCAN)
  - Scarce quality aggregates for top lift only
  - Recycled/marginal aggregates in lower lift
- **Design Features Catalog (1992 SCAN)**
  - *Standard design features for different types of roads*
  - *Highlight features necessary for long-life pavements*
- High Quality Foundations
  - Minimize/eliminate frost & swelling
  - Basics - good pavements start with good foundations!

German Design Catalog for Concrete Pavement Alternatives

10.6 in

9-in

Thickness [cm] ▼ E_{v2} - Bearing value [MN/m²]

Zeile	Bauklasse		SV				I				II				III			
	Äquivalente 10-t-Achsübergänge in Mio.	B	> 32				> 10 - 32				> 3 - 10				> 0,8 - 3			
	Dicke des frostsich. Oberbaues[1]		55	65	75	85	55	65	75	85	55	65	75	85	45	55	65	75
	Tragschicht mit hydraulischem Bindemittel auf Frostschutzschicht bzw. Schicht aus frostunempfindlichem Material																	
1.1	Betondecke, Vliesstoff, Hydraulisch gebundene Tragschicht (HGT), Frostschutzschicht																	
	Dicke der Frostschutzschicht		-	-	33[2]	43	-	25[3]	35	45	-	26[3]	36	46	-	-	27[3]	37
1.2	Betondecke, Vliesstoff, Verfestigung, Schicht aus frostunempfindlichem Material - weit- oder intermittierend gestuft gemäß DIN 18196 -																	
	Dicke der Schicht aus frostunempfindlichem Material		8[4]	18[4]	28	38	15[4]	25	35	45	16[4]	26	36	46	7[4]	17[4]	27	37
1.3	Betondecke, Vliesstoff, Verfestigung, Schicht aus frostunempfindlichem Material - enggestuft gemäß DIN 18196 -																	
	Dicke der Schicht aus frostunempfindlichem Material		3[4]	13[4]	23	33	10[4]	20	30	40	11[4]	21	31	41	2[4]	12[4]	22	32

Image Source: Hall, K.T, et al, 2007. Long-Life Concrete Pavements in Europe and Canada. *Report FHWA-PL-07-027.*

German Design Catalog for Highways

(>32 million ESALs)

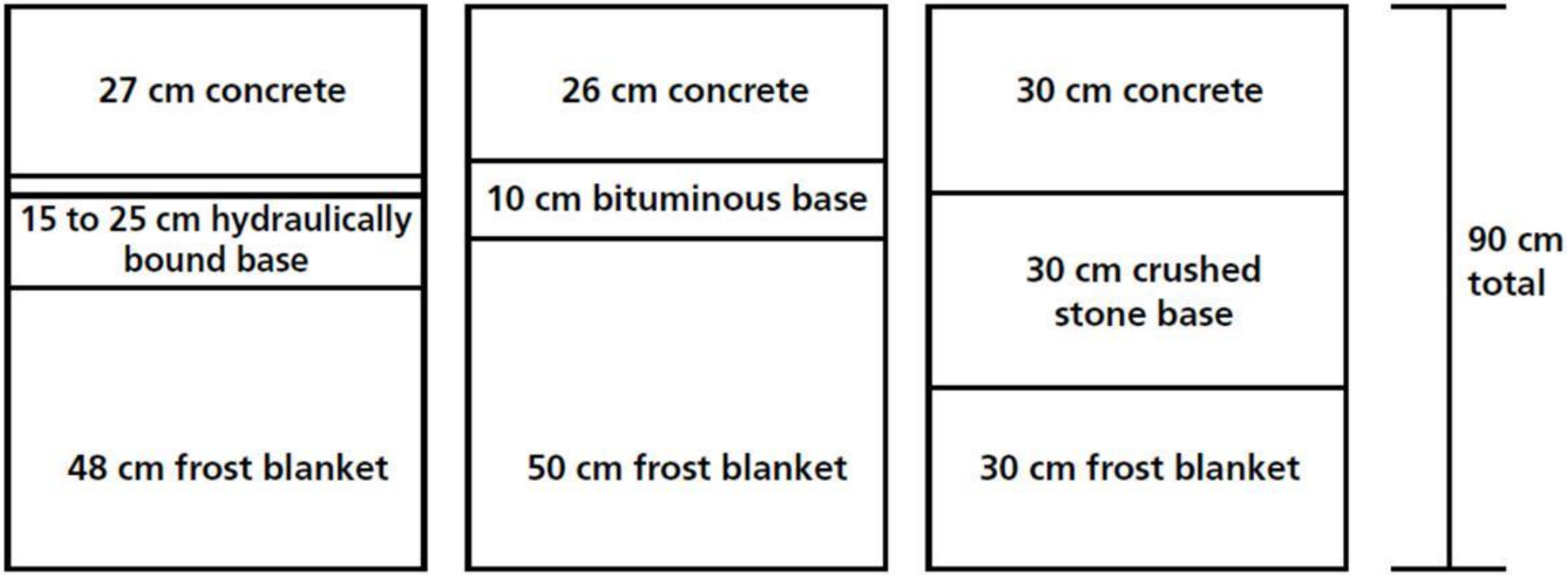
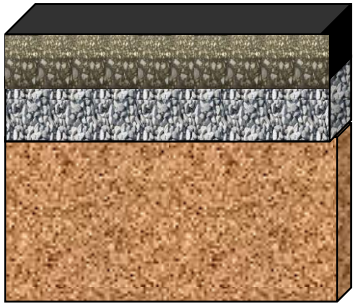


Image Source: Hall, K.T, et al, 2007. Long-Life Concrete Pavements in Europe and Canada. *Report FHWA-PL-07-027.*

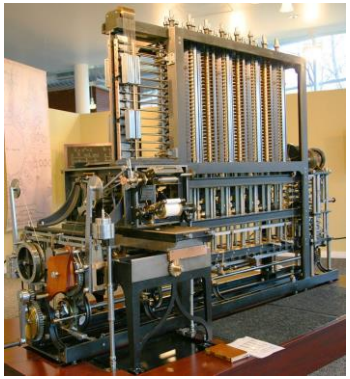
ME Design Process

EICM



Trial section and material properties

Traffic



Mechanistic Analysis

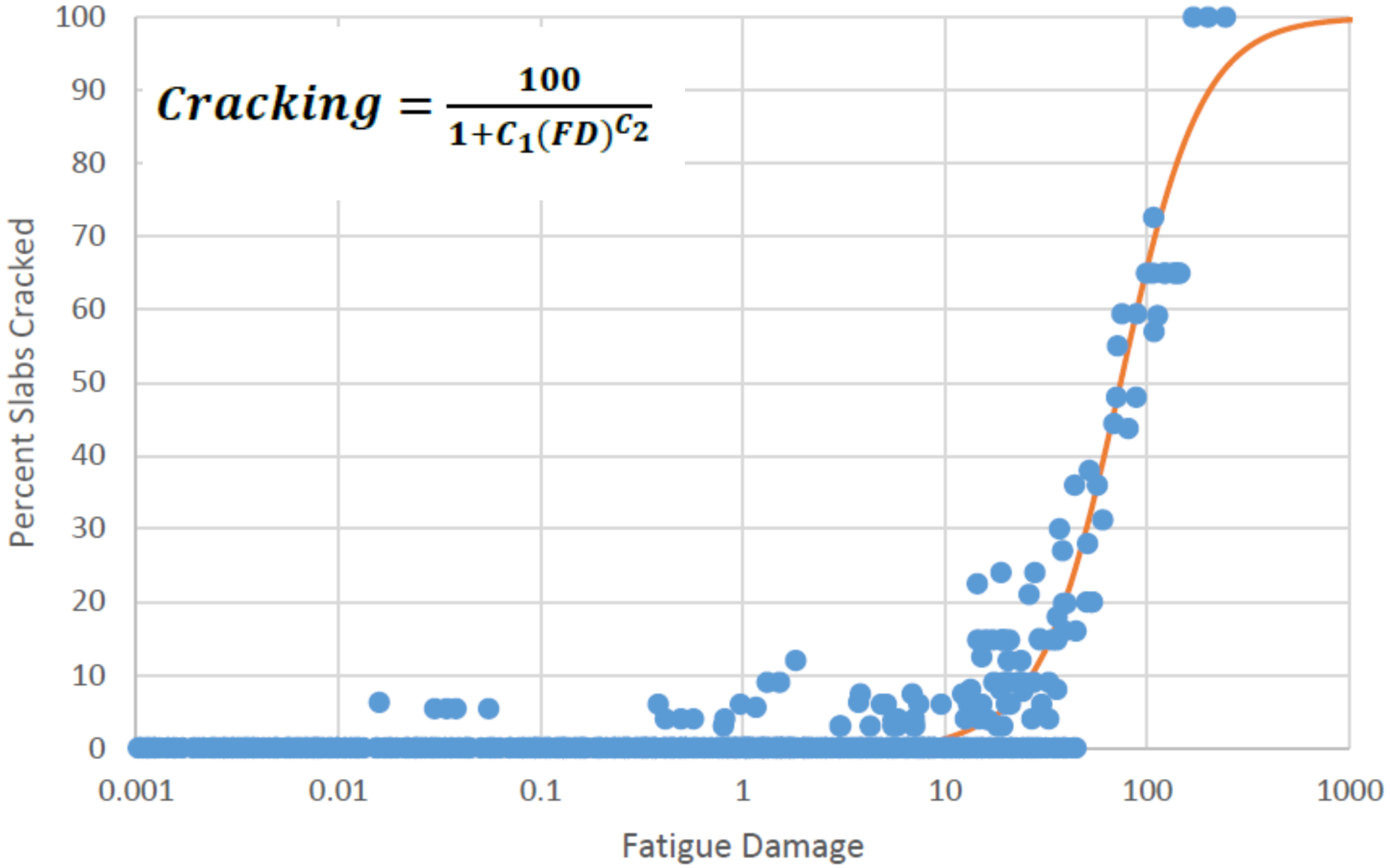
Transfer Functions

Predicted Performance

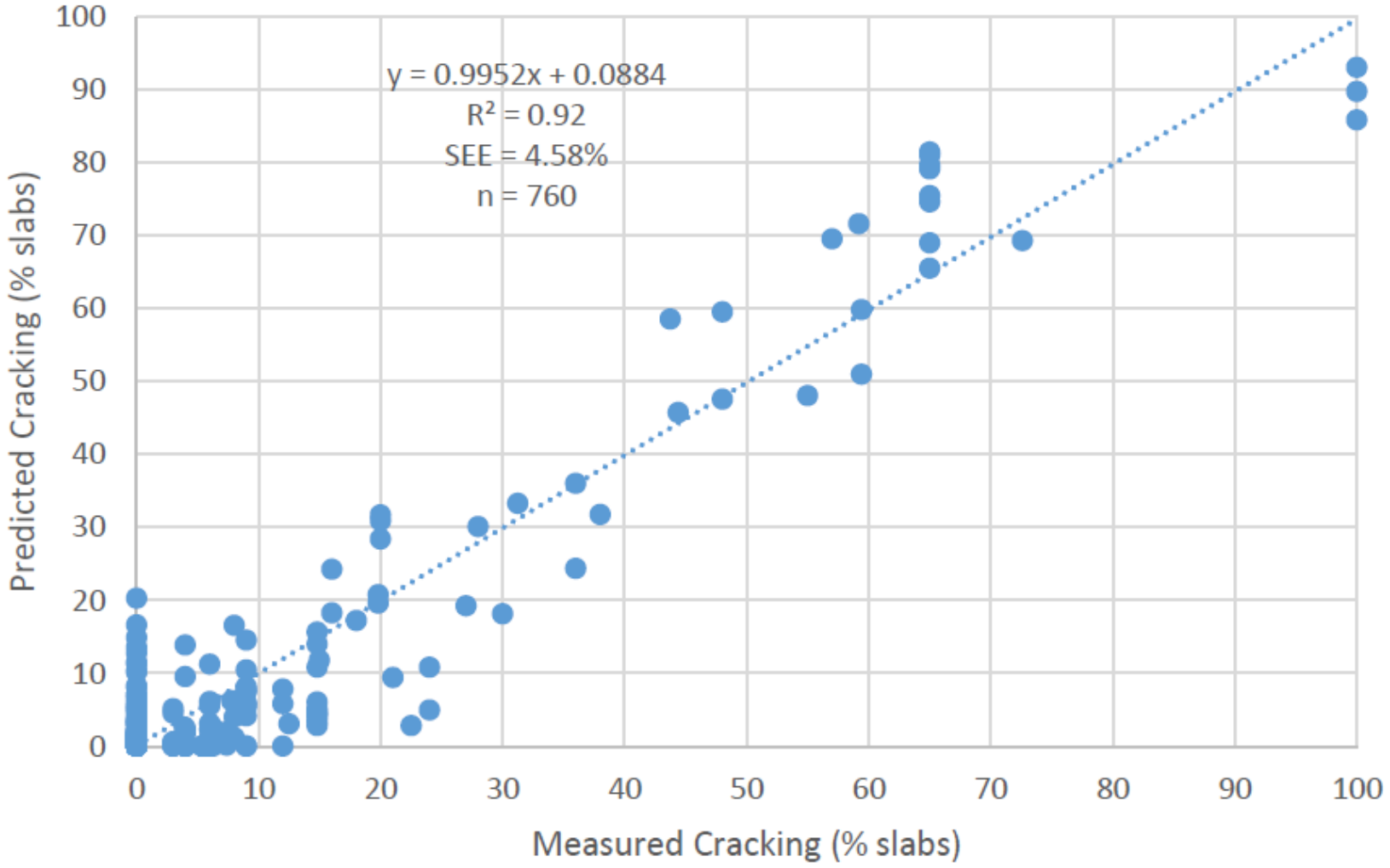
$$\boldsymbol{Distress} = f(\boldsymbol{M}, a, b, c, \ldots)$$

Image Sources: Top left, image found at https://bit.ly/2PDOzMP and used under license terms found at https://bit.ly/1kvyKWi; top center and right, FHWA; bottom left, FHWA; bottom right, image found at https://bit.ly/2MKrSJV and used under license terms found at https://bit.ly/1rRyEZO.

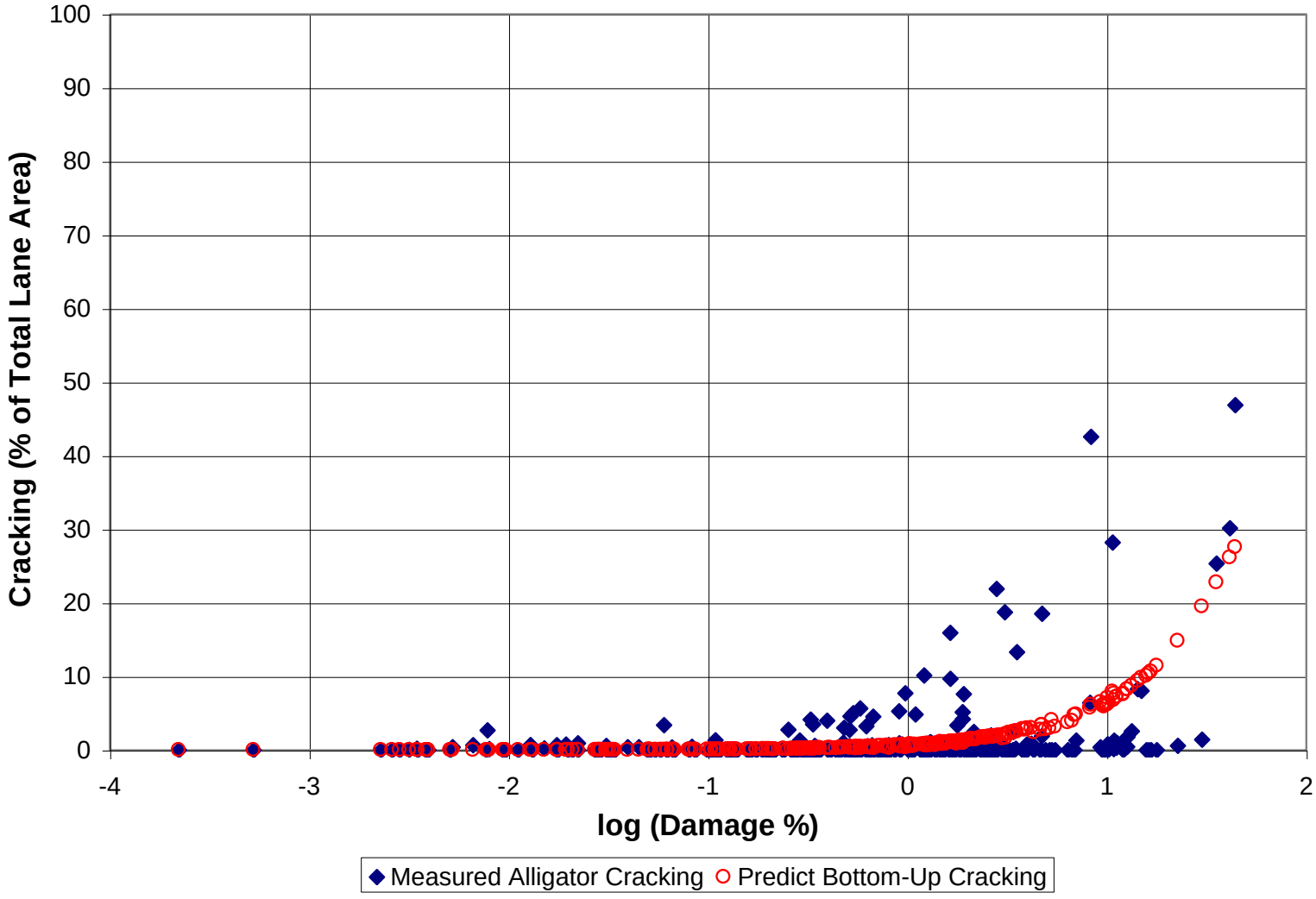
JPCP Cracking Model Calibration



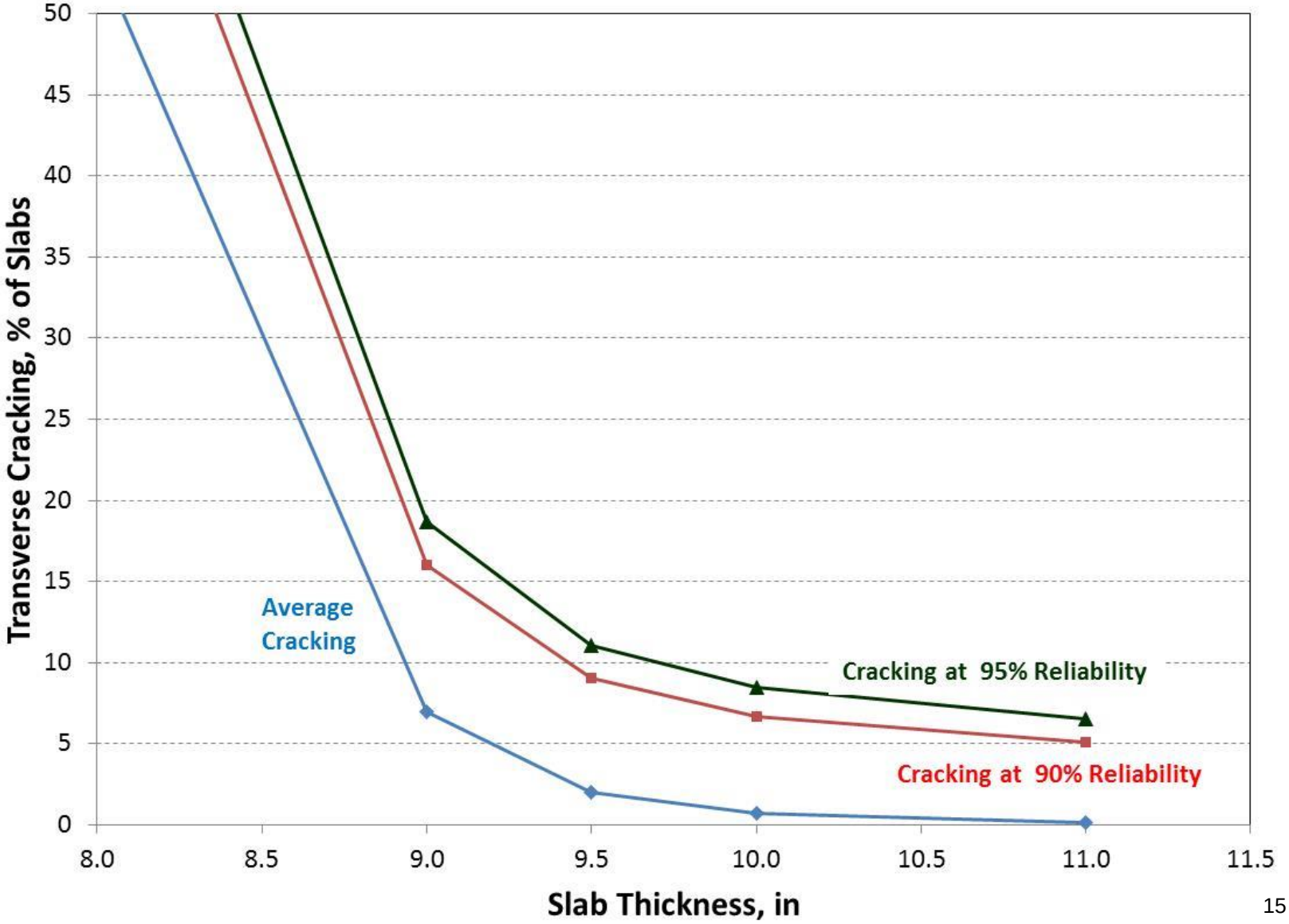
Prediction Errors in JPCP Cracking Model



AC Bottom-Up Fatigue Cracking Model

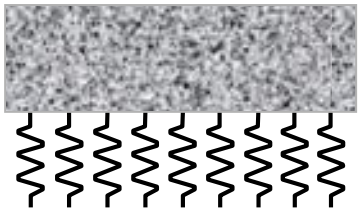


Slab Thickness vs. Cracking



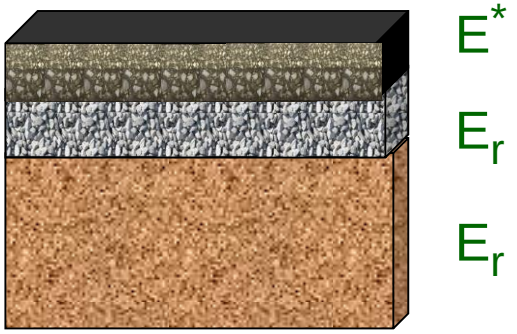
Structural Model

Plate on
elastic foundation



PCC Pavements

Elastic Layers



AC Pavements

Image Source: FHWA

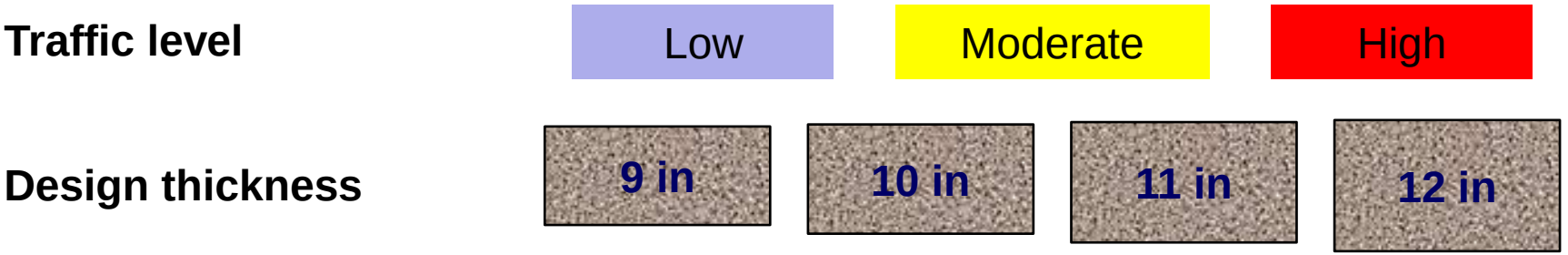
Keys to Achieving Well-Performing Pavement

Minimize the risk of poor performance

- Effective structural design
  - Good foundation
  - Adequate structural section
  - Appropriate design features
- Durable material
  - Durable surface
  - No material-related problems
- Quality construction

Slab thickness options

for highways



How many different ways can you design an 11-in concrete pavement?

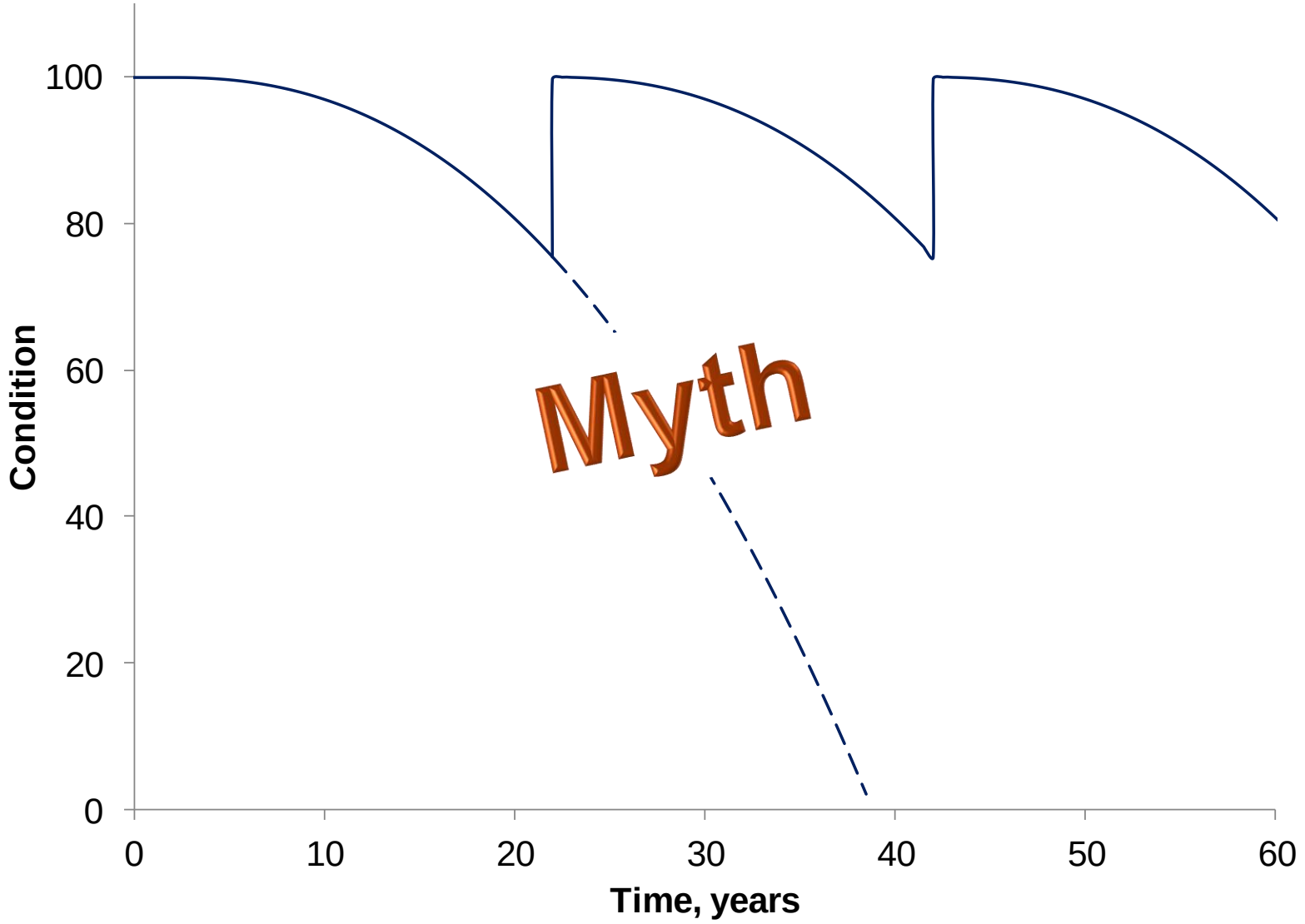
Design Objectives

- Provide safe, smooth, and quiet riding surface
- Requirements – low cost and least amount of interruptions to users:
  - Good performance (low distress) – no, lengthy lane closures for maintenance, repair, or rehabilitation
  - Long-life – relates to congestion, cost, and safety

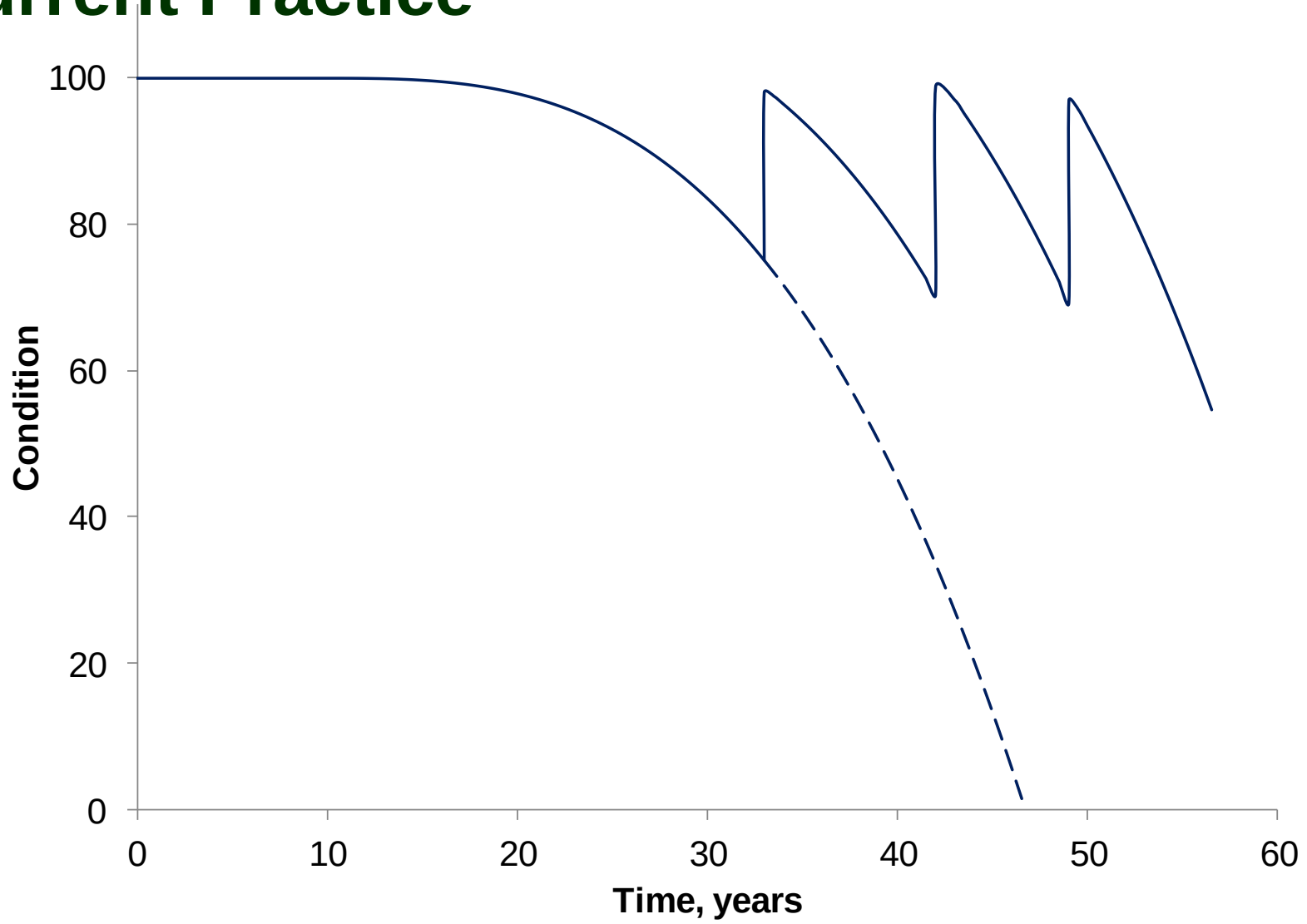
Current Practice

- Pavements are designed to fail
  - Finite design period
  - Pavements are designed for relatively high levels of distress at the end of the design period
- Repairs are not made until distresses progress to high severity
- Structural overlays are used primarily as a corrective measure
  - Typically used on pavements in poor condition
  - A thicker overlay is generally required

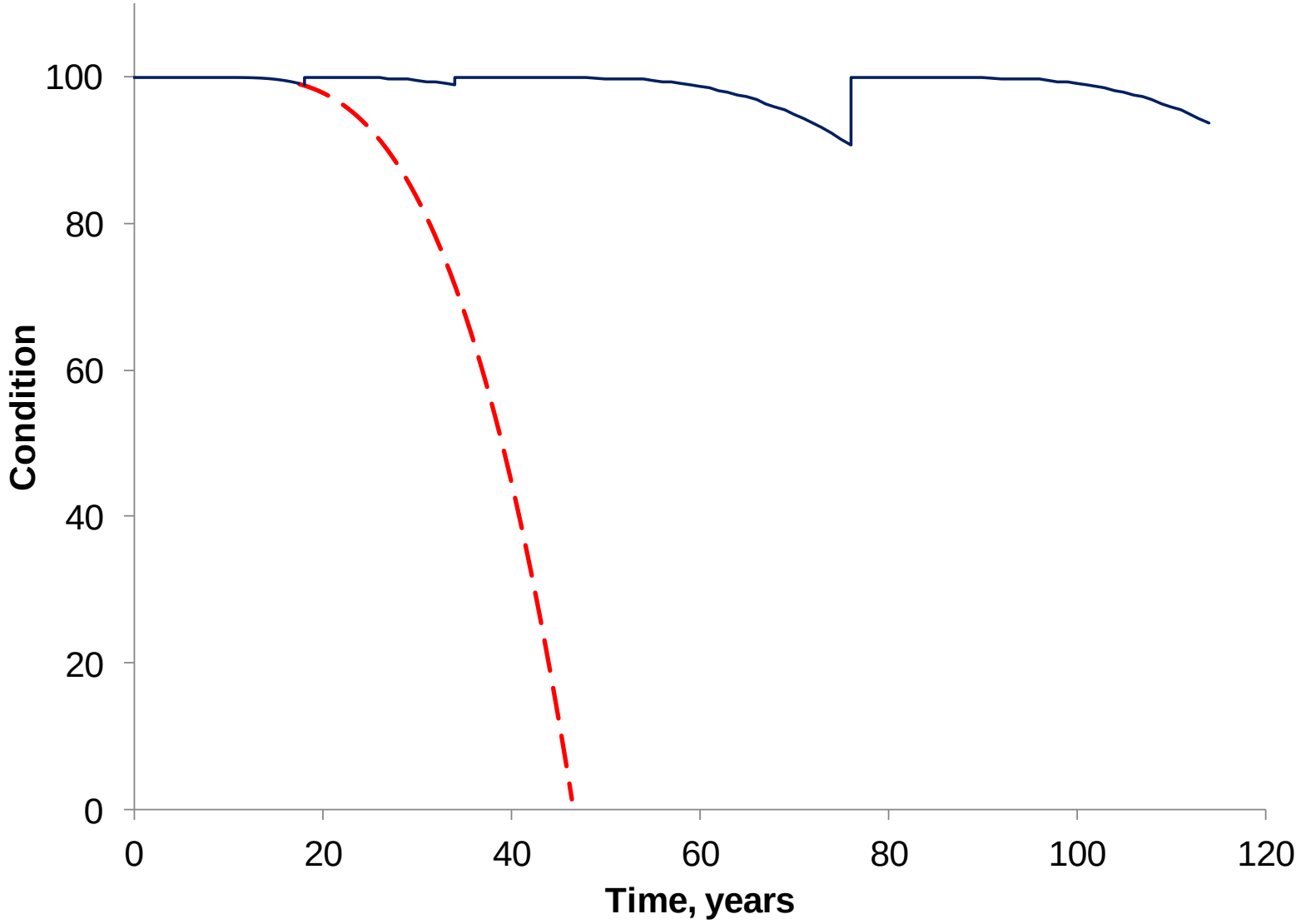
Pavement Condition vs. Age



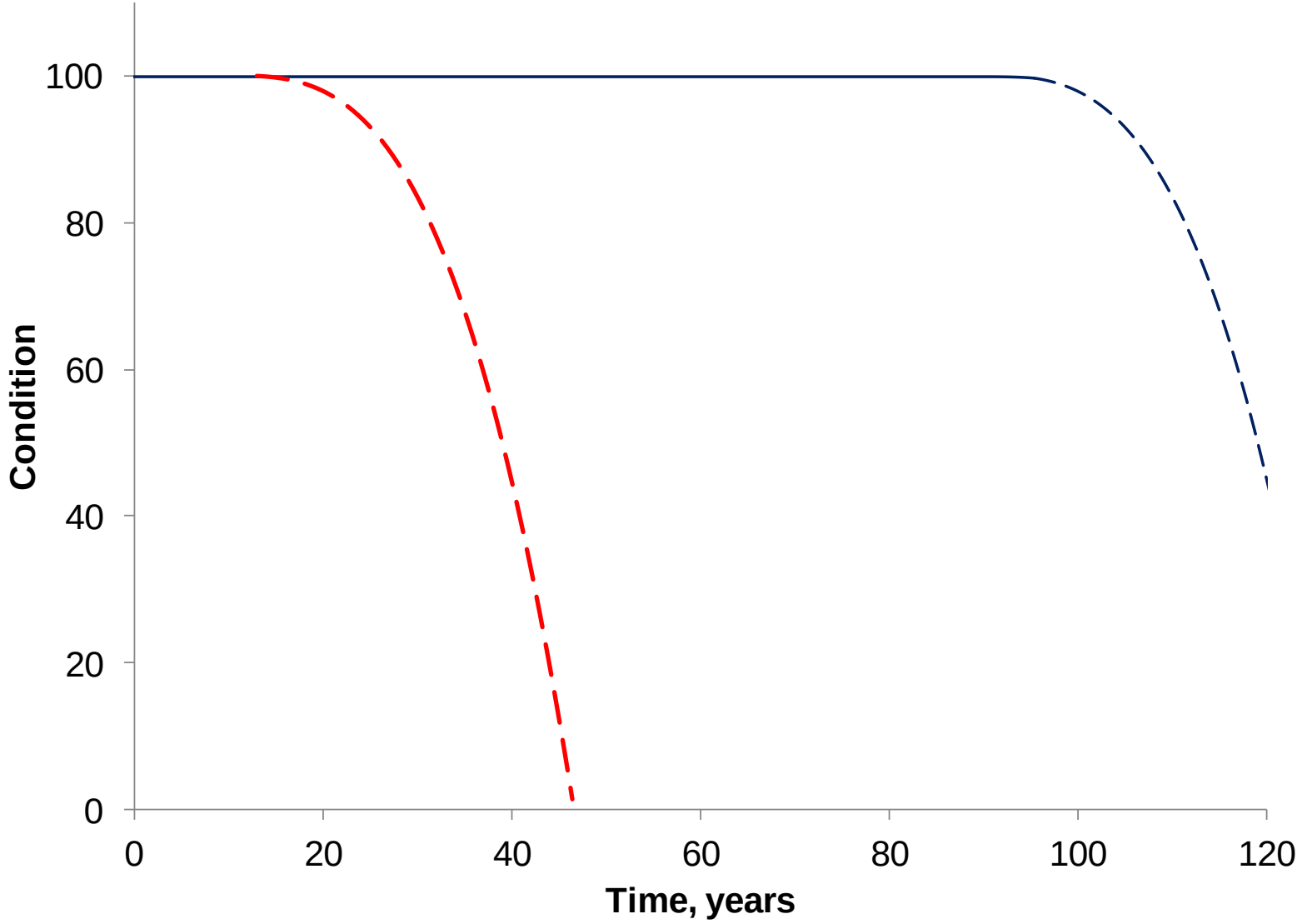
Pavement Condition vs. Age: Current Practice



Pavement Condition vs. Age
Preservation Approach



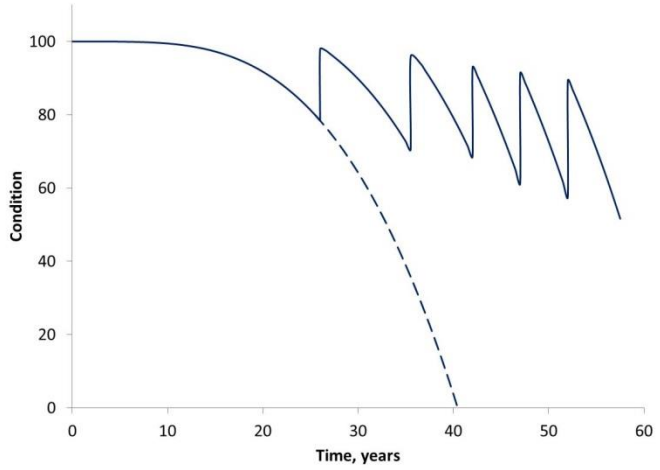
Pavement Condition vs. Age: Long-life Approach

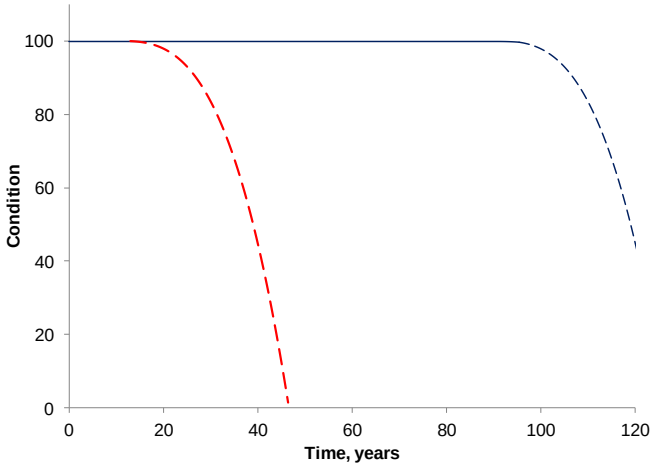


What Is Needed

- Design pavements to last as long as the materials
  - Pavements should remain distress-free within the design period
  - Utilize design features that ensure good long-term performance
- Build it right
- Apply preventive treatments to preserve the pavement structure
  - For sustainability, preservation is better than reconstruction
  - Prevention is the best preservation strategy

State-of-Good-Repair vs. Good Pavement





State of Good Repair

Condition: Fair

M&R: high

Cost: **$$$$**

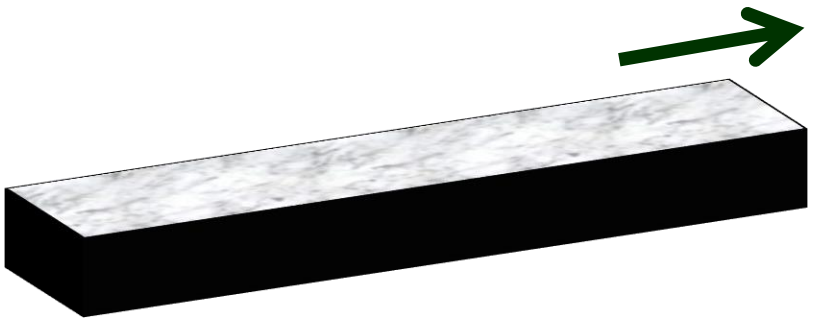
Good Pavement

Condition: Excellent

M&R: very low

Cost: **$$**

Two Dimensions of Paving



Unit of Paving = **lane-mile-years**
Pavement cost = $/lane-mi-yr

A network of x lane-miles of pavement requires an addition of x **lane-mile-years** of service life each year to maintain status quo

Image Source: A Quick Check of Your Highway Network Health: FHWA-IF-07-006

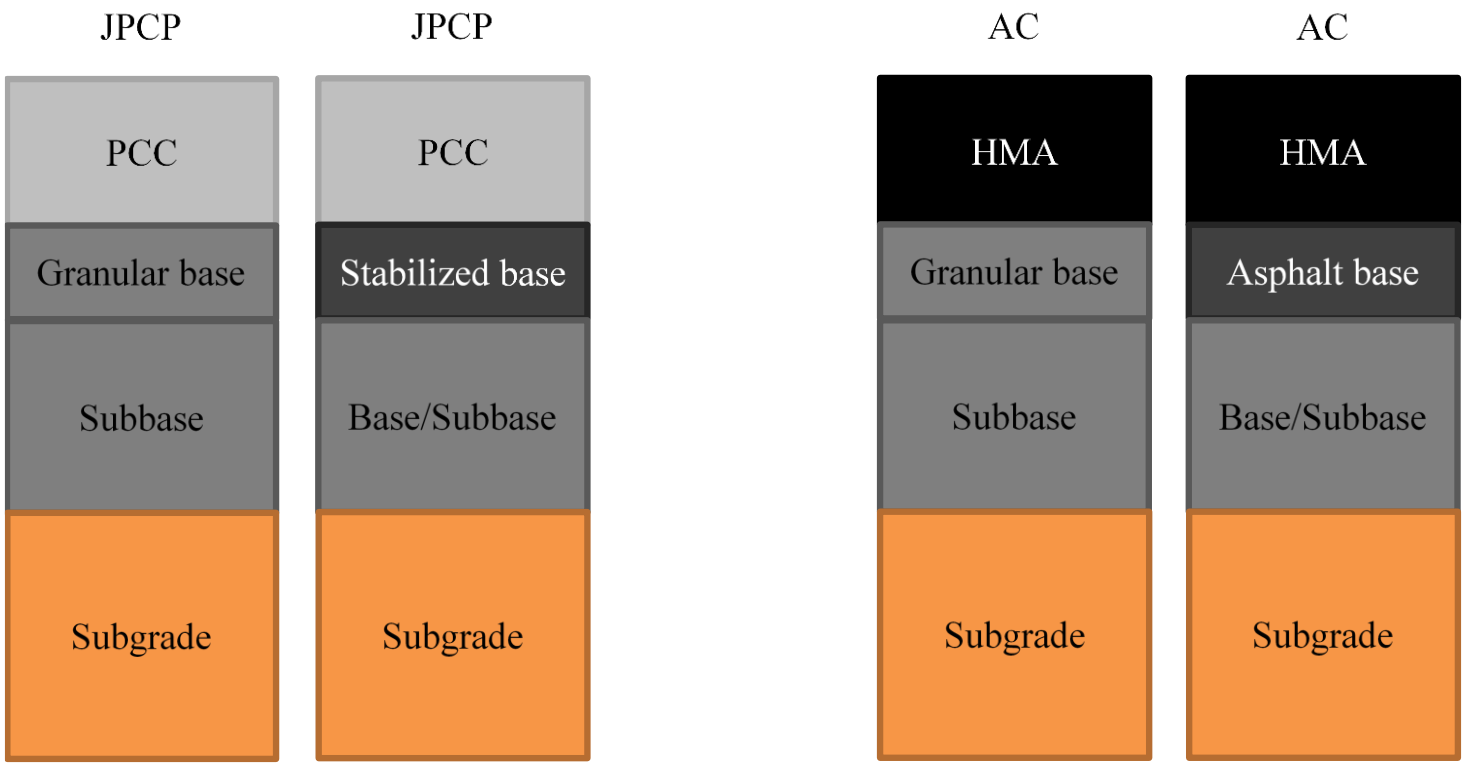
Cost considerations

- Highway investment decision is a resource allocation problem
  - Minimizing LCC of a single project does not provide the best results for the network level
  - At any given funding level, the optimum solution is one that buys the most service life for the network (total lane-mile-years)
- Relevant parameter is $/lane-mi-years
- Optimizing $/lane-mi-years ensures most value for the investment

Design Catalog

- Intended to promote good pavement designs to ensure good, long-term pavement performance
- Both AC and PCC pavements are included
- Design tables are provided that could be used for design checks

Types of Pavements Considered



Content of the Design Catalog

Chapter 1: Introduction

Chapter 2: Design considerations

Chapter 3: Subsurface drainage recommendations

Chapter 4: Special subsurface conditions

Chapter 5: Recommendations to reduce early distresses

Chapter 6: Structural design, JPCP

Chapter 7: Structural design, AC pavement

Chapter 8: References

Appendices

Guidelines Are the Catalog's Main Feature

- Design features for different design conditions
- Material considerations
  - AC and PCC
  - Base and subbase
  - Subgrade
- Special subsurface conditions
  - Subsurface problems and investigations
  - Subsurface water flow and saturated soils
  - Collapsible, swelling, and frost-susceptible soils
  - Variability of soil types
  - Subgrade improvement by stabilization
- Minimizing potential for early distress development

Key Design Parameters Considered

- Design Life
  - 20-year and 40-year (long-life) designs
- Subgrade
  - M_R of 8,000 to 18,000 psi
  - Three categories
- Traffic levels
  - Average Daily Truck Traffic (AADTT) from $\leq$ 500 to 10,000
  - Four categories
- Climate
  - Four LTPP climatic zones

Four Climatic Zones Considered (LTPP)

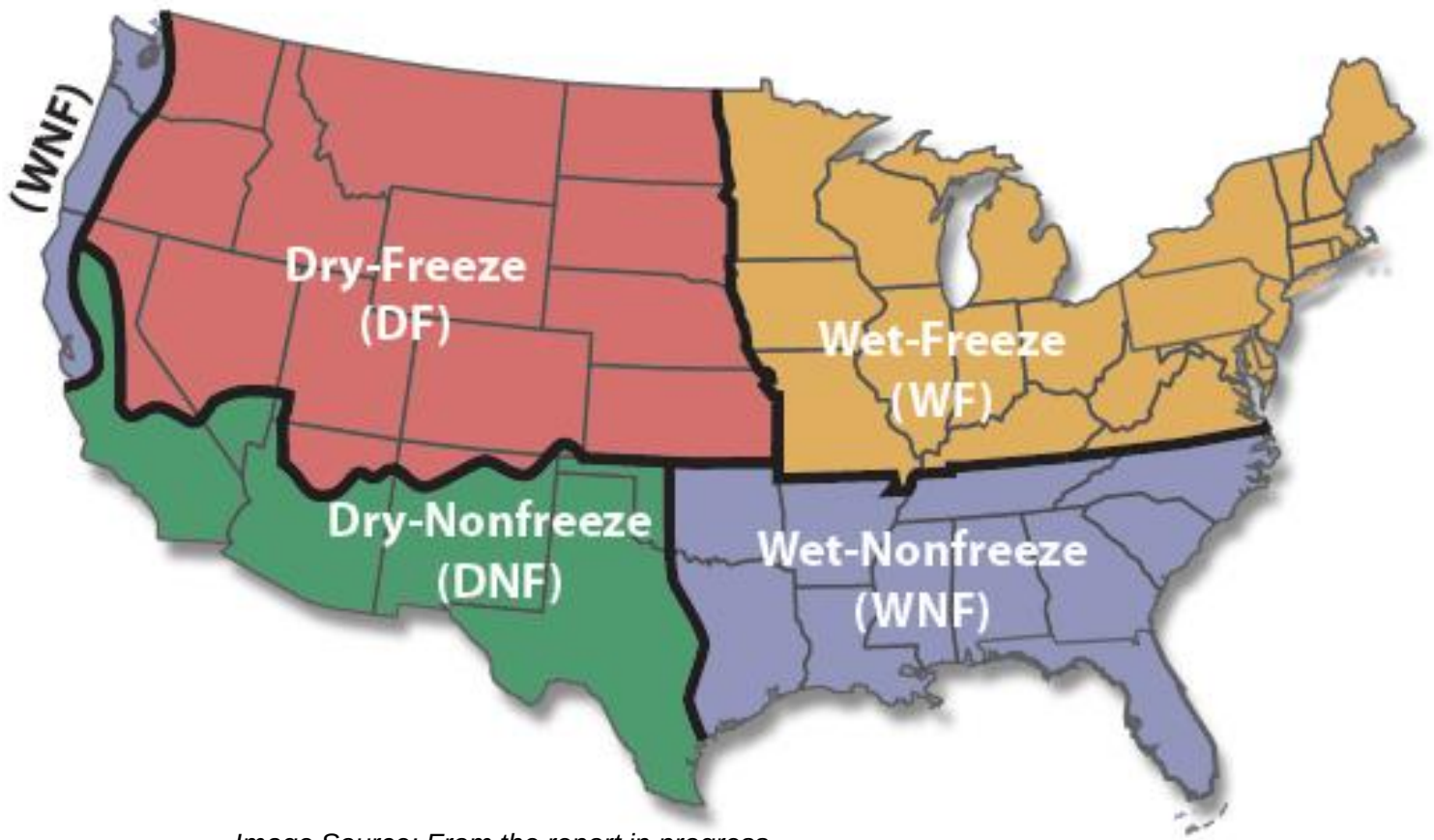


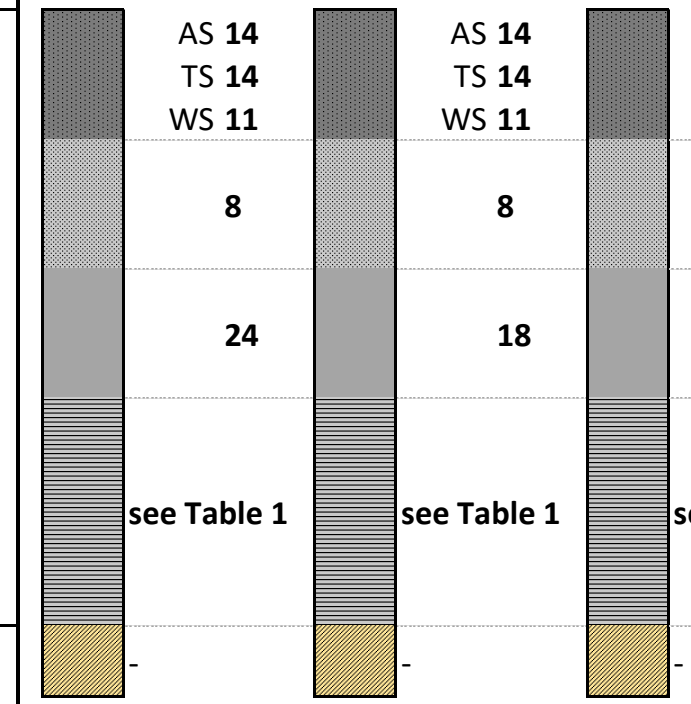
Image Source: From the report in progress.

Example Design Table

Traffic Class (AADTT) / Subgrade Resilient Modulus (psi)			≤ 500			1500/2000			4500		
			8000	13000	18000	8000	13000	18000	8000	13000	18000
PCC with granular base and subbase		Total "Thickness" should cover frost depth in Table 1.									
	JPCP		Feature Min "h": AS 7, TS 7, WS 6/9*	Feature Min "h": AS 7, TS 7, WS 6/9*	Feature Min "h": AS 7, TS 6, WS 6/9*	Feature Min "h": AS 8, TS 8, WS 7	Feature Min "h": AS 8, TS 8, WS 7	Feature Min "h": AS 8, TS 8, WS 7	Feature Min "h": AS 11, TS 11, WS 9	Feature Min "h": AS 11, TS 11, WS 9	Feature Min "h": AS 11, TS 11, WS 9
	Granular Base Course		4	4	4	6	6	6	8	8	8
	Subbase		-	-	-	-	-	-	18	12	8
	Frost Protection Layer		see Table 1	see Table 1	see Table 1	see Table 1	see Table 1	see Table 1	see Table 1	see Table 1	see Table 1
	Subgrade		-	-	-	-	-	-	-	-	-
	Notes		*With Dowel/Without Dowel								
PCC with Stabilized base		Total "Thickness" should cover frost depth in Table 1.									
	JPCP		Feature Min "h": AS 7/9*, TS 6/9*, WS 6/8*	Feature Min "h": AS 7/9*, TS 6/9*, WS 6/8*	Feature Min "h": AS 6/8*, TS 6/8*, WS 6/7*	Feature Min "h": AS 9, TS 9, WS 6	Feature Min "h": AS 9, TS 8, WS 6	Feature Min "h": AS 9, TS 7, WS 6	Feature Min "h": AS 11, TS 11, WS 8	Feature Min "h": AS 11, TS 11, WS 8	Feature Min "h": AS 8, TS 8, WS 7
	Stabilized Base		4	4	4	4	4	4	6	6	6
	Frost Protection Layer		see Table 1	see Table 1	see Table 1	see Table 1	see Table 1	see Table 1	see Table 1	see Table 1	see Table 1
	Subgrade		-	-	-	-	-	-	-	-	-
	Notes		*With Dowel/Without Dowel								

Example PCC Design

Traffic Class (AADTT) / Subgrade Resilient Modulus (psi)			4500 - 10000		
			8000	13000	18000
PCC with granular base and subbase			Feature / Min "h"	Feature / Min "h"	Feature / Min "h"
	JPCP	Total "Thickness" should cover frost depth in Table 1.	AS **14** TS **14** WS **11**	AS **14** TS **14** WS **11**	AS **14** TS **14** WS **10**
	Granular Base Course		**8**	**8**	**8**
	Subbase		**24**	**18**	**12**
	Frost Protection Layer		**see Table 1**	**see Table 1**	**see Table 1**
	Subgrade		-	-	-
			Notes		



Status

- Draft report near completion
  - Guidelines are mostly complete
  - Design tables are being completed
- Anticipated completion of the draft report: December 2018
- Final report will be released March 2019

Related Work

- Improving Foundation Designs
  - *Effective Foundation Design for Concrete Pavements (January 2020)*
- Improving Pavement Strategy (Long Life Pavements)
  - *Strategies for Concrete Pavement Preservation (January 2020)*
- Transportation Pooled-Fund – open solicitation
  - TPF 1469: *Road Foundation Contamination and Drainage – In-Service Evaluation and Best-Practice Recommendations*

Via Apia, built about 312 B.C.

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Acronyms

AC: Asphalt concrete

AADTT: Annual average daily truck traffic

ESAL: Equivalent single axle load

HMA: Hot mix asphalt

IRI: International roughness index

JPCP: Jointed plain concrete pavement

LTPP: Long-Term Pavement Performance program

M&R: Maintenance and repair

PCC: Portland cement concrete