

Celebrating Century of Pavement Foundation: 100-Year Design Life

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Today's Outline

- Introduction & Objectives
 - Factors influencing 100-year Design Life(Pavement and Foundation)
 - Pavement
 - Foundation
 - Case Study
 - Challenges and solution
 - Conclusion
-

Introduction & Objectives

- Why this topic matters?
 - Increased traffic loads & Climate changes
 - Need for long-lasting, cost-effective pavement solutions
 - Travelling public wants less maintenance/road repairs
 - Get in, Get out & Stay Out
-

Introduction(Ideal Pavement/100 Yrs Design life/Perpetual Pavement)

- Vision
- FHWA should lead the way to providing durable, long-life pavements that remain in excellent condition throughout their service lives



Image Source: FHWA

State-of-Good-Repair vs. Good Pavement

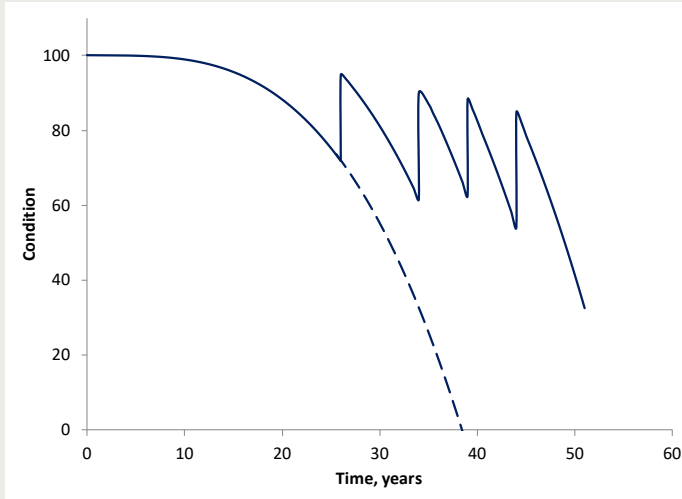


Image Source: FHWA

State of Good Repair

- Condition: Fair
- M&R: high
- Cost: \$\$\$\$

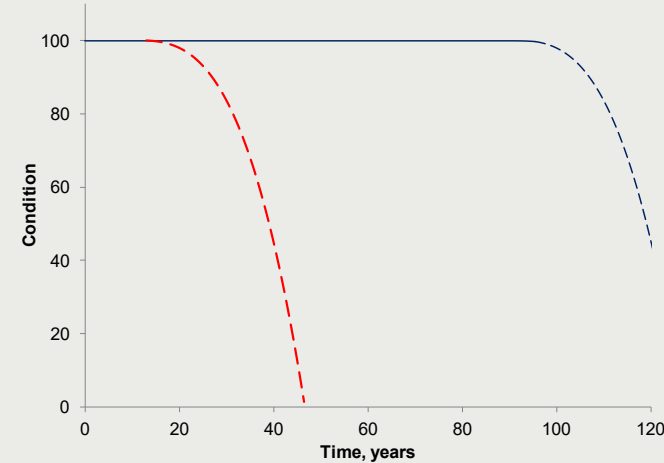


Image Source: FHWA

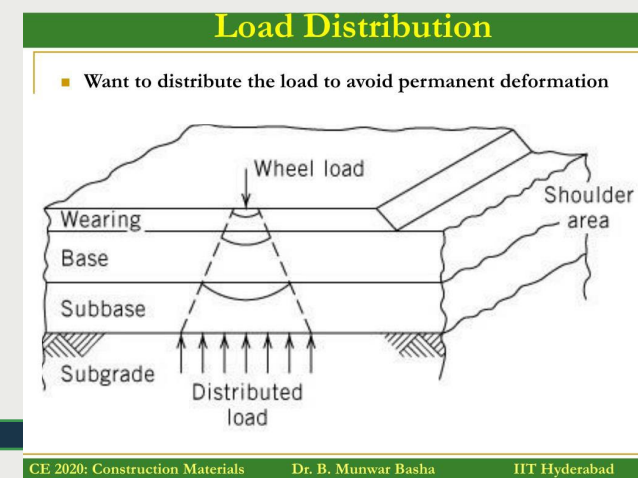
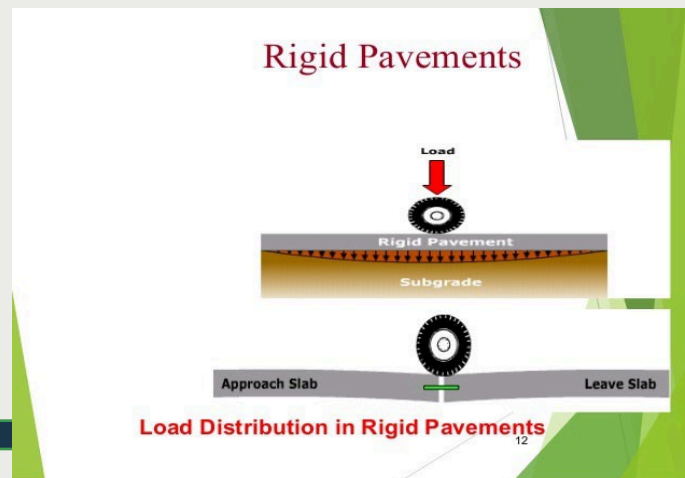
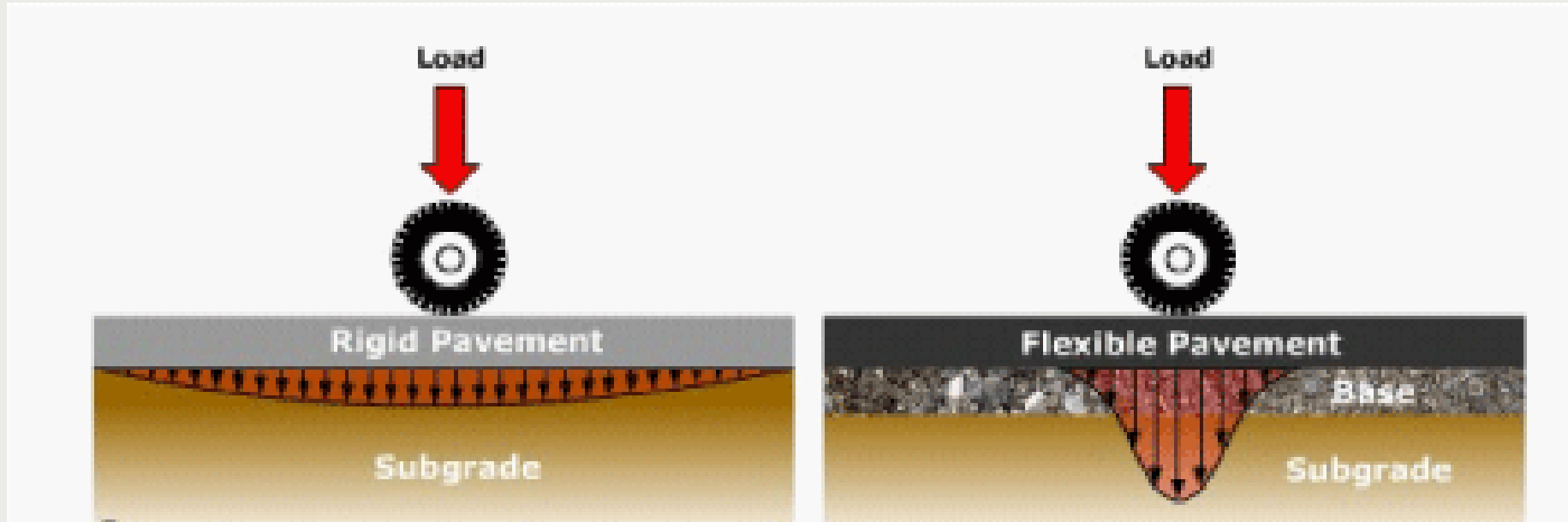
Good Pavement

- Condition: Excellent
- M&R: very low
- Cost: \$\$

What is needed

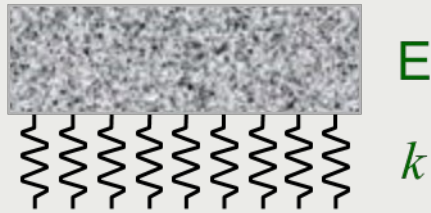
- Design pavements to last as long as the materials
 - Pavements should remain distress-free within the design period
 - Utilize design features that ensure good long-term performance
 - Build it right
 - Apply preventive treatments to preserve the pavement structure
-

Load distribution



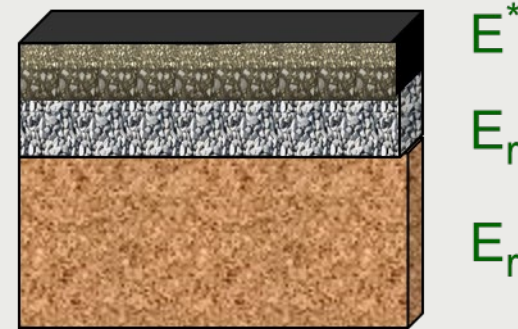
Structural Model

Plate on
elastic foundation



PCC Pavements

Elastic Layers



AC Pavements

Image Source: FHWA

Pavement Design

- Structural design
 - Focus on strength and stiffness
 - Surface thickness dominates the design; foundation layers have minimal impact
- Foundation
 - Not designed systematically in current practice
 - Different design requirements than the surface
 - Uniformity, adequate stiffness, and drainage
 - Must retain integrity throughout the life of the roadway
 - A separate design procedure is needed for pavement foundation design

Pavement Foundation Design Procedure

- Can be established based on existing knowledge
 - Priority is in formalizing the process
 - A comprehensive research program is not needed
 - Research needs can be identified for improvement over time
 - Refine over time through research
-

Ideal Pavement Design Process

- Foundation Design
 - Engineer the layering of materials from natural subgrade up to the surface layer
 - Design to remain in good condition (i.e., no degradation) throughout the life of the roadway
 - Use of chemical or mechanical stabilization as appropriate
 - Consideration of compatibility of adjacent layers to prevent decompaction
 - Incorporation of drainage features as appropriate
- Structural Design
 - Based on the layers defined in the foundation design
 - The layers can be abstracted in any manner appropriate for structural analysis

Pavement Foundation Design

- Practices vary from agency to agency
- No standard exists
- Best-practice needs to be established
 - Ensure uniformity at the time of construction
 - Prevent deterioration over time that leads to non-uniformity and localized failures
 - Pumping and loss of fines
 - Contamination
 - Decompaction
 - Include consideration of resilience

Keys to achieving well-performing pavement

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



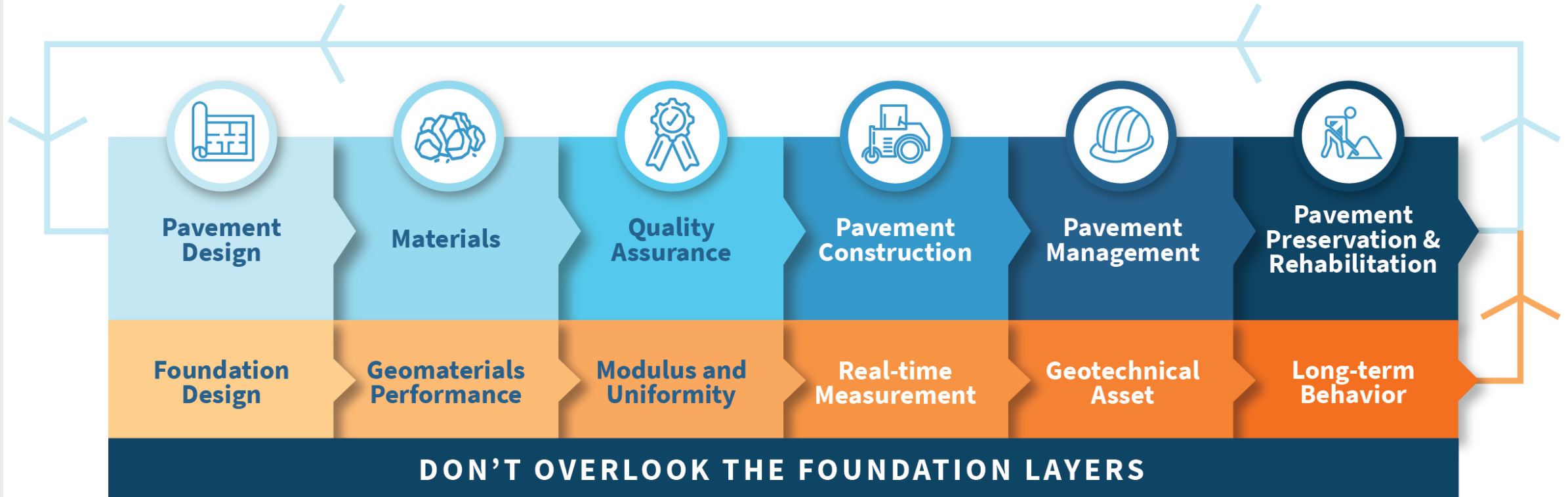
TPF-5(478) Engineered Pavement Foundations: *Virtual Open House*

June 11, 2025



U.S. Department of Transportation
Federal Highway Administration

Sustainable Pavement Systems



Foundations are Critical to Performance *and* to Achieving Sustainable Pavements

The foundation layer is largely ignored in modern day road construction techniques. This results in shorter project life-spans and expensive maintenance and repair cycles in the millions of dollars. 95% of these defects can be detected and remediated in real-time during the initial construction process.

Challenge facing the Iowa DOT

- Inadequate funding for the highway system
 - Pavements will need to last 100+ years
- Need to extend pavement life
 - Construct long life/permanent foundations
 - Remain in-place during future reconstruction
- How?
 - Improve pavement material performance ✓
 - Improve foundation longevity, uniformity
 - Improve construction quality



AID-PT Report Identifies Need to Focus on Improving Pavement Foundations

AID-PT *SHORT TAKE*

Pavement Foundation Research

Foundation design is a key aspect of pavements structural design that needs to be considered in design processes. The basis of design in current mechanistic-empirical (ME) design procedures are pavement responses such as stresses, strains, and deflections. Because the stiffness of unbound base layers is significantly less than that of surface layers, foundation layers have a relatively minor impact on pavement response. Thus, the benefits of a good foundation are not adequately reflected in the ME design process. While fundamentally, the ME design concept is sound, the ME designs do not consider the effects of any deterioration or spatial variability in the foundation layers. Over time, the conditions of the foundation layers can degrade and deform under the influence of repeated heavy loads, leading to non-uniform support conditions and localized failures. Thus, the principal role of a robust pavement foundation is ensuring the foundation layers retain their integrity throughout the pavement life.



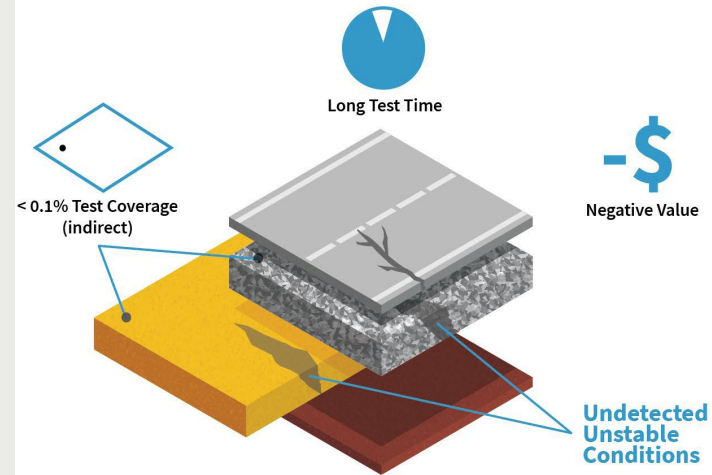
Improving pavement foundation design is a focus area for FHWA. A pavement foundation that does not degrade over time does not need to be replaced, which may translate to significant sustainability benefits in environmental impact and costs. In congested areas, eliminating the need to replace the foundation could be highly advantageous by expediting pavement rehabilitation.

Current pavement foundation process

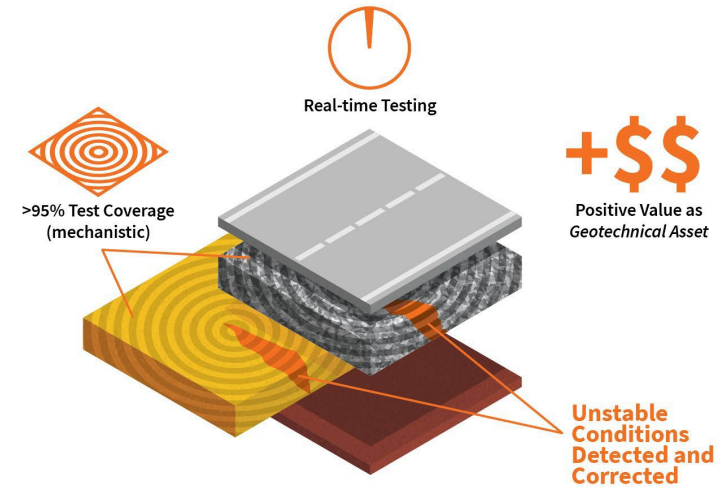
- Embankment - remove unsuitable soils
- Subgrade (Method spec)
 - Moisture control and lift thickness and compaction
 - Specifies equipment size/weight for compaction
 - Select Soil or dense graded aggregate
 - Proof roll subgrade prior to placement of drainable base
 - Geogrid included on some projects
- Drainable base with subdrains
 - Not completely open graded
 - Balance drainage and stability



~40 year lifespan=
state of practice for pavement
design life



100+ year lifespan=
engineering requirement for
sustainable pavement systems



Improved pavement foundations extend pavement
life and decrease project costs over time.



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Explorer

- Projects
 - Project 1
 - Traffic
 - Single Axle Distribution
 - Tandem Axle Distribution
 - Tridem Axle Distribution
 - Quad Axle Distribution
 - Climate
 - JPCP Design Properties
 - Pavement Structure
 - Layer 1 PCC : JPCP Default
 - Layer 2 Non-stabilized Base : Crushed stone (A-1-a)
 - Layer 3 Subgrade : A-7-6
 - Maintenance Strategy
 - Project Specific Calibration Factors
 - New Flexible
 - Rehabilitation Flexible
 - New Rigid
 - Restore Rigid
 - Bonded Rigid
 - Unbonded Rigid
 - Sensitivity
 - Optimization
 - PDF Output Report
 - Multiple Project Summary
 - Batch Run
 - Tools
 - ME Design Calibration Factors

Project1:Project* Project1:Traffic Project1:Climate

General Information

Design type: New Pavement

Pavement type: Jointed Plain Concrete Pavement

Design life (years): 20

Pavement construction: June 2023

Traffic opening: September 2023

☐ Special traffic loading for flexible pavements

+ Add Layer - Remove Layer

Performance Criteria

	Limit	Reliability	Report Visibility
Initial IRI (in/mile)	63		☒
Terminal IRI (in/mile)	172	90	☒
JPCP transverse cracking (percent slabs)	15	90	☒
Mean joint faulting (in)	0.12	90	☒

Layer 2 Non-stabilized Base : Crushed stone (A-1-a)

Unbound

Coefficient of lateral earth pressure (k0)	☒	0.5
Layer thickness (in)	☒	10
Poisson's ratio	☒	0.35

Modulus

Resilient modulus (psi)	☒	20000
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Sieve

Gradation & other engineering properties	☒	A-1-a
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Identifiers

Approver	
Date approved	1/1/2011
Author	AASHTO
Date created	1/1/2011
County	
Description of object	Default material
Direction of travel	
Display name/identifier	Crushed stone
District	

Coefficient of lateral earth pressure (k0)

The ratio of the lateral earth pressure to the vertical earth pressure. Use a default value of 0.5. Recommended min/max: 0.4/0.8.

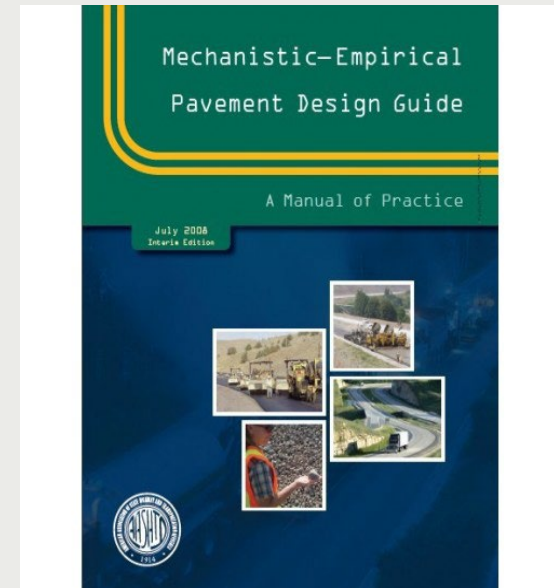
Error List

Indot criteria of Ideal Pavement or Long-Lasting Pavement

- What is 100-year Design Consideration?
 - Longer design life....50 to 100 years
 - Fewer rehabilitation cycles
 - Less maintenance
 - Lower Cost/lane mile/year & Life Cycle Cost Analysis
 - Sustainable(Recycling FDR etc., Self healing asphalt)
 - Compatible (durable & environmentally responsible)
-

Factors Influencing Longevity

- Design considerations(AASHTO 1993 & MEPDG)
 - Pavement performance
 - Traffic
 - Roadbed soil
 - Materials of construction
 - Environment
 - Drainage
 - Reliability
 - Life Cycle Costs, and
 - Shoulder design
- Material selection
 - High quality Material (SMA and high-performance concrete)
- Construction practices
- Maintenance strategies



INDOT Pavement Design

- Asphalt Pavement Design
 - 50 yrs. design life (structural)
 - < 5% of fatigue cracking (bottom up)
 - No adding structure in 50 yrs., we do mill and fill as per LCPCA
 - SMA Surface
 - VRAM
 - Spray paver
 - Stabilized Subgrade
 - Stabilized Foundation (if required)
 - Optimized pavement design by MEPDG
-

HMA pavement cross section

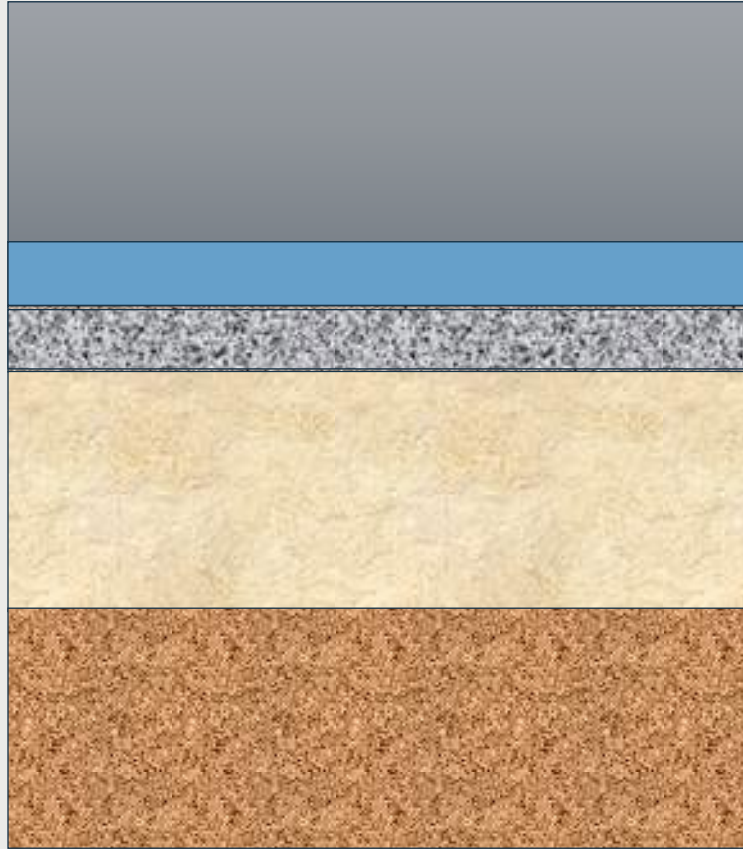


- ← 1.5" SMA Surface
- ← 3.0" HMA Intermediate
- ← 12"+/- HMA DGB
- ← 3" OG/HMA OG (Drainage layer)
- ← 6" DGAB (Separation layer) on Geotextile
- ← 12" Cement Stabilized Soil treatment
- ← Soil Subgrade Foundation if required

INDOT Pavement Design

- Concrete Pavement Design
 - 50 yrs. design life (structural)
 - 15-ft Joint spacing, 1.5-inch dowel, widened slab(14 ft)
 - < 10% of cracking
 - Longitudinal tining
 - No adding structure in 50 yrs., we do CPR
 - Stabilized Subbase
 - Stabilized Subgrade
 - Optimized pavement design by MEPDG
 - Example Design: I-65 in Boone County

JPCP cross section



- ← 12" – 14" JPCP
- ← 3" OG/HMA OG (Drainage layer)
- ← 6" DGAB (Separation layer) on Geotextile)
- ← 12" Cement Stabilized Soil treatment
- ← Soil subgrade Foundation if required

Case Study

- I-65 in Clark County
 - 6-mile Added Travel Lanes (Divided Highway)
 - 6 lanes
 - AADTT =14720
 - Design Bid Best Build(\$200+M, Letting March 2025)
 - Const 2025-26

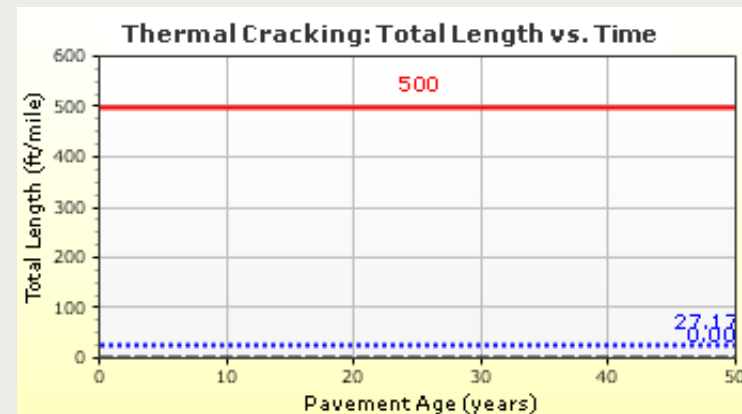
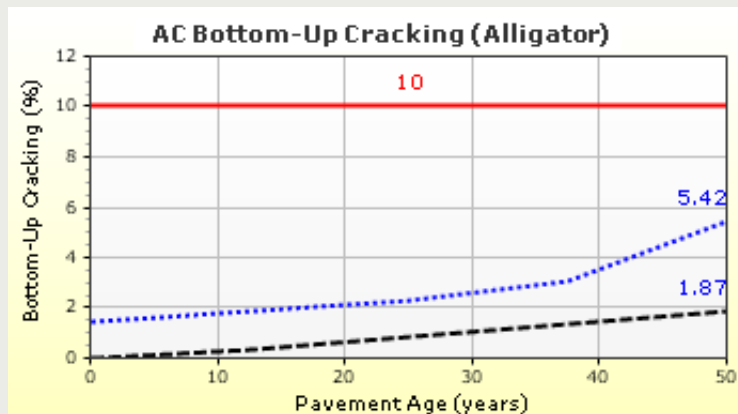
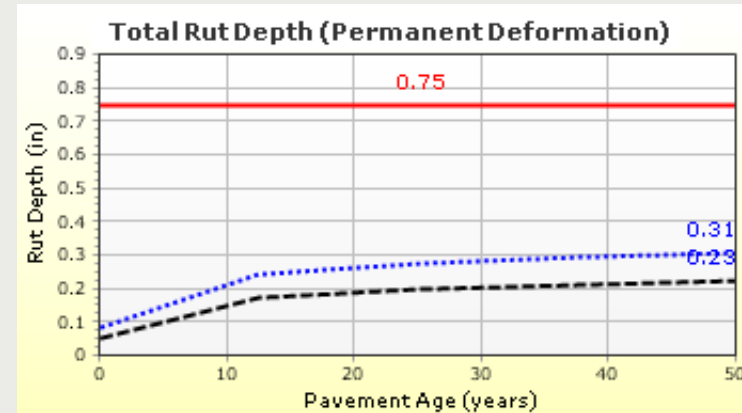
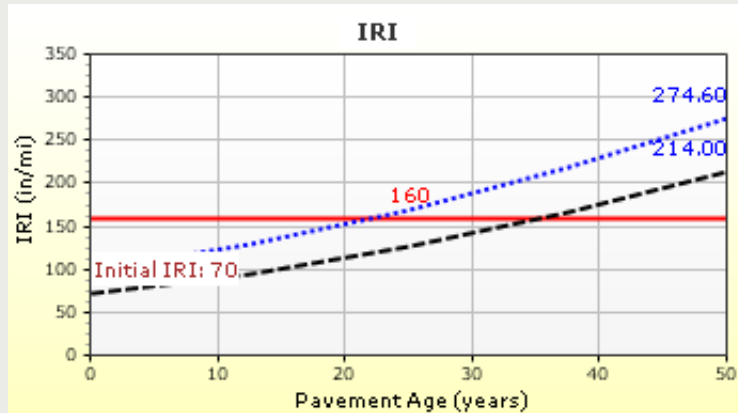
Designed both HMA and JPCP

Both types are designed as long-lasting pavement (50 years)

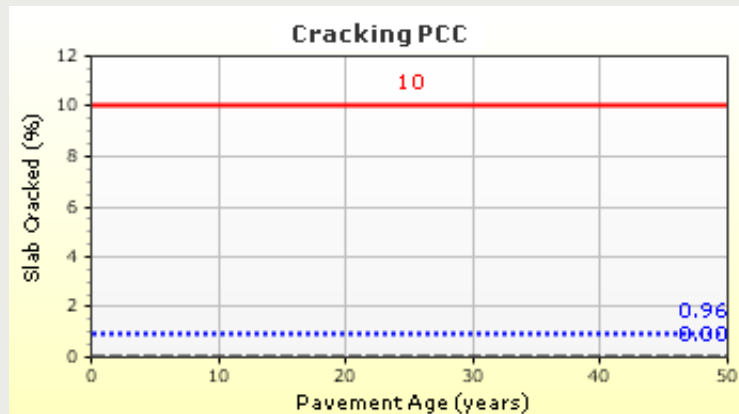
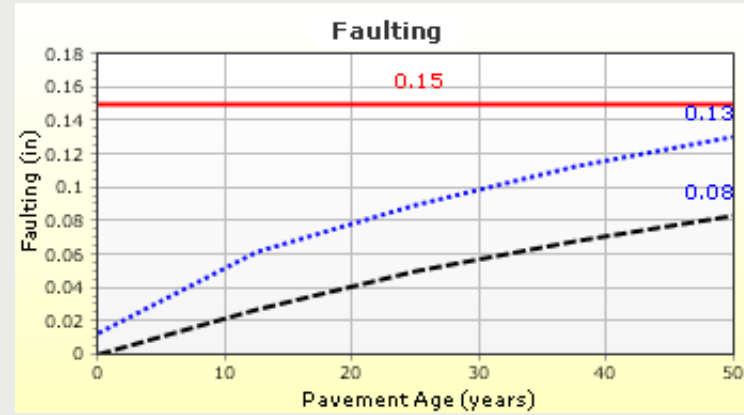
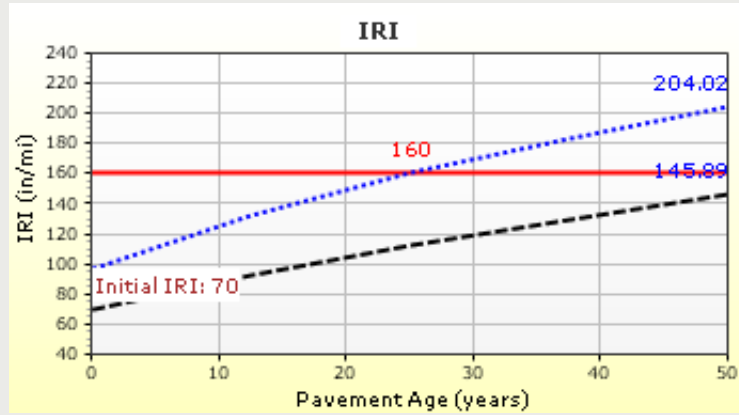
Both pavements have stabilized subgrade treatment & Foundation Tret.

Both pavement have stabilized drainage and separation layers

HMA MEPDG Output



JPCP MEPDG Output



Cement Stabilized Subgrade





I-69

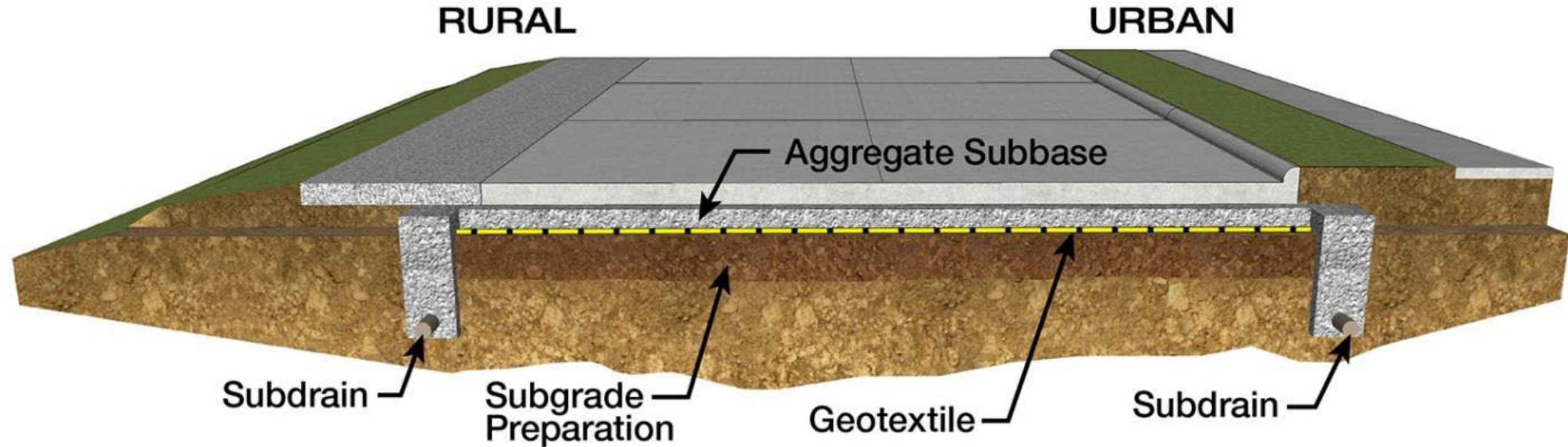


I-69 Clear Path

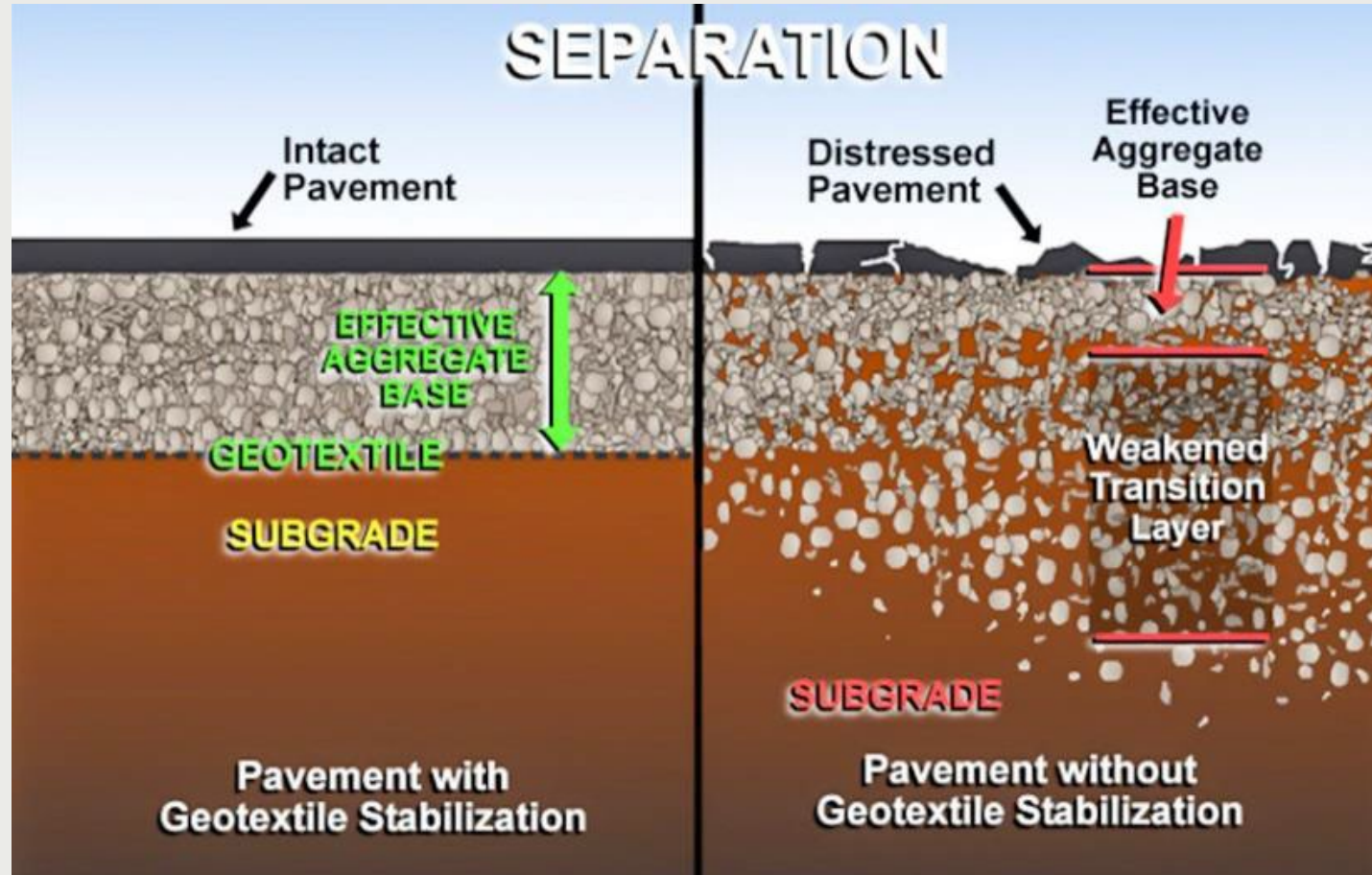




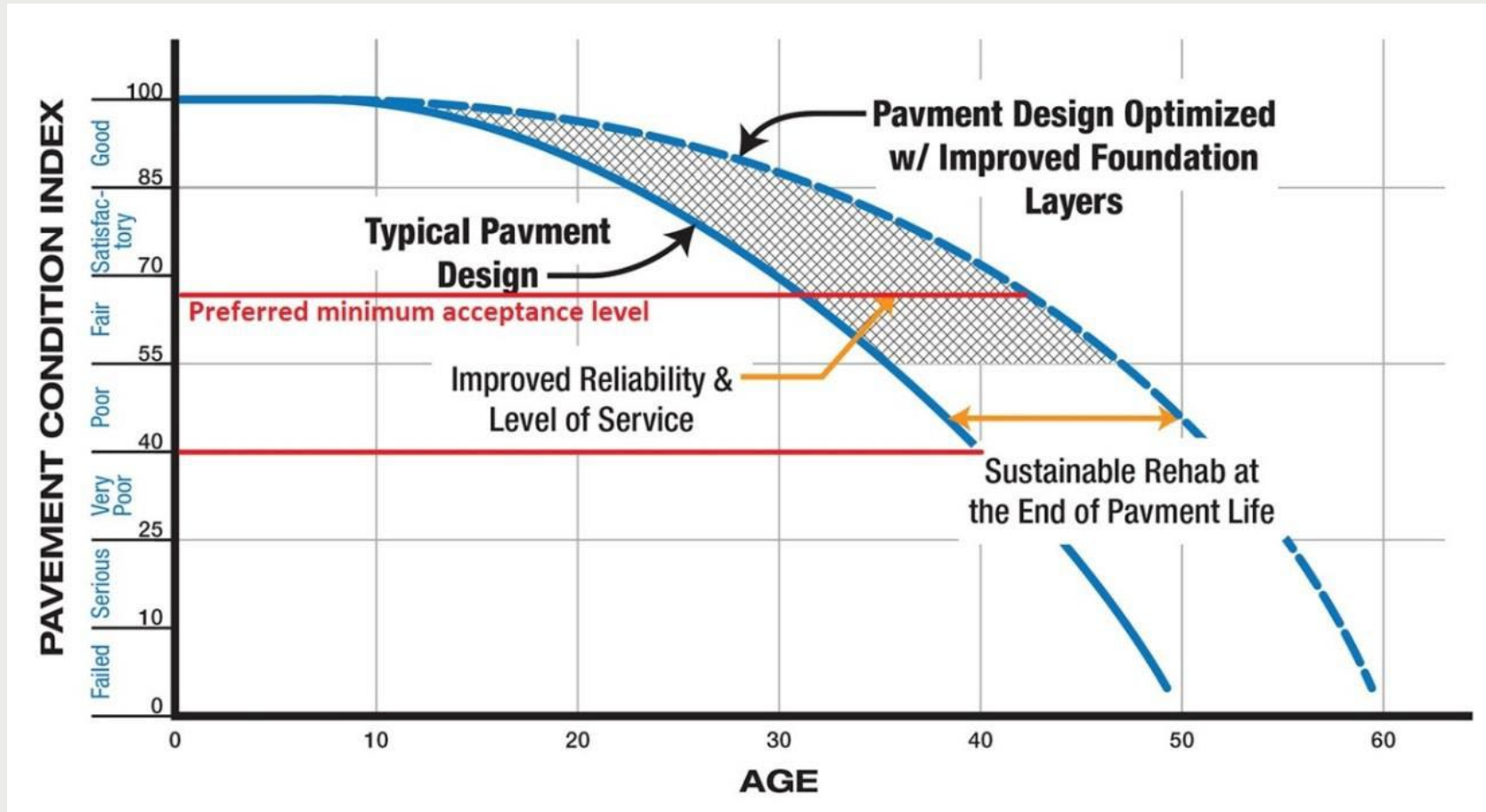
Guidance to improve performance for Local Roads (NCPTC CPTech)



Guidance to improve performance for Local Roads



Pavement Performance Curve with improved foundation layers



Challenges and Solutions

- Initial cost
 - Quality construction
 - Maintenance cycles
 - Cost/lane mile/year
 - Drainage(pavement & subgrade)
 - Industry(Asphalt and Concrete) perspectives/capabilities
-

Conclusions

- There is a strong need for Long-lasting pavement
 - Less disruption to traveling public
 - Subgrade/Foundation is very important
 - Quality material and Construction is equally important
 - LCCA and cost/lane mile/year is less compared to traditional Pavement
 - Nondestructive Testing is important verification
 - Pavement and subgrade drainage will enhance pavement life
-

Talking Points

- Pavement design is not an art but science now.
 - Design smartly
 - MEPDG
 - How do you design pavement for longer life >50 yrs ?
 - Geotechnical Engineer, Pavement Engineer and Construction Engineer must talk with each other
 - How do we make our foundation uniform and stable for 100 year?
 - How do you take care of pavement drainage?
-

Implications for pavement design

- DOTs are transitioning to PMED for PCC and HMA design
- Subgrade/Subbase material strength values have been historical relationships based on density and material type or in some cases back-calculated from FWD.
- No process to verify that design values are met in the field.
 - Instead used moisture/density control and proof rolling.
- Assure design values are being met
- Typical values provided in the ME Design guide based on soil classification may not be reliable for your materials
 - Performance specification utilizing Modulus mapping



- E-C296

TRANSPORTATION RESEARCH
CIRCULAR
Number E-C296 November 2024

**Foundation Design
and Construction for
100-Year Pavement
Systems**

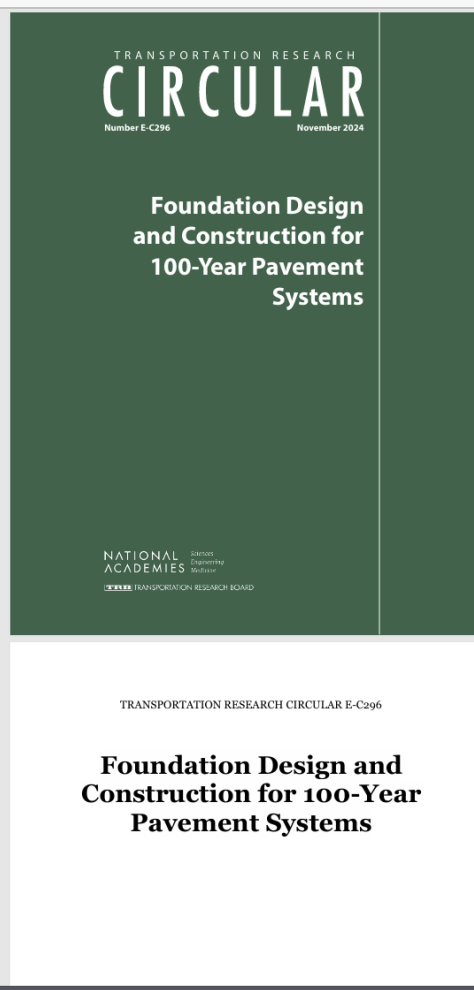
Increasing Expectations for Pavement Foundations

KUMAR DAVE

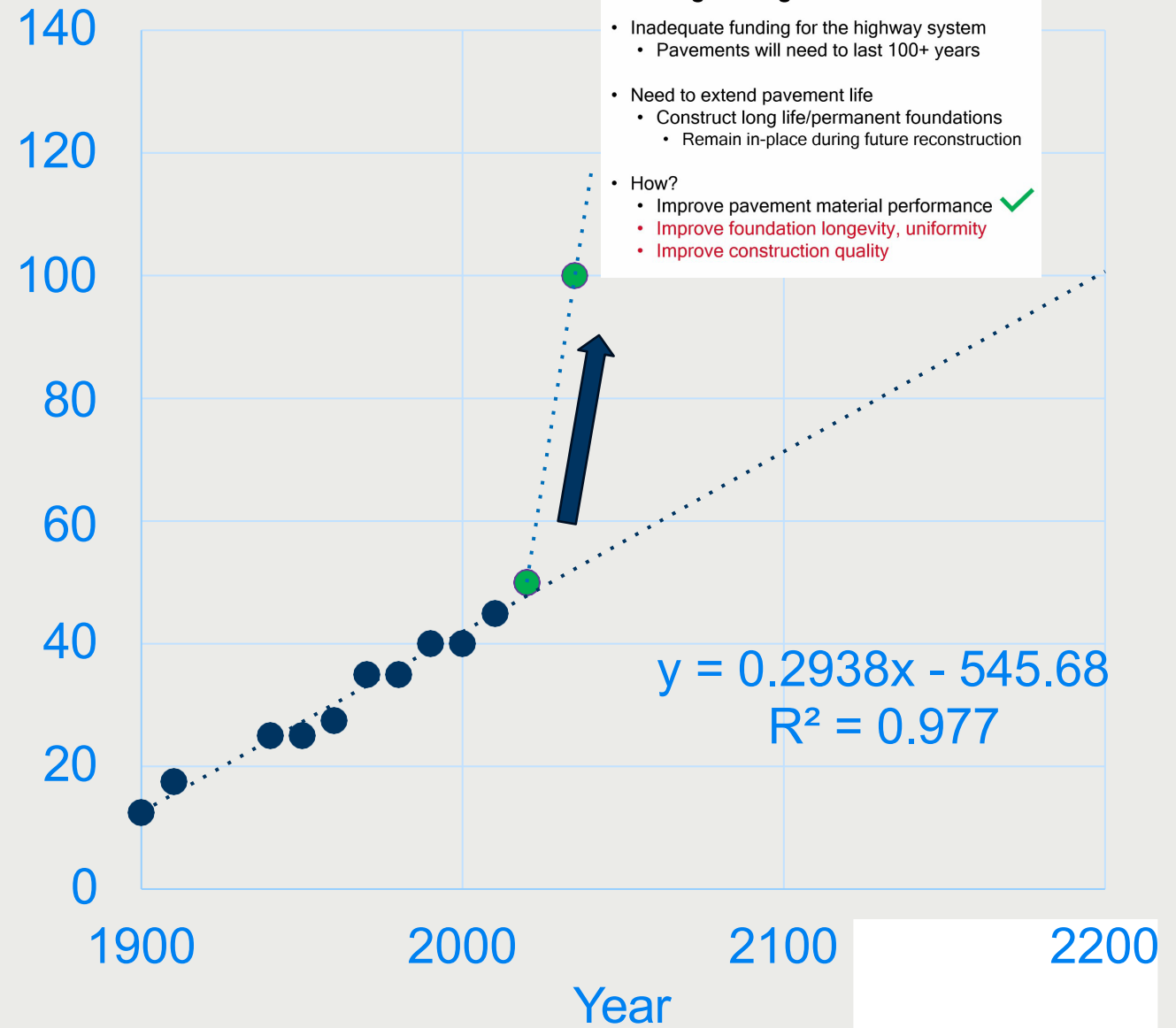
NAYYAR SIDDIKI

Indiana Department of Transportation

<https://www.trb.org/Publications/Blurbs/183300.aspx>



Pavement Design Life (years)



2023 & 24 Perpetual Pavement National Award



Celebrating Century of Pavement Foundation: 100-Year Design Life

Outline

- Need for foundation improvements
 - Geotechnical Recommendations (See Geotechnical Report)
 - Cement Stabilized Subgrade Soil, Sec 219
 - Design Procedures for Cement Stabilization
 - Testing Requirements
 - QC/QA Testing
 - Recommendations (During Construction)
-

Need for Pavement Foundation Improvement

- Subgrade is defined as the roadbed portion on which pavement is constructed.
- Pavement design is engineered to distribute stresses imposed by traffic to the foundation.
- The pavement foundation conditions have a significant influence on the choice and thickness of the pavement structure.
- Geotechnical investigation should include foundation soil conditions and its engineering properties, along with ground water.
- Variability of engineering properties of subgrade soils may be reduced.
- Subgrade and its foundation properties may be improved with the use of mechanical, chemical, or geosynthetic modification.
- INDOT initiated with the pavement foundation improvement with “Cement Stabilization of Subgrade Soils”.

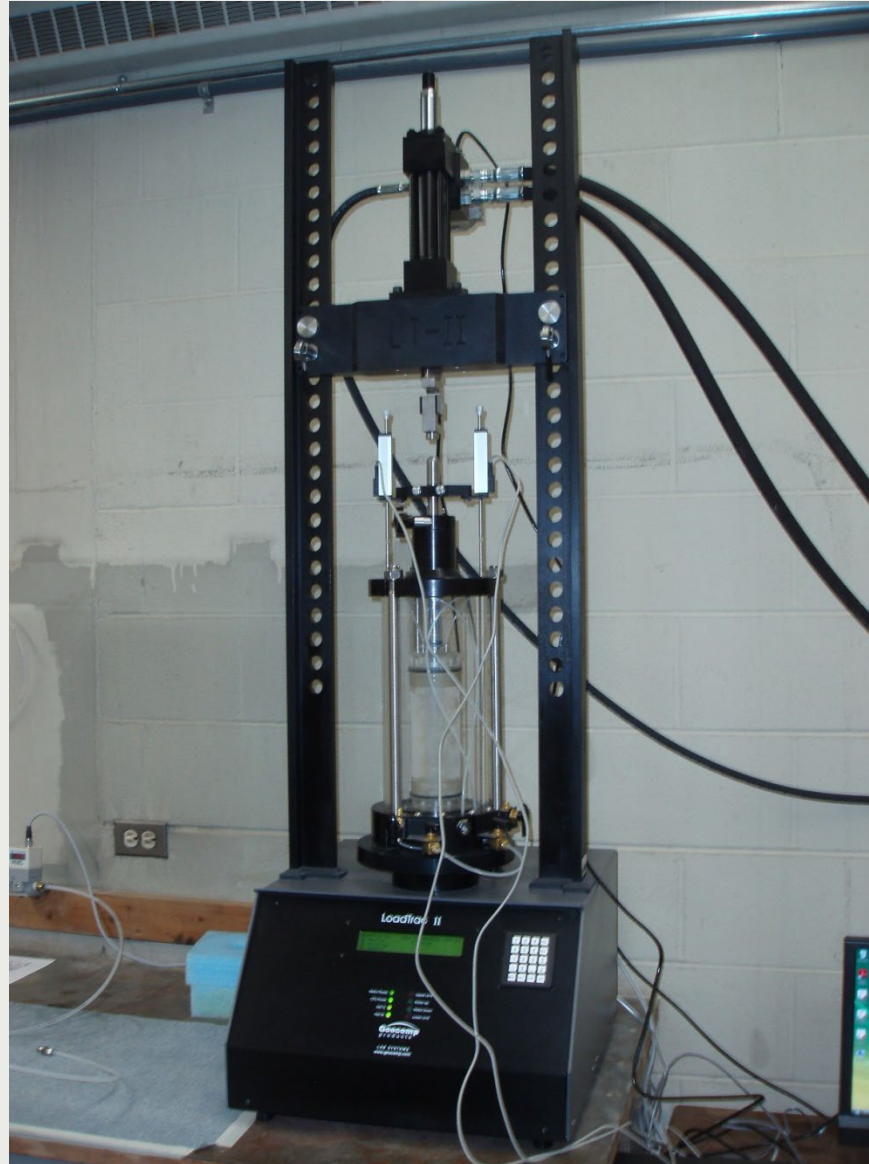
Geotechnical Subgrade Recommendations

- Soil cement stabilization
 - Foundation treatment requirement delineated when needed
 - Chemical Modification, Aggregate , Geosynthetics, or moisture control
 - Subgrade and foundation resilient moduli
 - Organic, Marl, sulfate of soil, and water
 - Ground water elevation, subsurface drain, and geotextile selection
-

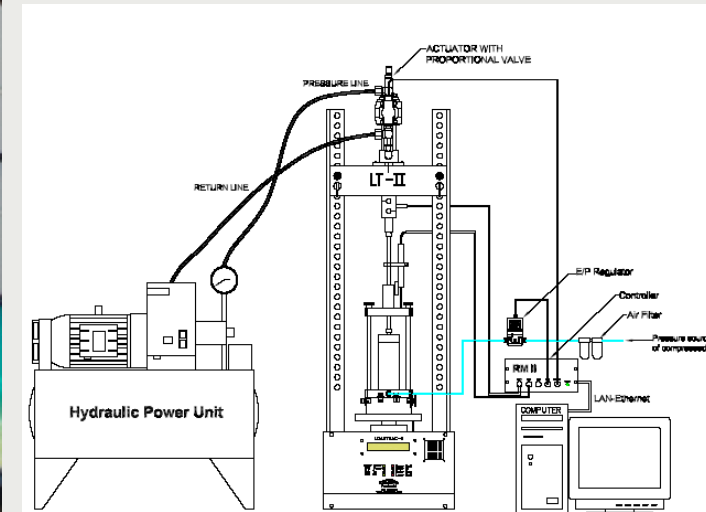
Cement Stabilized Samples



Resilient Modulus Machine



AASHTO T307



Cement Stabilized Soil Resilient Modulus Data

RM TEST

Summary Data

Confining Stress S3 psi	Nom. Max. Deviator Stress psi	Mean Deviator Stress psi	Std. Dev. Deviator Stress psi	Mean Bulk Stress psi	Mean Resilient Strain %	Std. Dev. Resilient Strain %	Mean Resilient Modulus psi	Std. Dev. Resilient Modulus psi
6.082	2.000	2.011	0.0558	20.26	0.01	0.00	18659.	328.36
6.059	4.000	3.986	0.0570	22.16	0.02	0.00	20188.	214.92
6.082	6.000	5.997	0.0862	24.24	0.03	0.00	20607.	159.07
6.120	8.000	7.951	0.1265	26.31	0.03	0.00	20755.	254.24
6.053	10.00	9.925	0.0615	28.08	0.04	0.00	24125.	333.66
4.083	2.000	1.993	0.0146	14.24	0.01	0.00	17421.	342.88
4.056	4.000	3.971	0.0643	16.14	0.02	0.00	19923.	272.41
4.044	6.000	5.988	0.1020	18.12	0.02	0.00	22937.	144.70
4.081	8.000	7.955	0.0798	20.20	0.03	0.00	22903.	267.96
4.108	10.00	9.912	0.0889	22.24	0.04	0.00	23889.	123.64
2.130	2.000	2.018	0.0581	8.409	0.01	0.00	21563.	614.51
2.078	4.000	3.980	0.0244	10.21	0.02	0.00	20863.	231.84
2.082	6.000	5.991	0.0425	12.24	0.03	0.00	21523.	296.40
2.102	8.000	7.996	0.1016	14.30	0.03	0.00	23591.	227.76
2.107	10.00	9.922	0.0571	16.24	0.04	0.00	23665.	133.44

Resilient Modulus

The mathematical equation of the three parameters

$$M_R = k_1 P_a \left(\frac{\sigma_3}{P_a} \right)^{k_2} \left(\frac{\sigma_d}{P_a} \right)^{k_3}$$

- Resilient modulus (M_R)
- Model constant = k_1 , k_2 , and k_3
- Atmospheric pressure = P_a
- Confining stress (σ_3)
- Deviator stress ($\sigma_1 - \sigma_3$)
- Model parameter k_1 indicator of M_R magnitude
- Model parameter k_2 increase of stiffness with increase in bulk stress.
- Model constant k_3 is positive for cement stabilization (no different pattern)
- Confining stress does not change resilient modulus

Three Perimeter Model for Cement Stabilized Soils

Soil Type	Resilient Modulus	Cement %	Curing Period	K_1	K_2	K_3	R^2
A-6	M_R	6% Cement	7 Days	1752	0.0973	0.162	0.87
A-6	M_R	6% Cement	7 Days	1319	0.08	0.214	0.94

Three parameter model for Cement Stabilized soils (A. Puppala)

Specimen Group	Cement Dosage	Curing Period	K_1	K_2	K_3	R^2
ML	0	0 Days	829.8	0.4667	-2.425	0.95
ML+C7%	7%	7 Days	3147.4	0.4846	0.1762	0.98
		14 Days	2987.5	0.4825	0.2565	0.97
		28 Days	2901.2	0.4905	0.2279	0.95

Conclusion Of Resilient Modulus Test

- Cement and soils should be mixed well, and sample should be prepared in accordance AASHTO T307.
- M_R decreases with increase of deviator stress when soils are untreated.
It shows stress softening behavior.
- M_R increases as cement treated soils show stress hardening.
- M_R does not affect significantly with the increase of confining stress.
- Resilient strain is very small for cement stabilized soils.
- Resilient strain increases with increase deviator stress for both untreated and treated soils.

Cement Stabilized Subgrade Soil (CSS)

- Strength: 300 psi minimum at seven days.
- CSS shall be 12 inches thick
- M_R shall be 18,000 psi or as recommended.
- Durability of CSS is greater than Cement Modified Subgrade.

Cement Stabilized Subgrade Soil

- **Description**

- Stabilizing 12 in. soils (in place) by uniformly mixing cement to achieve the desired unconfined compressive strength in accordance with 105.03.

- **Materials**

- Material shall be in accordance with the following:
 - *Portland* Cement, Type 1, Type 1L.....901.01(b)
 - Water.....913.01
 - Portland cement may be used dry or as a slurry
 - Soil shall meet the requirements of 215.02

Soil Suitable for Stabilization

Soils for cement stabilization shall meet the following requirements:

Soil Property	Test Method	Requirement
Maximum Dry Density	AASHTO T 99	≥ 90 pcf
Organic Material	AASHTO T 267	$\leq 6\%$
Sulfate Content	ITM 510	$\leq 1,000$ ppm

Testing and Mixed Design Recommendations

- Contactor shall perform all tests required to determine the optimum cement content for stabilization.
- Testing shall be performed by a qualified geotechnical consultant. The list is available on the INDOT website: <https://www.in.gov/indot/doing-business-with-indot/files/QualifiedGeotechnicalConsultants.pdf>
 - CSS shall have minimum strength of 300 psi,
 - Sulfate content in soil shall be ≤ 1000 ppm,
 - Sulfate in water shall be < 500 ppm,
 - Soil shall meet the requirements of 215.
 - Reviewing the project geotechnical recommendations for foundation soils.

Continued

- Mix design and test results shall be submitted to the Engineer.
 - Submit a Quality Control Plan, QCP in accordance with ITM 803.
 - Recommendations for mixing, pulverization, compaction, and curing.
 - Maintain adequate moisture during mixing.
 - Recommend proofrolling of the grade and suggest remedial foundation measures if needed.
-

Construction Requirements

- Temperature shall be 45° F or above.
 - Adequate drainage shall be provided during construction.
 - Proofroll to identify the poor foundation prior to stabilization and prepare the foundation as recommended in geotechnical report
 - Rocks >2 inches shall be removed during mixing.
 - Surface shall be maintained in a moist condition with no visible dry areas for the first 7 days after mixing with cement.
-

Construction Sequence

Spreading



Mixing



Compaction



QC/QA Specifications

- Quality Control (QC): The Contractor shall be responsible for the quality of construction of the finished product and for compliance with the construction documents, drawings, and specifications.
 - Quality Assurance (QA): INDOT will have ultimate responsibility for the oversight of construction and for conformance with the construction drawings, specifications, and quality assurance requirements.
-

QC/QA Testing

- **QC:** Testing shall be performed by contractor
 - LWD test /1000 Syd at 7 days after compaction
 - Moisture test/ 1000 Syd during mixing
 - Gradation test/1000 Syd
 - Spread rate and mixing depth/ 2000 ft / lane width
- **QA:** INDOT will perform
 - LWD test/ 2000 Syd
 - Moisture tests/ 1000 Syd during mixing
 - Proofrolling entire grade



LWD Testing

QA Testing

- Acceptance testing will be performed by INDOT.
- LWD test will be performed on the finished grade in accordance with 203.24(b). The allowable average deflection and maximum deflection for cement stabilized subgrade soil will be in accordance with the following:

Material Type	Allowable Average Deflection (mm)	Maximum Deflection at a Single Test Location (mm)
Cement Stabilized Subgrade Soil	0.14	0.17

- Moisture Tests for cement stabilized soils mixture will be performed in accordance with ITM 506 at every 1000 ft during cement and soils mixing.

I-70 Design Build, R-43375-B

I-70 Median Line F	Date	TM 506)	219.11 (c) Gradation Testing (ITM 516)					219.11 (a) LWD (ISS 203.24b)			
		MC (0.1%)	Total Soil Wt. (lbs.)	Soil Wt. Pass 1"	Soil Wt. Pass No.4	Percent Pass 1"	Percent Pass No.4	LWD 1 (mm)	LWD 2 (mm)	LWD 3 (mm)	LWD Avg. (mm)
697+00 WB	5/27/2025	14.6%	5.00	5.00	4.01	100%	80%	0.127	0.112	0.123	0.121
699+50 WB	5/27/2025	12.0%	5.00	5.00	3.95	100%	79%	0.107	0.104	0.103	0.105
702+00 WB	5/27/2025	13.3%	5.00	5.00	4.06	100%	81%	0.114	0.130	0.128	0.124
704+50 WB	5/27/2025	14.6%	5.00	5.00	3.68	100%	74%	0.081	0.077	0.081	0.080
707+00 WB	5/27/2025	14.6%	5.00	5.00	4.02	100%	80%	0.127	0.117	0.107	0.117
709+50 WB	5/27/2025	12.1%	5.00	5.00	3.65	100%	73%	0.127	0.125	0.125	0.126
712+00 WB	5/27/2025	13.1%	5.00	5.00	3.76	100%	75%	0.137	0.138	0.126	0.134
701+00 EB	6/3/2025	14.6%	5.00	5.00	3.56	100%	71%	0.083	0.074	0.073	0.076
705+00 EB	6/3/2025	15.9%	5.00	5.00	3.72	100%	74%	0.131	0.128	0.129	0.129
709+00 EB	6/3/2025	15.9%	5.00	5.00	3.70	100%	74%	0.094	0.090	0.088	0.090
723+00 EB	6/4/2025	13.3%	5.00	5.00	3.58	100%	72%	0.057	0.061	0.064	0.061
720+50 EB	6/4/2025	13.3%	5.00	5.00	3.80	100%	76%	0.088	0.083	0.084	0.085
718+00 EB	6/4/2025	17.2%	5.00	5.00	3.70	100%	74%	0.065	0.063	0.065	0.064
715+00 EB	6/4/2025	14.6%	5.00	5.00	3.86	100%	77%	0.134	0.134	0.136	0.135
713+00 EB	6/4/2025	17.2%	5.00	5.00	3.66	100%	73%	0.103	0.090	0.093	0.095
720+00 WB	6/12/2025	14.6%	5.00	5.00	4.02	100%	80%	**	**	**	**
722+50 WB	6/12/2025	14.6%	5.00	5.00	4.02	100%	80%	**	**	**	**
717+50 EB	6/12/2025	15.9%	5.00	5.00	3.74	100%	75%	0.083	0.084	0.087	0.085
725+50	6/27/2025	15.9%	5.00	5.00	3.64	100%	74%	0.116	0.109	0.102	0.109
727+00	6/27/2025	14.6%	5.00	5.00	3.97	100%	79%	0.111	0.110	0.105	0.109
728+50	6/27/2025	14.6%	5.00	5.00	3.50	100%	70%	0.107	0.102	0.114	0.111
730+50	6/27/2025	15.9%	5.00	5.00	3.92	100%	78%	***	***	***	***
732+50	6/27/2025	15.9%	5.00	5.00	4.00	100%	80%	***	***	***	***
734+00	6/27/2025	14.6%	5.00	5.00	3.98	100%	80%	***	***	***	***

Cement Stabilized Depth Check

- Cement raises the pH of the soil.
- Phenolphthalein, a color sensitive indicator solution, can be sprayed on the soil to determine the presence of cement. When cement is present, a reddish-pink color develops. See the figure below.



(a) Well mixed lime-soil modified soil



(b) Poorly mixed lime-soil modified soil

Cement stabilized soil (I-70 in Wayne County)



Proofrolling of cement stabilized subgrade



A fully legally loaded tri-axle dump truck. (About 35 t.)

- Dump truck with a minimum tire pressure of 90 psi.
- Dump truck weighing at least 33 t.
- Single pass for all proofrolled surfaces.
- Truck speed shall not exceed 2 mph.
- Deflections or rutting in excess of 1/4 in. shall require remediation.

Geotextile Placement



Talking Points

- Subsurface investigation (Site condition, moisture , other geological hazards)
 - Geotechnical recommendations and coordination with pavement engineers
 - Subgrade and foundation preparation
 - QC/QA specifications
 - Assist construction staff during construction
 - Subsurface drain video
 - Proofrolling of subgrade
-

Cement Stabilized Soils

- INDOT Requirement for Interstate Projects
 - Geotechnical Design Memo No. 2021-03 *“Cement stabilization of subgrade soils shall be considered for use on projects where interstate reconstruction or lane widening is proposed”*

Questions

?



Celebrating Century of Pavement Foundation: 100-Year Design Life

Kumar Dave, P.E. Indot
Nayyar Siddiki, P.E. Indot

September 24th, 2025

2025 Midwest Geotechnical Conf

Sardar Sarovar Dam-India



Dam Structure & Dimensions

- **Type:** A concrete gravity dam.
- **Height:** 163 meters (535 feet) from the deepest foundation level.
- **Length:** 1,210 meters (0.75 miles).
- **World Ranking:** The third-highest concrete dam in India and one of the largest concrete gravity dams in the world by volume of concrete.

Statue of unity Height: 597 ft

Today's Outline

- Introduction & Objectives
 - Factors influencing 100-year Design Life(Pavement and Foundation)
 - Pavement
 - Foundation
 - Case Study
 - Challenges and solution
 - Conclusion
-

Introduction & Objectives

- Why this topic matters?
 - Increased traffic loads & Climate changes
 - Need for long-lasting, cost-effective pavement solutions
 - Travelling public wants less maintenance/road repairs
 - Get in, Get out & Stay Out
-

Introduction(Ideal Pavement/100 Yrs Design life/Perpetual Pavement)

- Vision
- FHWA should lead the way to providing durable, long-life pavements that remain in excellent condition throughout their service lives



Image Source: FHWA

State-of-Good-Repair vs. Good Pavement

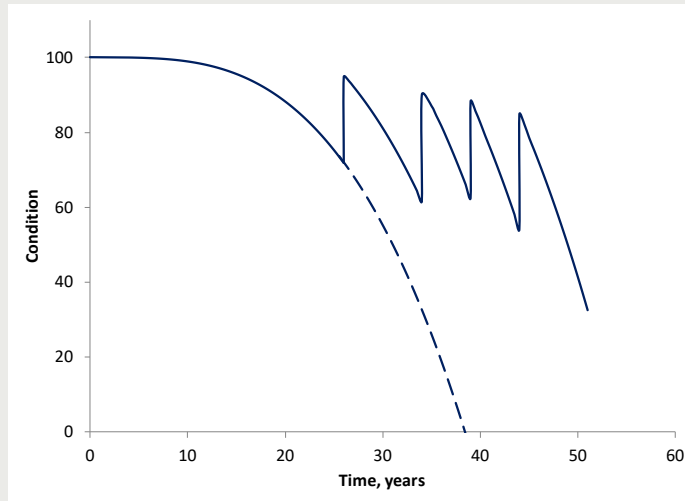


Image Source: FHWA

State of Good Repair

- Condition: Fair
- M&R: high
- Cost: \$\$\$\$

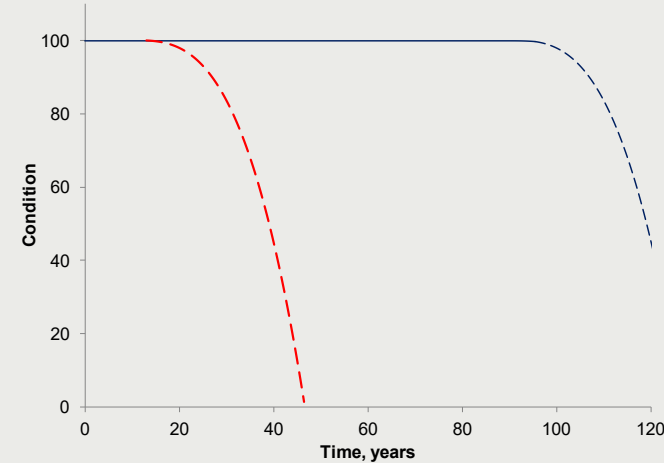


Image Source: FHWA

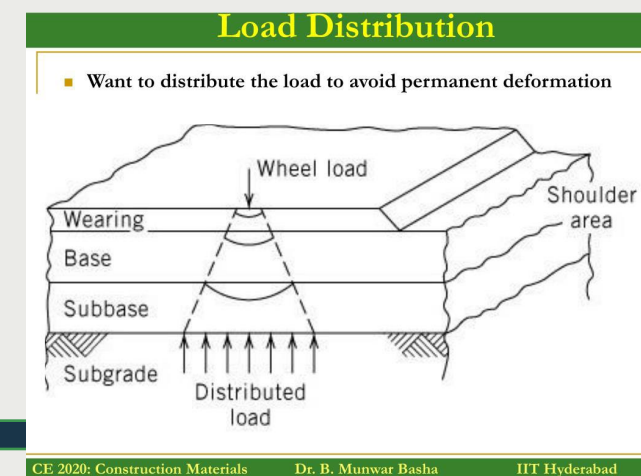
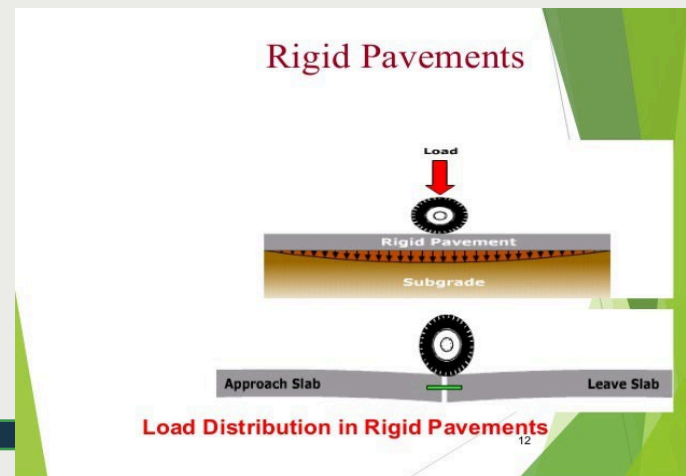
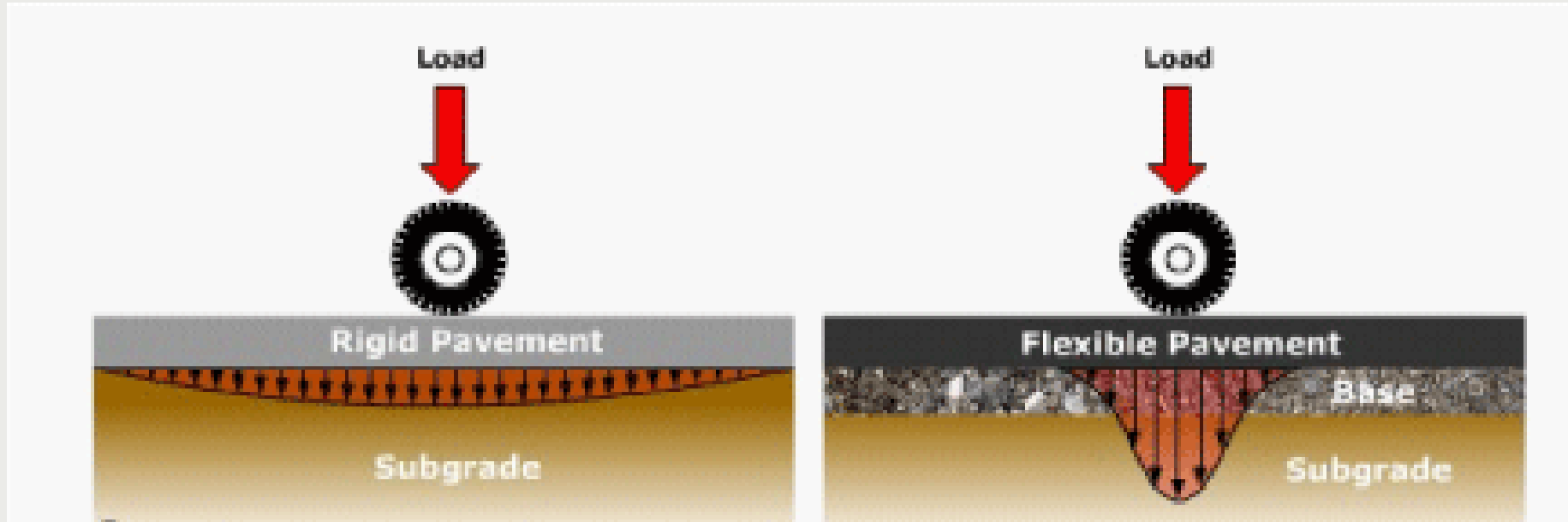
Good Pavement

- Condition: Excellent
- M&R: very low
- Cost: \$\$

What is needed

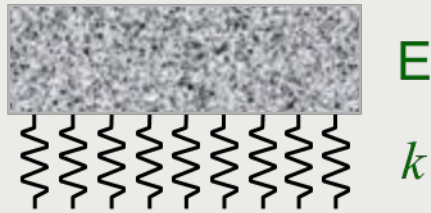
- Design pavements to last as long as the materials
 - Pavements should remain distress-free within the design period
 - Utilize design features that ensure good long-term performance
 - Build it right
 - Apply preventive treatments to preserve the pavement structure
-

Load distribution



Structural Model

Plate on
elastic foundation

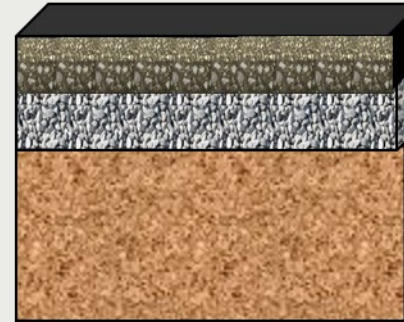


E

k

PCC Pavements

Elastic Layers



E^*

E_r

E_r

AC Pavements

Image Source: FHWA

Pavement Design

- Structural design
 - Focus on strength and stiffness
 - Surface thickness dominates the design; foundation layers have minimal impact
- Foundation
 - Not designed systematically in current practice
 - Different design requirements than the surface
 - Uniformity, adequate stiffness, and drainage
 - Must retain integrity throughout the life of the roadway
 - A separate design procedure is needed for pavement foundation design

Pavement Foundation Design Procedure

- Can be established based on existing knowledge
 - Priority is in formalizing the process
 - A comprehensive research program is not needed
 - Research needs can be identified for improvement over time
 - Refine over time through research
-

Ideal Pavement Design Process

- Foundation Design
 - Engineer the layering of materials from natural subgrade up to the surface layer
 - Design to remain in good condition (i.e., no degradation) throughout the life of the roadway
 - Use of chemical or mechanical stabilization as appropriate
 - Consideration of compatibility of adjacent layers to prevent decompaction
 - Incorporation of drainage features as appropriate
- Structural Design
 - Based on the layers defined in the foundation design
 - The layers can be abstracted in any manner appropriate for structural analysis

Pavement Foundation Design

- Practices vary from agency to agency
- No standard exists
- Best-practice needs to be established
 - Ensure uniformity at the time of construction
 - Prevent deterioration over time that leads to non-uniformity and localized failures
 - Pumping and loss of fines
 - Contamination
 - Decompaction
 - Include consideration of resilience

Keys to achieving well-performing pavement

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



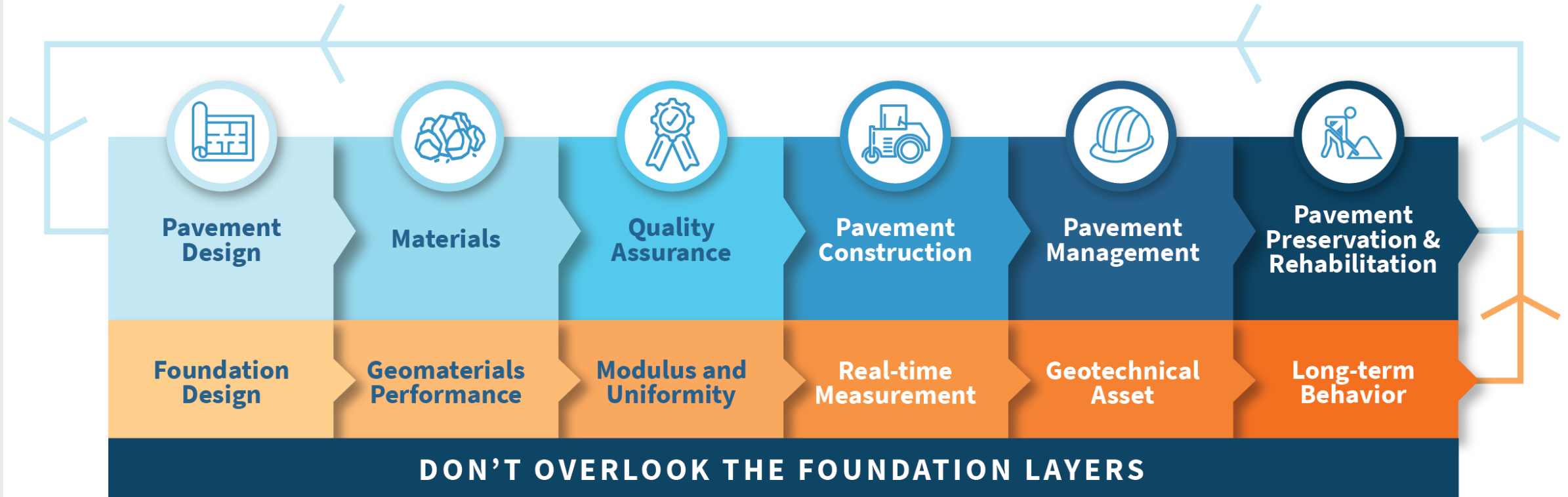
TPF-5(478) Engineered Pavement Foundations: *Virtual Open House*

June 11, 2025



U.S. Department of Transportation
Federal Highway Administration

Sustainable Pavement Systems



Foundations are Critical to Performance *and* to Achieving Sustainable Pavements

The foundation layer is largely ignored in modern day road construction techniques. This results in shorter project life-spans and expensive maintenance and repair cycles in the millions of dollars. 95% of these defects can be detected and remediated in real-time during the initial construction process.

Challenge facing the Iowa DOT

- Inadequate funding for the highway system
 - Pavements will need to last 100+ years
- Need to extend pavement life
 - Construct long life/permanent foundations
 - Remain in-place during future reconstruction
- How?
 - Improve pavement material performance ✓
 - Improve foundation longevity, uniformity
 - Improve construction quality



AID-PT Report Identifies Need to Focus on Improving Pavement Foundations

AID-PT *SHORT TAKE*

Pavement Foundation Research

Foundation design is a key aspect of pavements structural design that needs to be considered in design processes. The basis of design in current mechanistic-empirical (ME) design procedures are pavement responses such as stresses, strains, and deflections. Because the stiffness of unbound base layers is significantly less than that of surface layers, foundation layers have a relatively minor impact on pavement response. Thus, the benefits of a good foundation are not adequately reflected in the ME design process. While fundamentally, the ME design concept is sound, the ME designs do not consider the effects of any deterioration or spatial variability in the foundation layers. Over time, the conditions of the foundation layers can degrade and deform under the influence of repeated heavy loads, leading to non-uniform support conditions and localized failures. Thus, the principal role of a robust pavement foundation is ensuring the foundation layers retain their integrity throughout the pavement life.



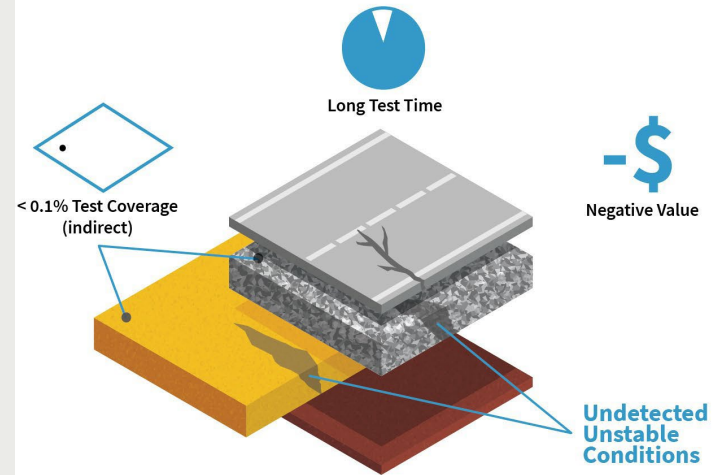
Improving pavement foundation design is a focus area for FHWA. A pavement foundation that does not degrade over time does not need to be replaced, which may translate to significant sustainability benefits in environmental impact and costs. In congested areas, eliminating the need to replace the foundation could be highly advantageous by expediting pavement rehabilitation.

Current pavement foundation process

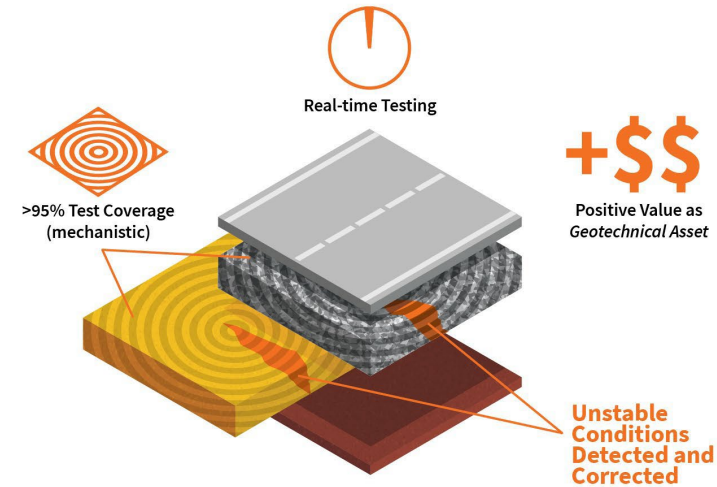
- Embankment - remove unsuitable soils
- Subgrade (Method spec)
 - Moisture control and lift thickness and compaction
 - Specifies equipment size/weight for compaction
 - Select Soil or dense graded aggregate
 - Proof roll subgrade prior to placement of drainable base
 - Geogrid included on some projects
- Drainable base with subdrains
 - Not completely open graded
 - Balance drainage and stability



~40 year lifespan=
state of practice for pavement
design life



100+ year lifespan=
engineering requirement for
sustainable pavement systems



Improved pavement foundations extend pavement
life and decrease project costs over time.



Menu
Recent Files

New Open SaveAs Save SaveAll Close Exit Run Batch Import Export Undo Redo Help

Explorer

- Projects
 - Project 1
 - Traffic
 - Single Axle Distribution
 - Tandem Axle Distribution
 - Tridem Axle Distribution
 - Quad Axle Distribution
 - Climate
 - JPCP Design Properties
 - Pavement Structure
 - Layer 1 PCC : JPCP Default
 - Layer 2 Non-stabilized Base : Crushed stone (A-1-a)
 - Layer 3 Subgrade : A-7-6
 - Maintenance Strategy
 - Project Specific Calibration Factors
 - New Flexible
 - Rehabilitation Flexible
 - New Rigid
 - Restore Rigid
 - Bonded Rigid
 - Unbonded Rigid
 - Sensitivity
 - Optimization
 - PDF Output Report
 - Multiple Project Summary
 - Batch Run
 - Tools
 - ME Design Calibration Factors

Project1:Project* Project1:Traffic Project1:Climate

General Information

Design type: New Pavement

Pavement type: Jointed Plain Concrete Pavement

Design life (years): 20

Pavement construction: June 2023

Traffic opening: September 2023

☐ Special traffic loading for flexible pavements

+ Add Layer - Remove Layer

Performance Criteria

	Limit	Reliability	Report Visibility
Initial IRI (in/mile)	63		☒
Terminal IRI (in/mile)	172	90	☒
JPCP transverse cracking (percent slabs)	15	90	☒
Mean joint faulting (in)	0.12	90	☒

Layer 2 Non-stabilized Base : Crushed stone (A-1-a)

Click here to edit Layer 1 PCC : JPCP Default

Click here to edit Layer 2 Non-stabilized Base : Crushed stone (A-1-a)

Click here to edit Layer 3 Subgrade : A-7-6

Unbound

Coefficient of lateral earth pressure (k0)	☒	0.5
Layer thickness (in)	☒	10
Poisson's ratio	☒	0.35
Modulus		
Resilient modulus (psi)	☒	20000
Sieve		
Gradation & other engineering properties	☒	A-1-a
Identifiers		
Approver		
Date approved		1/1/2011
Author		AASHTO
Date created		1/1/2011
County		
Description of object		Default material
Direction of travel		
Display name/identifier		Crushed stone
District		

Coefficient of lateral earth pressure (k0)

The ratio of the lateral earth pressure to the vertical earth pressure. Use a default value of 0.5. Recommended min/max: 0.4/0.8.

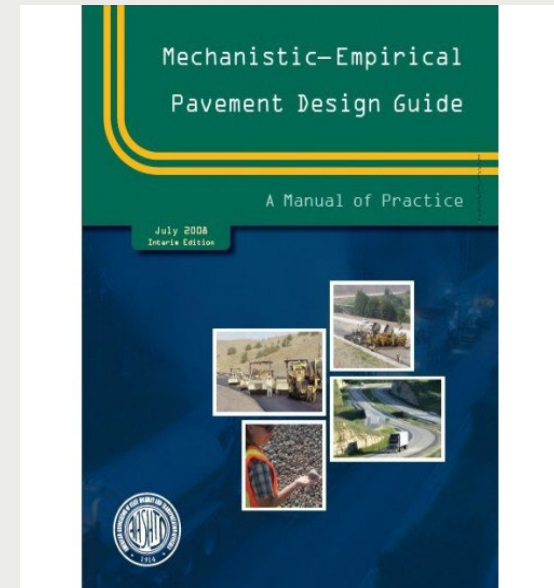
Error List

Indot criteria of Ideal Pavement or Long-Lasting Pavement

- What is 100-year Design Consideration?
 - Longer design life....50 to 100 years
 - Fewer rehabilitation cycles
 - Less maintenance
 - Lower Cost/lane mile/year & Life Cycle Cost Analysis
 - Sustainable(Recycling FDR etc., Self healing asphalt)
 - Compatible (durable & environmentally responsible)
-

Factors Influencing Longevity

- Design considerations(AASHTO 1993 & MEPDG)
 - Pavement performance
 - Traffic
 - Roadbed soil
 - Materials of construction
 - Environment
 - Drainage
 - Reliability
 - Life Cycle Costs, and
 - Shoulder design
- Material selection
 - High quality Material (SMA and high-performance concrete)
- Construction practices
- Maintenance strategies



INDOT Pavement Design

- Asphalt Pavement Design
 - 50 yrs. design life (structural)
 - < 5% of fatigue cracking (bottom up)
 - No adding structure in 50 yrs., we do mill and fill as per LCPCA
 - SMA Surface
 - VRAM
 - Spray paver
 - Stabilized Subgrade
 - Stabilized Foundation (if required)
 - Optimized pavement design by MEPDG

HMA pavement cross section

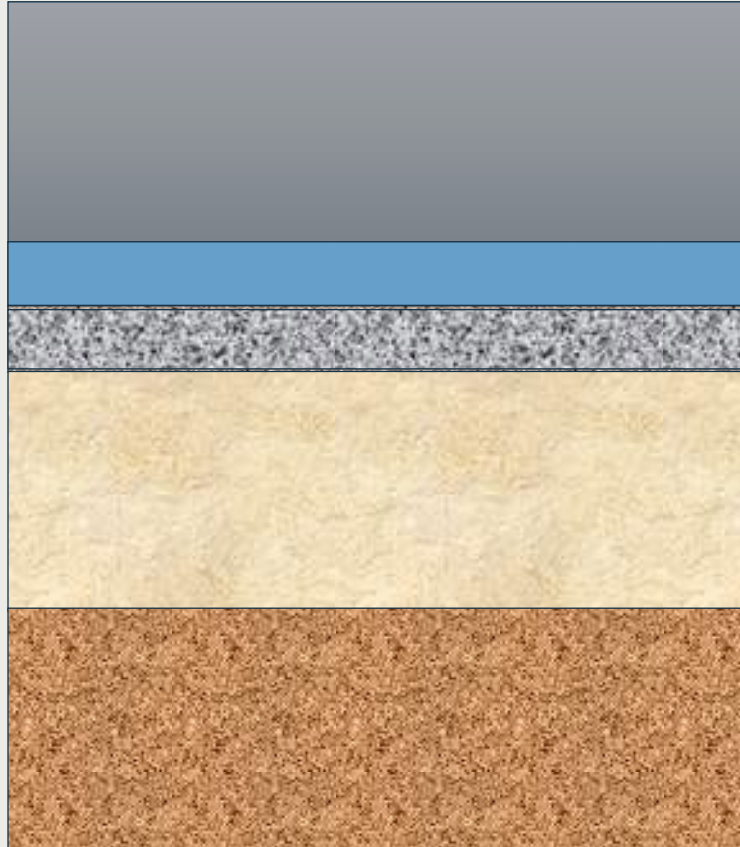


- ← 1.5" SMA Surface
- ← 3.0" HMA Intermediate
- ← 12"+/- HMA DGB
- ← 3" OG/HMA OG (Drainage layer)
- ← 6" DGAB (Separation layer) on Geotextile
- ← 12" Cement Stabilized Soil treatment
- ← Soil Subgrade Foundation if required

INDOT Pavement Design

- Concrete Pavement Design
 - 50 yrs. design life (structural)
 - 15-ft Joint spacing, 1.5-inch dowel, widened slab(14 ft)
 - < 10% of cracking
 - Longitudinal tining
 - No adding structure in 50 yrs., we do CPR
 - Stabilized Subbase
 - Stabilized Subgrade
 - Optimized pavement design by MEPDG
 - Example Design: I-65 in Boone County

JPCP cross section



← 12" – 14" JPCP

← 3" OGB/HMA OG (Drainage layer)

← 6" DGAB (Separation layer) on Geotextile)

← 12" Cement Stabilized Soil treatment

← Soil subgrade Foundation if required

Case Study

- I-65 in Clark County
 - 6-mile Added Travel Lanes (Divided Highway)
 - 6 lanes
 - AADTT =14720
 - Design Bid Best Build(\$200+M, Letting March 2025)
 - Const 2025-26

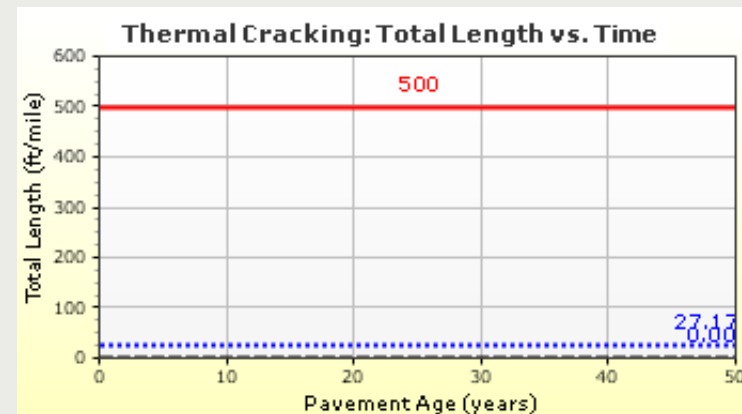
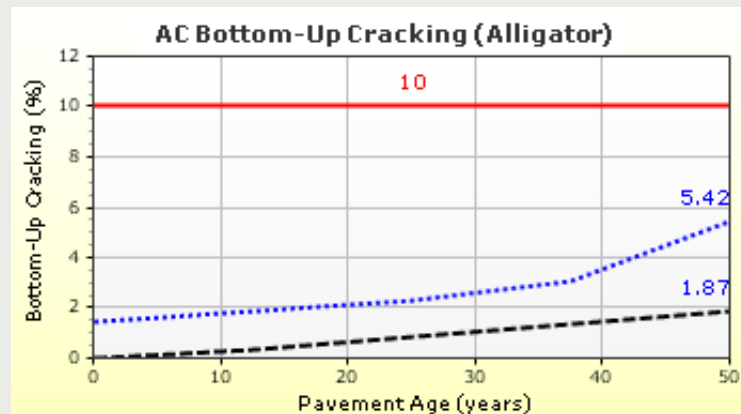
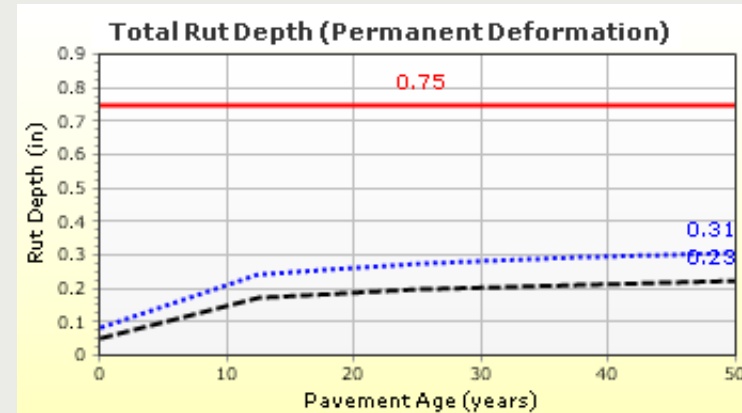
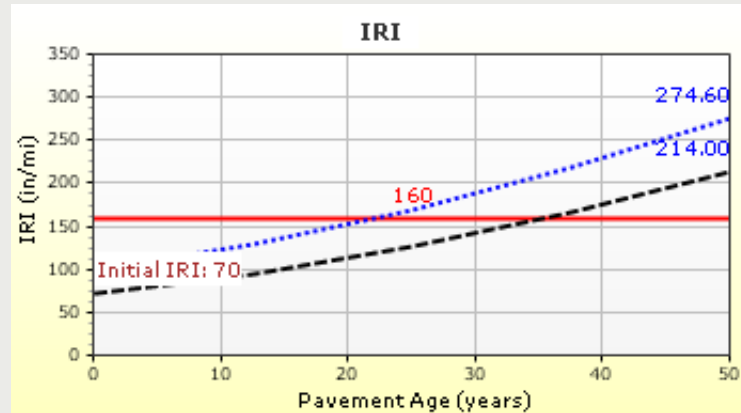
Designed both HMA and JPCP

Both types are designed as long-lasting pavement (50 years)

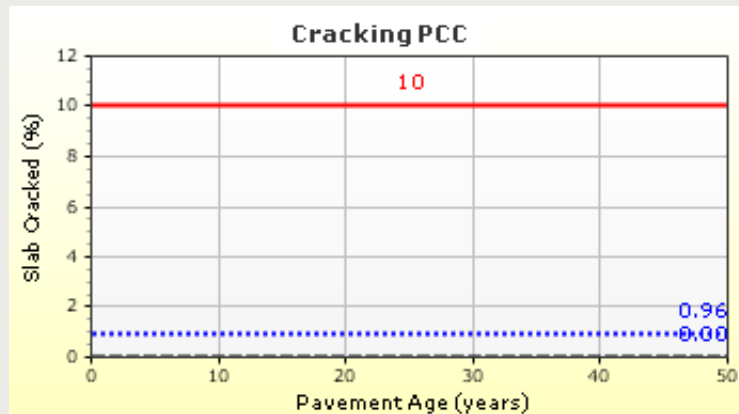
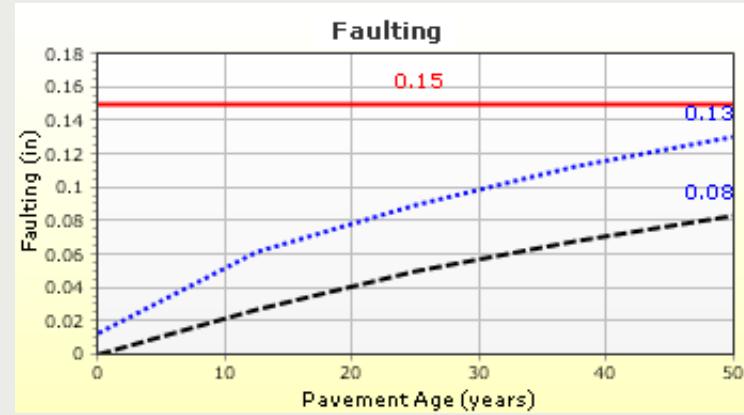
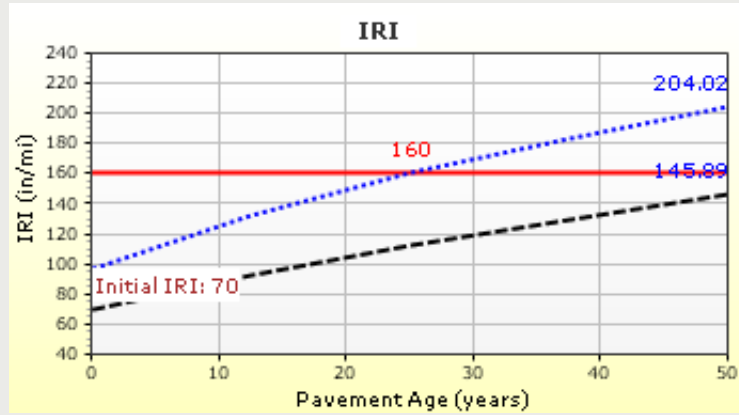
Both pavements have stabilized subgrade treatment & Foundation Tret.

Both pavement have stabilized drainage and separation layers

HMA MEPDG Output



JPCP MEPDG Output



MEPDG Subgrade Treatment

- Resilient Modulus, Gradation, and Atterberg Limits
 - Chemical Soil Modification – input as a compacted soil
 - Aggregate Subgrade Treatment - input as a crushed stone

Layer 6 Subgrade : Subgrade Treatment (A-4)

Unbound	
Layer thickness (in)	14.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
12000.0

Use Correction factor for NDT modulus?	-
---	---

Sieve

Liquid Limit	21.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	118.4
Saturated hydraulic conductivity (ft/hr)	False	8.325e-06
Specific gravity of solids	False	2.7
Water Content (%)	False	11.8

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	60.6
#100	
#80	73.9
#60	
#50	
#40	82.7
#30	
#20	
#16	
#10	89.9
#8	
#4	93.0
3/8-in.	95.6
1/2-in.	96.7
3/4-in.	98.0
1-in.	98.7
1 1/2-in.	99.4
2-in.	99.6
2 1/2-in.	
3-in.	
3 1/2-in.	99.8

MEPDG Natural Subgrade

- Resilient Modulus, Gradation, and Atterberg Limits
 - Modulus strength effected by water table depth

Layer 7 Subgrade : Natural Subgrade (A-6)

Unbound	
Layer thickness (in)	Semi-infinite
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
6000.0

Use Correction factor for NDT modulus?	-
--	---

Sieve	
Liquid Limit	33.0
Plasticity Index	16.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (pcf)	False	107.9
Saturated hydraulic conductivity (ft/hr)	False	1.95e-05
Specific gravity of solids	False	2.7
Water Content (%)	False	17.1

User-defined Soil Water Characteristic Curve

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
#200	83.2
#100	
#80	73.5
#60	
#50	
#40	82.4
#30	
#20	
#16	
#10	90.2
#8	
#4	93.5
3/8-in.	96.4
1/2-in.	97.4
3/4-in.	98.4
1-in.	99.0
1 1/2-in.	99.5
2-in.	99.8
2 1/2-in.	
3-in.	
3 1/2-in.	100.0

MEPDG Climate Data

- Dept
subg

Climate Inputs

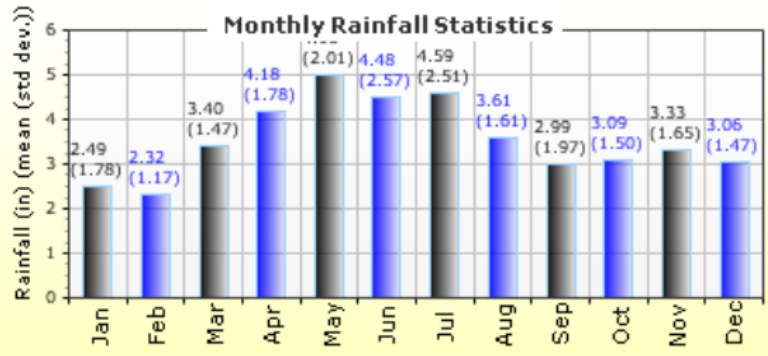
Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(ft))
INDIANAPOLIS, IN	39.71000 -86.27200 790
INDIANAPOLIS, IN	39.82500 -86.29600 816
SHELBYVILLE, IN	39.57800 -85.80300 804

Annual Statistics:

Mean annual air temperature (°F)	53.05
Mean annual precipitation (in)	42.53
Freezing index (°F - days)	516.70
Average annual number of freeze/thaw cycles:	59.57

Monthly Climate Summary:



Water table depth
(ft)

6.00

of the

Cement Stabilized Subgrade





I-69

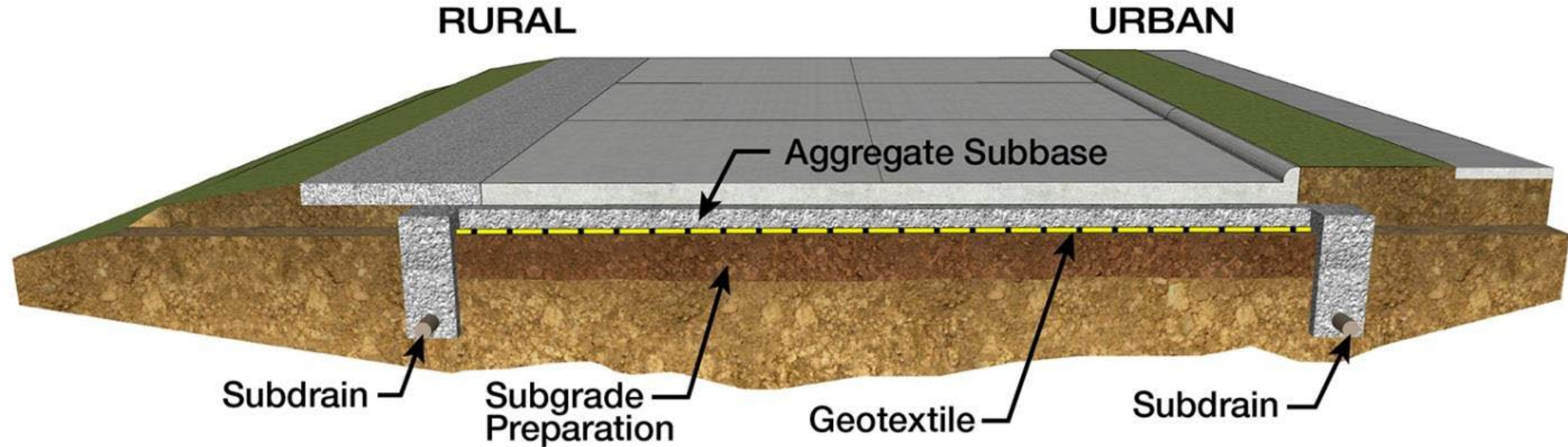


I-69 Clear Path

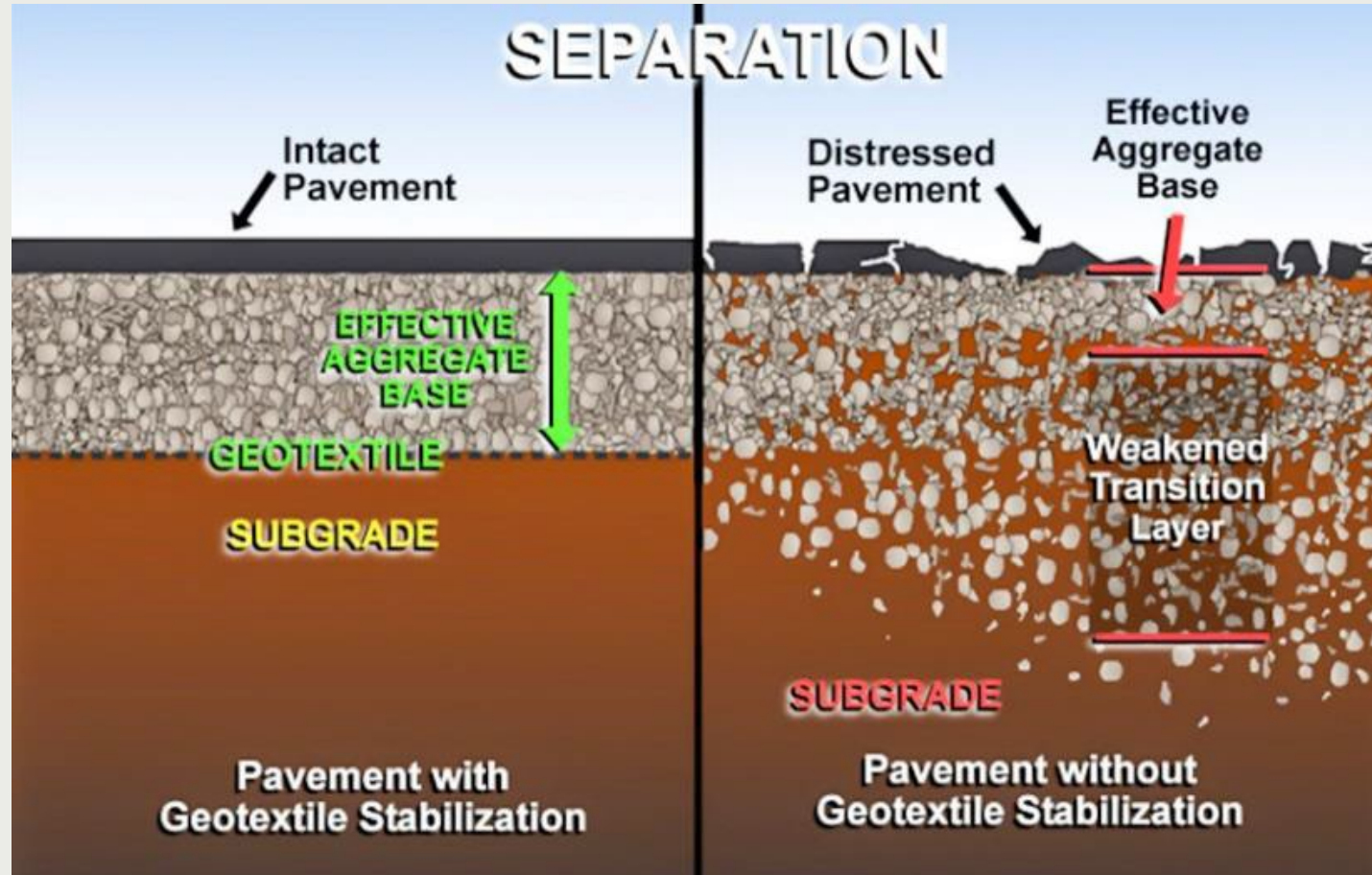




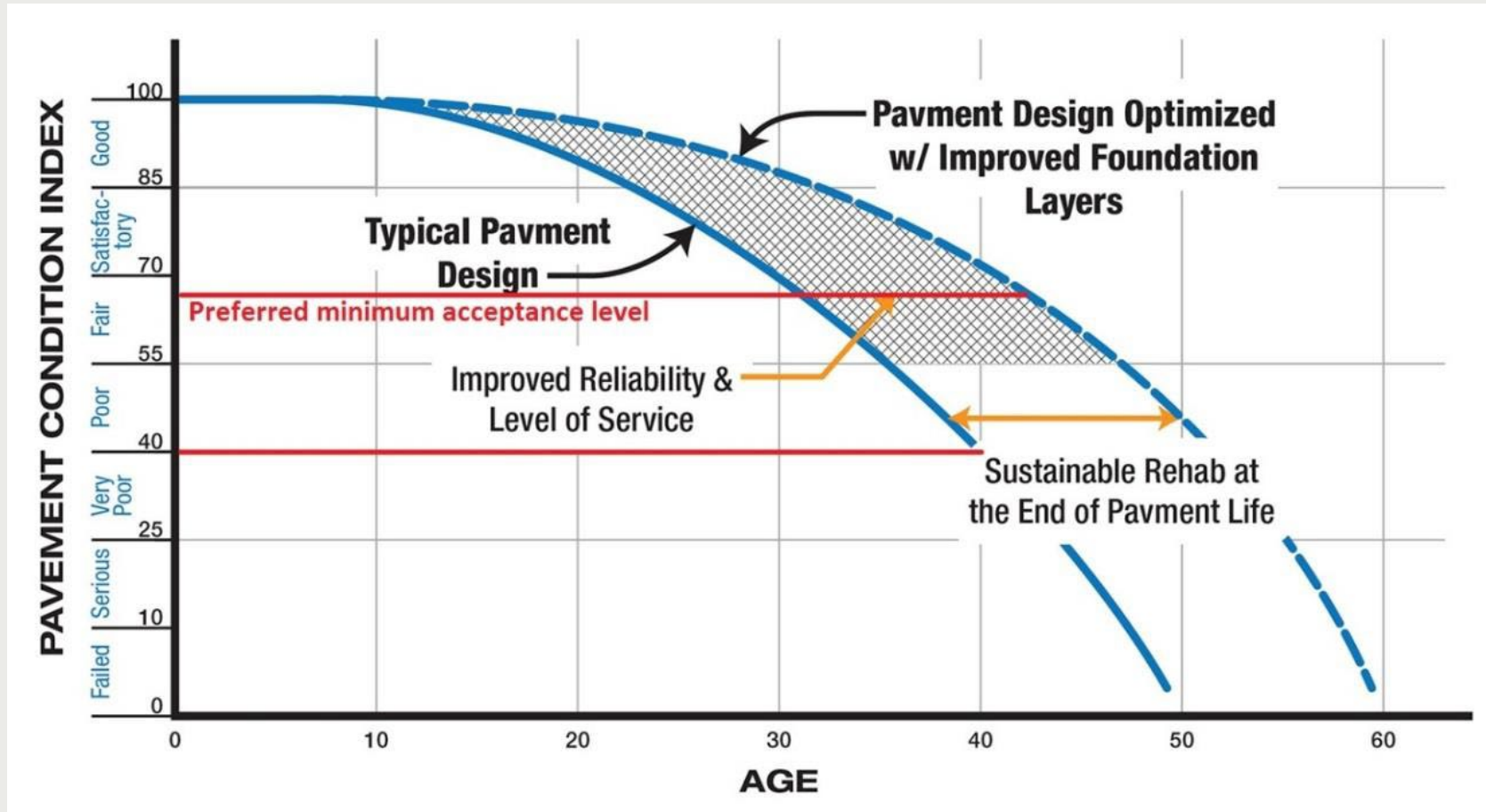
Guidance to improve performance for Local Roads (NCPTC CPTech)



Guidance to improve performance for Local Roads



Pavement Performance Curve with improved foundation layers



Challenges and Solutions

- Initial cost
 - Quality construction
 - Maintenance cycles
 - Cost/lane mile/year
 - Drainage(pavement & subgrade)
 - Industry(Asphalt and Concrete) perspectives/capabilities
-

Conclusions

- There is a strong need for Long-lasting pavement
 - Less disruption to traveling public
 - Subgrade/Foundation is very important
 - Quality material and Construction is equally important
 - LCCA and cost/lane mile/year is less compared to traditional Pavement
 - Nondestructive Testing is important verification
 - Pavement and subgrade drainage will enhance pavement life
-

Talking Points

- Pavement design is not an art but science now.
 - Design smartly
 - MEPDG(AASHTO Pavement ME)
 - How do you design pavement for longer life >50 yrs ?
- Geotechnical Engineer, Pavement Engineer, Construction Engineer & Asset Engineer must talk with each other
 - How do we make our foundation uniform and stable for 100 year?
 - How do you take care of pavement drainage?

Engineering the Foundation Layers for Long-Life Pavement System

- Pooled Fund#1632

Implications for pavement design

- DOTs are transitioning to PMED for PCC and HMA design
- Subgrade/Subbase material strength values have been historical relationships based on density and material type or in some cases back-calculated from FWD.
- No process to verify that design values are met in the field.
 - Instead used moisture/density control and proof rolling.
- Assure design values are being met
- Typical values provided in the ME Design guide based on soil classification may not be reliable for your materials
 - Performance specification utilizing Modulus mapping



- E-C296

TRANSPORTATION RESEARCH
CIRCULAR
Number E-C296 November 2024

**Foundation Design
and Construction for
100-Year Pavement
Systems**

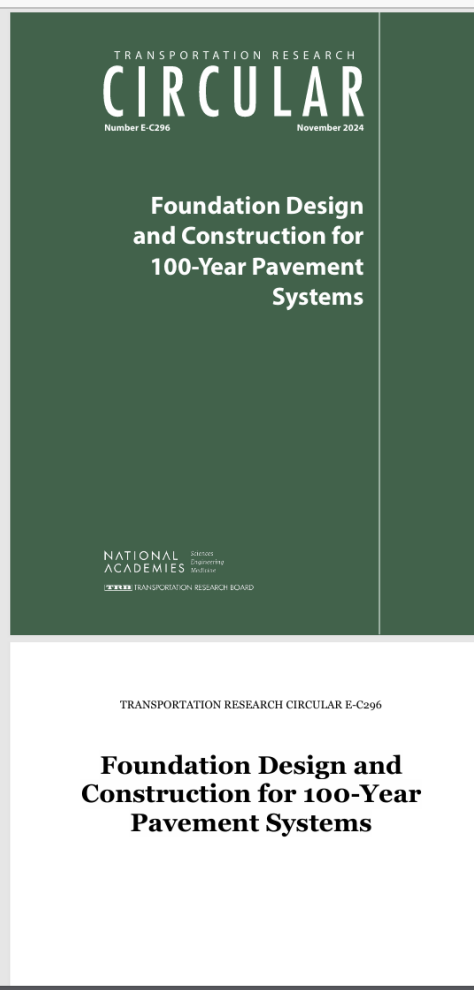
Increasing Expectations for Pavement Foundations

KUMAR DAVE

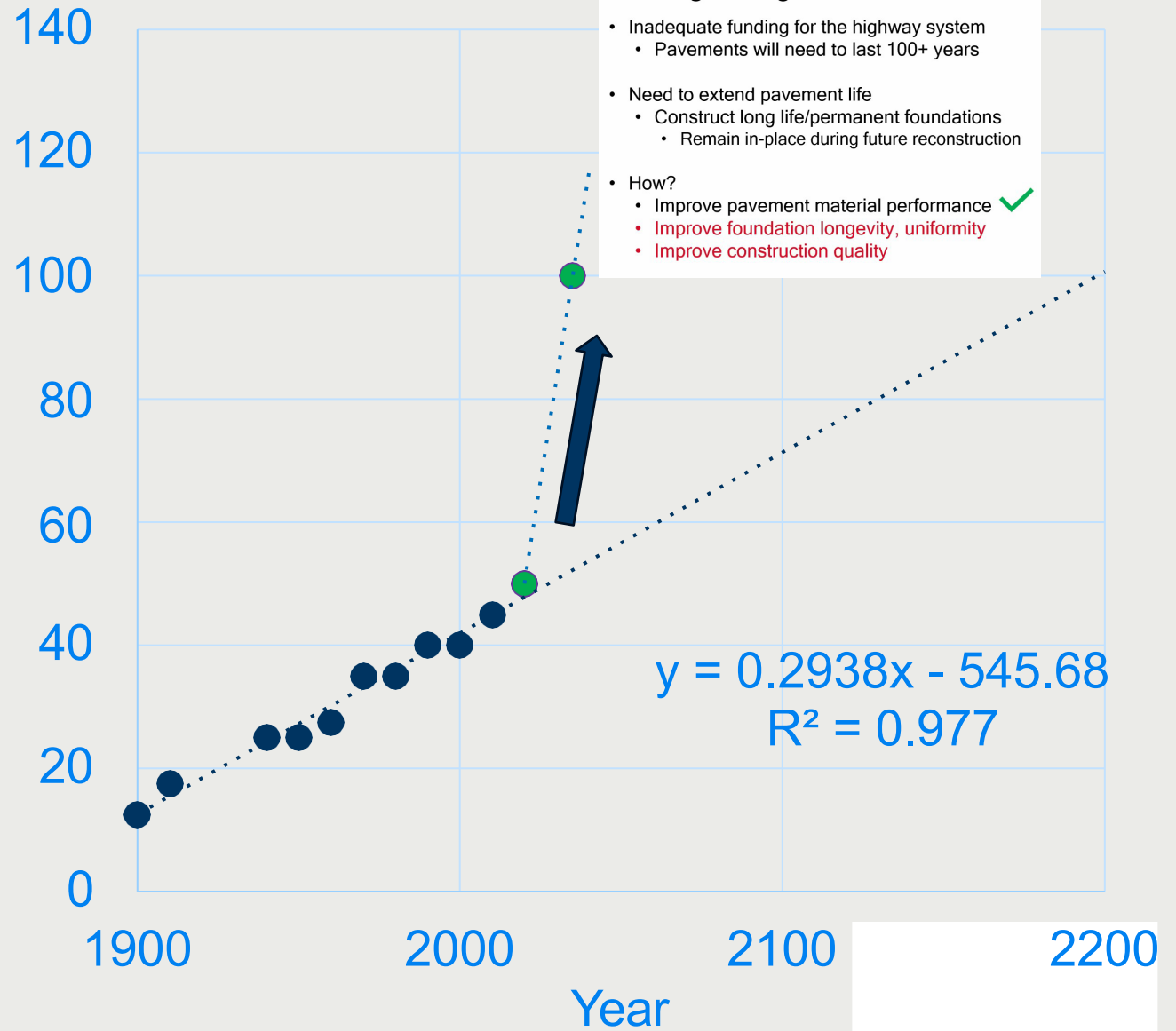
NAYYAR SIDDIKI

Indiana Department of Transportation

<https://www.trb.org/Publications/Blurbs/183300.aspx>



Pavement Design Life (years)



2023 & 24 Perpetual Pavement National Award



Thank you!

Kumar Dave
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317-809-2145

Celebrating A Century of Pavement Foundation: Geotechnical Contribution to Roadway Excellence

Midwest Geotechnical Conference

Kumar Dave MS., PE.

Nayyar Siddiki MS., PE.

Outline

- Need for foundation improvements
 - Geotechnical Recommendations (See Geotechnical Report)
 - Cement Stabilized Subgrade Soil, Sec 219
 - Design Procedures for Cement Stabilization
 - Testing Requirements
 - QC/QA Testing
 - Recommendations (During Construction)
-

Need for Pavement Foundation Improvement

- Subgrade is defined as the roadbed portion on which pavement is constructed.
- Pavement design is engineered to distribute stresses imposed by traffic to the foundation.
- The pavement foundation conditions have a significant influence on the choice and thickness of the pavement structure.
- Geotechnical investigation should include foundation soil conditions and its engineering properties, along with ground water.
- Variability of engineering properties of subgrade soils may be reduced.
- Subgrade and its foundation properties may be improved with the use of mechanical, chemical, or geosynthetic modification.
- INDOT initiated with the pavement foundation improvement with “Cement Stabilization of Subgrade Soils”.

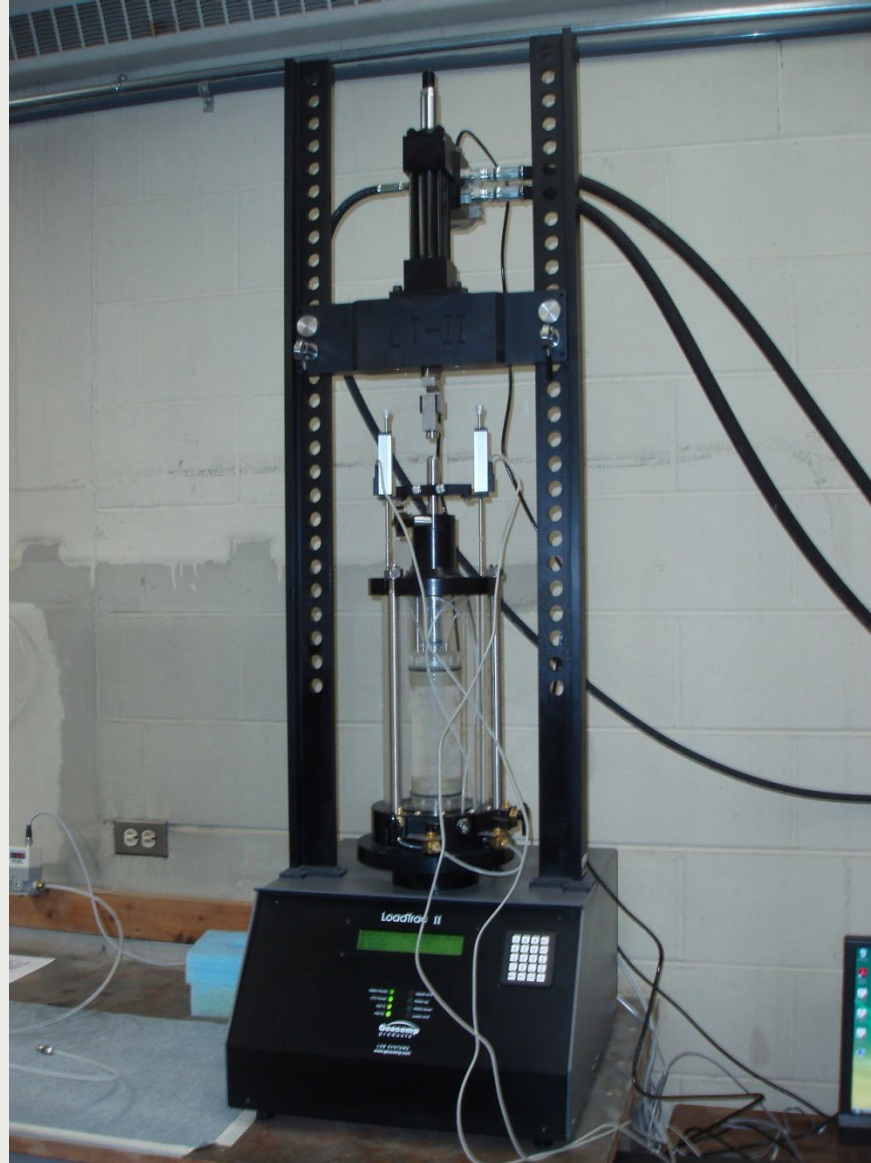
Geotechnical Subgrade Recommendations

- Soil cement stabilization
- Foundation treatment requirement delineated when needed
 - Chemical Modification, Aggregate , Geosynthetics, or moisture control
- Subgrade and foundation resilient moduli
- Organic, Marl, sulfate of soil, and water
- Ground water elevation, subsurface drain, and geotextile selection

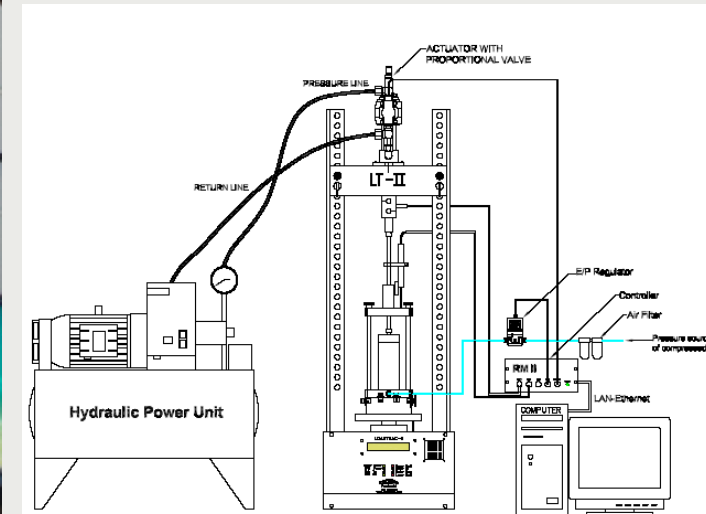
Cement Stabilized Samples



Resilient Modulus Machine



AASHTO T307



Cement Stabilized Soil Resilient Modulus Data

RM TEST

Summary Data

Confining Stress S3 psi	Nom. Max. Deviator Stress psi	Mean Deviator Stress psi	Std. Dev. Deviator Stress psi	Mean Bulk Stress psi	Mean Resilient Strain %	Std. Dev. Resilient Strain %	Mean Resilient Modulus psi	Std. Dev. Resilient Modulus psi
6.082	2.000	2.011	0.0558	20.26	0.01	0.00	18659.	328.36
6.059	4.000	3.986	0.0570	22.16	0.02	0.00	20188.	214.92
6.082	6.000	5.997	0.0862	24.24	0.03	0.00	20607.	159.07
6.120	8.000	7.951	0.1265	26.31	0.03	0.00	20755.	254.24
6.053	10.00	9.925	0.0615	28.08	0.04	0.00	24125.	333.66
4.083	2.000	1.993	0.0146	14.24	0.01	0.00	17421.	342.88
4.056	4.000	3.971	0.0643	16.14	0.02	0.00	19923.	272.41
4.044	6.000	5.988	0.1020	18.12	0.02	0.00	22937.	144.70
4.081	8.000	7.955	0.0798	20.20	0.03	0.00	22903.	267.96
4.108	10.00	9.912	0.0889	22.24	0.04	0.00	23889.	123.64
2.130	2.000	2.018	0.0581	8.409	0.01	0.00	21563.	614.51
2.078	4.000	3.980	0.0244	10.21	0.02	0.00	20863.	231.84
2.082	6.000	5.991	0.0425	12.24	0.03	0.00	21523.	296.40
2.102	8.000	7.996	0.1016	14.30	0.03	0.00	23591.	227.76
2.107	10.00	9.922	0.0571	16.24	0.04	0.00	23665.	133.44

Resilient Modulus

The mathematical equation of the three parameters

$$M_R = k_1 p_a \left(\frac{\sigma_3}{p_a} \right)^{k_2} \left(\frac{\sigma_d}{p_a} \right)^{k_3}$$

- Resilient modulus (M_R)
- Model constant = k_1 , k_2 , and k_3
- Atmospheric pressure = p_a
- Confining stress (σ_3)
- Deviator stress ($\sigma_1 - \sigma_3$)
- Model parameter k_1 indicator of M_R magnitude
- Model parameter k_2 increase of stiffness with increase in bulk stress.
- Model constant k_3 is positive for cement stabilization (no different pattern)
- Confining stress does not change resilient modulus

Three Perimeter Model for Cement Stabilized Soils

Soil Type	Resilient Modulus	Cement %	Curing Period	K_1	K_2	K_3	R^2
A-6	M_R	6% Cement	7 Days	1752	0.0973	0.162	0.87
A-6	M_R	6% Cement	7 Days	1319	0.08	0.214	0.94

Three parameter model for Cement Stabilized soils (A. Puppala)

Specimen Group	Cement Dosage	Curing Period	K_1	K_2	K_3	R^2
ML	0	0 Days	829.8	0.4667	-2.425	0.95
ML+C7%	7%	7 Days	3147.4	0.4846	0.1762	0.98
		14 Days	2987.5	0.4825	0.2565	0.97
		28 Days	2901.2	0.4905	0.2279	0.95

Conclusion Of Resilient Modulus Test

- Cement and soils should be mixed well, and sample should be prepared in accordance AASHTO T307.
- M_R decreases with increase of deviator stress when soils are untreated. It shows stress softening behavior.
- M_R increases as cement treated soils show stress hardening.
- M_R does not affect significantly with the increase of confining stress.
- Resilient strain is very small for cement stabilized soils.
- Resilient strain increases with increase deviator stress for both untreated and treated soils.

Cement Stabilized Subgrade Soil (CSS)

- Strength: 300 psi minimum at seven days.
- CSS shall be 12 inches thick
- M_R shall be 18,000 psi or as recommended.
- Durability of CSS is greater than Cement Modified Subgrade.

Cement Stabilized Subgrade Soil

Description

- Stabilizing 12 in. soils (in place) by uniformly mixing cement to achieve the desired unconfined compressive strength in accordance with 105.03.

Materials

- Material shall be in accordance with the following:
 - *Portland* Cement, Type 1, Type 1L.....901.01(b)
 - Water.....913.01
 - Portland cement may be used dry or as a slurry
 - Soil shall meet the requirements of 215.02

Soil Suitable for Stabilization

Soils for cement stabilization shall meet the following requirements:

Soil Property	Test Method	Requirement
Maximum Dry Density	AASHTO T 99	≥ 90 pcf
Organic Material	AASHTO T 267	$\leq 6\%$
Sulfate Content	ITM 510	$\leq 1,000$ ppm

Testing and Mixed Design Recommendations

- Contactor shall perform all tests required to determine the optimum cement content for stabilization.
- Testing shall be performed by a qualified geotechnical consultant. The list is available on the INDOT website: <https://www.in.gov/indot/doing-business-with-indot/files/QualifiedGeotechnicalConsultants.pdf>
 - CSS shall have minimum strength of 300 psi,
 - Sulfate content in soil shall be ≤ 1000 ppm,
 - Sulfate in water shall be < 500 ppm,
 - Soil shall meet the requirements of 215.
 - Reviewing the project geotechnical recommendations for foundation soils.

Continued

- Mix design and test results shall be submitted to the Engineer.
 - Submit a Quality Control Plan, QCP in accordance with ITM 803.
 - Recommendations for mixing, pulverization, compaction, and curing.
 - Maintain adequate moisture during mixing.
 - Recommend proofrolling of the grade and suggest remedial foundation measures if needed.
-

Construction requirements

- Temperature shall be 45° F or above.
- Adequate drainage shall be provided during construction.
- Proofroll to identify the poor foundation prior to stabilization and prepare the foundation as recommended in geotechnical report
- Rocks >2 inches shall be removed during mixing.
- Surface shall be maintained in a moist condition with no visible dry areas for the first 7 days after mixing with cement.

Construction Sequence

Spreading



Mixing



Compaction



QC/QA Specifications

- Quality Control (QC): The Contractor shall be responsible for the quality of construction of the finished product and for compliance with the construction documents, drawings, and specifications.
 - Quality Assurance (QA): INDOT will have ultimate responsibility for the oversight of construction and for conformance with the construction drawings, specifications, and quality assurance requirements.
-

QC/QA Testing

- **QC:** Testing shall be performed by contractor
 - LWD test /1000 Syd at 7 days after compaction
 - Moisture test/ 1000 Syd during mixing
 - Gradation test/1000 Syd
 - Spread rate and mixing depth/ 2000 ft / lane width
- **QA:** INDOT will perform
 - LWD test/ 2000 Syd
 - Moisture tests/ 1000 Syd during mixing
 - Proofrolling entire grade



LWD Testing

QA Testing

- Acceptance testing will be performed by INDOT.
- LWD test will be performed on the finished grade in accordance with 203.24(b). The allowable average deflection and maximum deflection for cement stabilized subgrade soil will be in accordance with the following:

Material Type	Allowable Average Deflection (mm)	Maximum Deflection at a Single Test Location (mm)
Cement Stabilized Subgrade Soil	0.14	0.17

- Moisture Tests for cement stabilized soils mixture will be performed in accordance with ITM 506 at every 1000 ft during cement and soils mixing.

I-70 Design Build, R-43375-B

I-70 Median Line F	Date	TM 506)	219.11 (c) Gradation Testing (ITM 516)					219.11 (a) LWD (ISS 203.24b)			
		MC (0.1%)	Total Soil Wt. (lbs.)	Soil Wt. Pass 1"	Soil Wt. Pass No.4	Percent Pass 1"	Percent Pass No.4	LWD 1 (mm)	LWD 2 (mm)	LWD 3 (mm)	LWD Avg. (mm)
697+00 WB	5/27/2025	14.6%	5.00	5.00	4.01	100%	80%	0.127	0.112	0.123	0.121
699+50 WB	5/27/2025	12.0%	5.00	5.00	3.95	100%	79%	0.107	0.104	0.103	0.105
702+00 WB	5/27/2025	13.3%	5.00	5.00	4.06	100%	81%	0.114	0.130	0.128	0.124
704+50 WB	5/27/2025	14.6%	5.00	5.00	3.68	100%	74%	0.081	0.077	0.081	0.080
707+00 WB	5/27/2025	14.6%	5.00	5.00	4.02	100%	80%	0.127	0.117	0.107	0.117
709+50 WB	5/27/2025	12.1%	5.00	5.00	3.65	100%	73%	0.127	0.125	0.125	0.126
712+00 WB	5/27/2025	13.1%	5.00	5.00	3.76	100%	75%	0.137	0.138	0.126	0.134
701+00 EB	6/3/2025	14.6%	5.00	5.00	3.56	100%	71%	0.083	0.074	0.073	0.076
705+00 EB	6/3/2025	15.9%	5.00	5.00	3.72	100%	74%	0.131	0.128	0.129	0.129
709+00 EB	6/3/2025	15.9%	5.00	5.00	3.70	100%	74%	0.094	0.090	0.088	0.090
723+00 EB	6/4/2025	13.3%	5.00	5.00	3.58	100%	72%	0.057	0.061	0.064	0.061
720+50 EB	6/4/2025	13.3%	5.00	5.00	3.80	100%	76%	0.088	0.083	0.084	0.085
718+00 EB	6/4/2025	17.2%	5.00	5.00	3.70	100%	74%	0.065	0.063	0.065	0.064
715+00 EB	6/4/2025	14.6%	5.00	5.00	3.86	100%	77%	0.134	0.134	0.136	0.135
713+00 EB	6/4/2025	17.2%	5.00	5.00	3.66	100%	73%	0.103	0.090	0.093	0.095
720+00 WB	6/12/2025	14.6%	5.00	5.00	4.02	100%	80%	**	**	**	**
722+50 WB	6/12/2025	14.6%	5.00	5.00	4.02	100%	80%	**	**	**	**
717+50 EB	6/12/2025	15.9%	5.00	5.00	3.74	100%	75%	0.083	0.084	0.087	0.085
725+50	6/27/2025	15.9%	5.00	5.00	3.64	100%	74%	0.116	0.109	0.102	0.109
727+00	6/27/2025	14.6%	5.00	5.00	3.97	100%	79%	0.111	0.110	0.105	0.109
728+50	6/27/2025	14.6%	5.00	5.00	3.50	100%	70%	0.107	0.102	0.114	0.111
730+50	6/27/2025	15.9%	5.00	5.00	3.92	100%	78%	***	***	***	***
732+50	6/27/2025	15.9%	5.00	5.00	4.00	100%	80%	***	***	***	***
734+00	6/27/2025	14.6%	5.00	5.00	3.98	100%	80%	***	***	***	***

Cement Stabilized Depth Check

- Cement raises the pH of the soil.
- Phenolphthalein, a color sensitive indicator solution, can be sprayed on the soil to determine the presence of cement. When cement is present, a reddish-pink color develops. See the figure below.

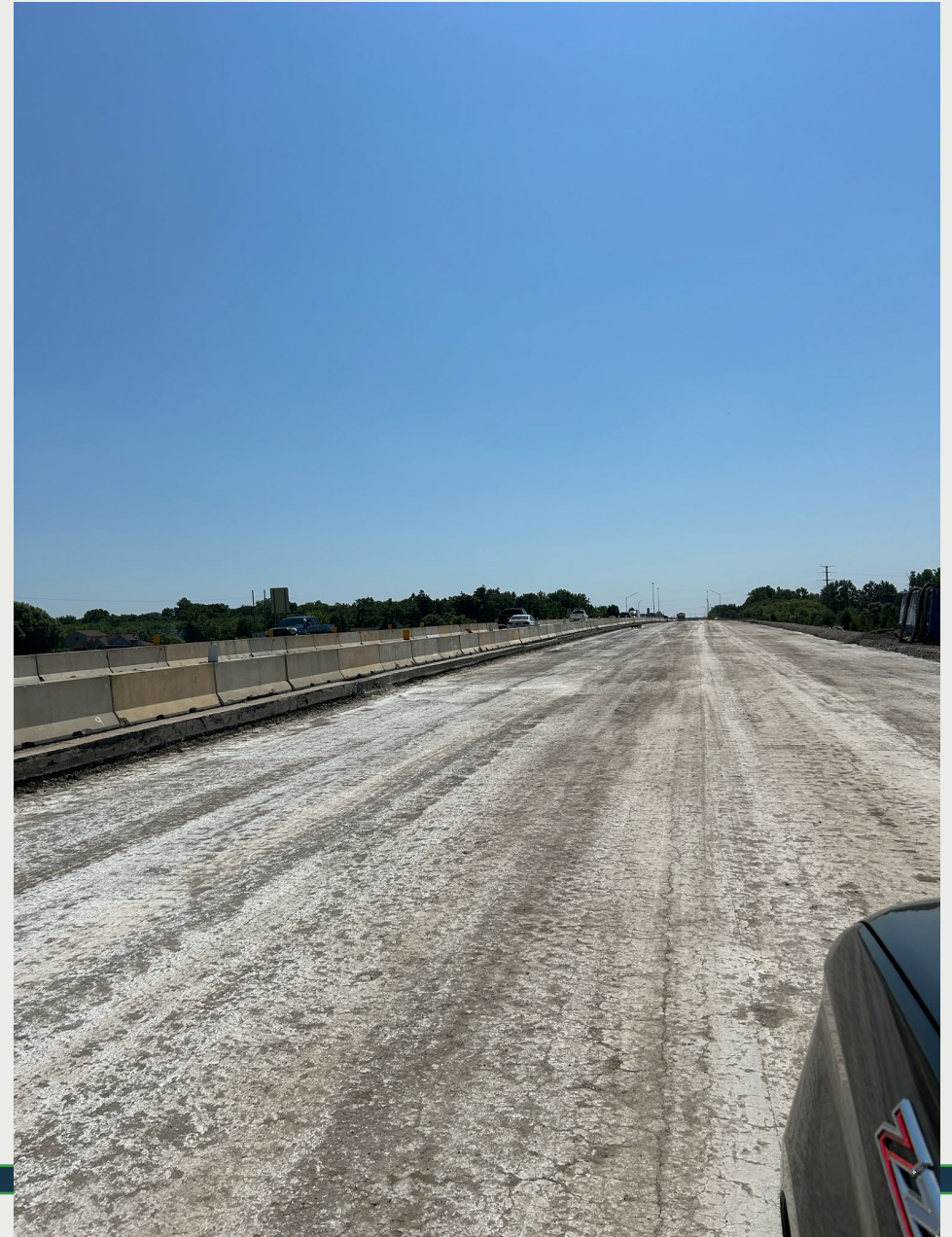


(a) Well mixed lime-soil modified soil



(b) Poorly mixed lime-soil modified soil

Cement stabilized soil (I-70 in Wayne County)



Proofrolling of cement stabilized subgrade



A fully legally loaded tri-axle dump truck. (About 35 t.)

- Dump truck with a minimum tire pressure of 90 psi.
- Dump truck weighing at least 33 t.
- Single pass for all proofrolled surfaces.
- Truck speed shall not exceed 2 mph.
- Deflections or rutting in excess of 1/4 in. shall require remediation.

Geotextile Placement



TRANSPORTATION RESEARCH
CIRCULAR

Number E-C296

November 2024

**Foundation Design
and Construction for
100-Year Pavement
Systems**

NATIONAL
ACADEMIES

Sciences
Engineering
Medicine

TRB TRANSPORTATION RESEARCH BOARD

Talking Points

- Subsurface investigation (Site condition, moisture , other geological hazards)
 - Geotechnical recommendations and coordination with pavement engineers
 - Subgrade and foundation preparation
 - QC/QA specifications
 - Assist construction staff during construction
 - Subsurface drain video
 - Proofrolling of subgrade
- 

Cement Stabilized Soils

- INDOT Requirement for Interstate Projects

Geotechnical Design Memo No. 2021-03 *“Cement stabilization of subgrade soils shall be considered for use on projects where interstate reconstruction or lane widening is proposed”*

Questions

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