Optimizing Design Decisions and Construction Procedures for Full-Depth Pavement Recycling

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NATIONAL PAVEMENT PRESERVATION CONFERENCE
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IMPACTS AND BENEFITS FROM PAVEMENT PRESERVATION

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AASHTO TSP2 PAVEMENT PRESERVATION

ROCKY MOUNTAIN WEST PAVEMENT PRESERVATION PARTNERSHIP
SOUTHEAST PAVEMENT PRESERVATION PARTNERSHIP
MIDWESTERN PAVEMENT PRESERVATION PARTNERSHIP
NORTHEAST PAVEMENT PRESERVATION PARTNERSHIP

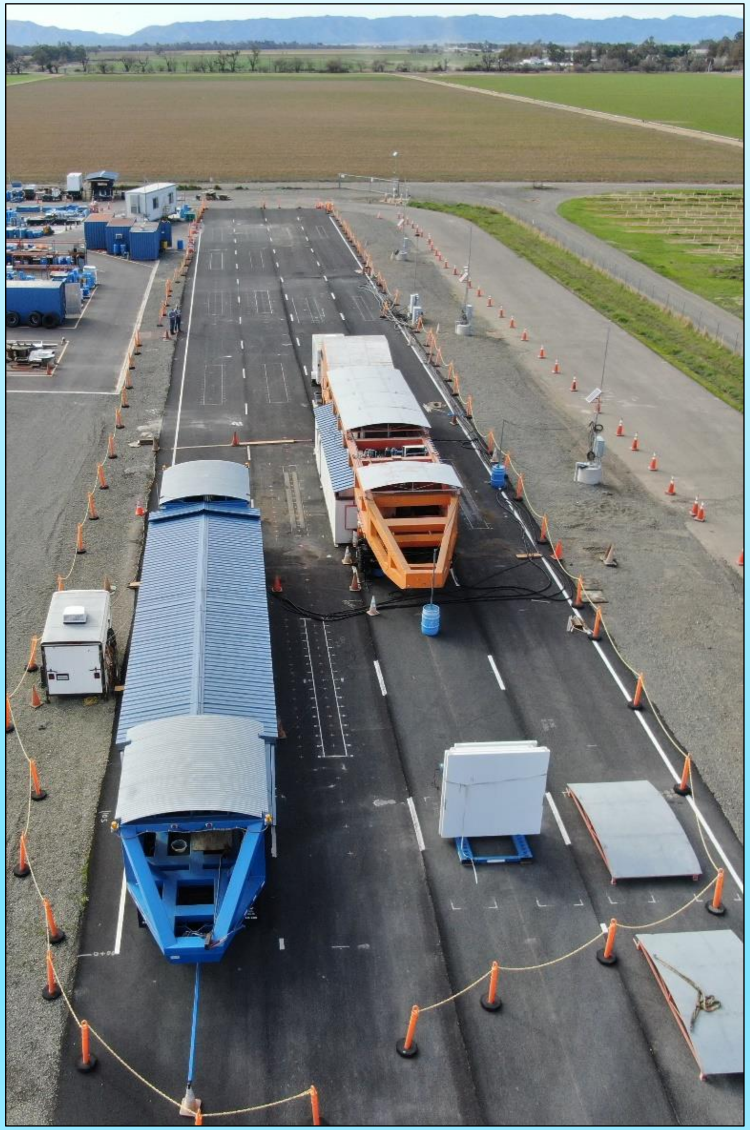
Outline

- Introduction
- Site investigation / strategy choice
- Design
- Construction
- Conclusions

Full-Depth Recycling (FDR)

- FDR is not a preservation treatment per se, but extends pavement life/increases resilience using in situ materials
- Used primarily for rehabilitation and/or structural improvement
  - Bottom-up distresses
- Typical design is 8-12in. (200-300mm) of FDR with 1.8-5in. (45-125mm) of AC
  - Chip seals used on lower volume roads
- Used nationwide / internationally
  - Not as widely as it should be

UCPRC Research



- Multi-phase research study on CR
  - Questioning everything!
- Phase 2: FDR: Extensive lab testing, long-term field performance monitoring, APT, and ME modeling
  - Pilot studies, incl. 21-yr old FDR-FA project
  - APT on FDR-N, FDR-FA, FDR-EA, and FDR-C
    - >34 million ESALs to 6mm rut in AC with loads up to 2.5x legal limit; no fatigue cracking
  - 36-cell test road to assess shrinkage crack mitigation measures on FDR-C
  - ME performance models for CR

Full-Depth Recycling

FDR-FA Layer

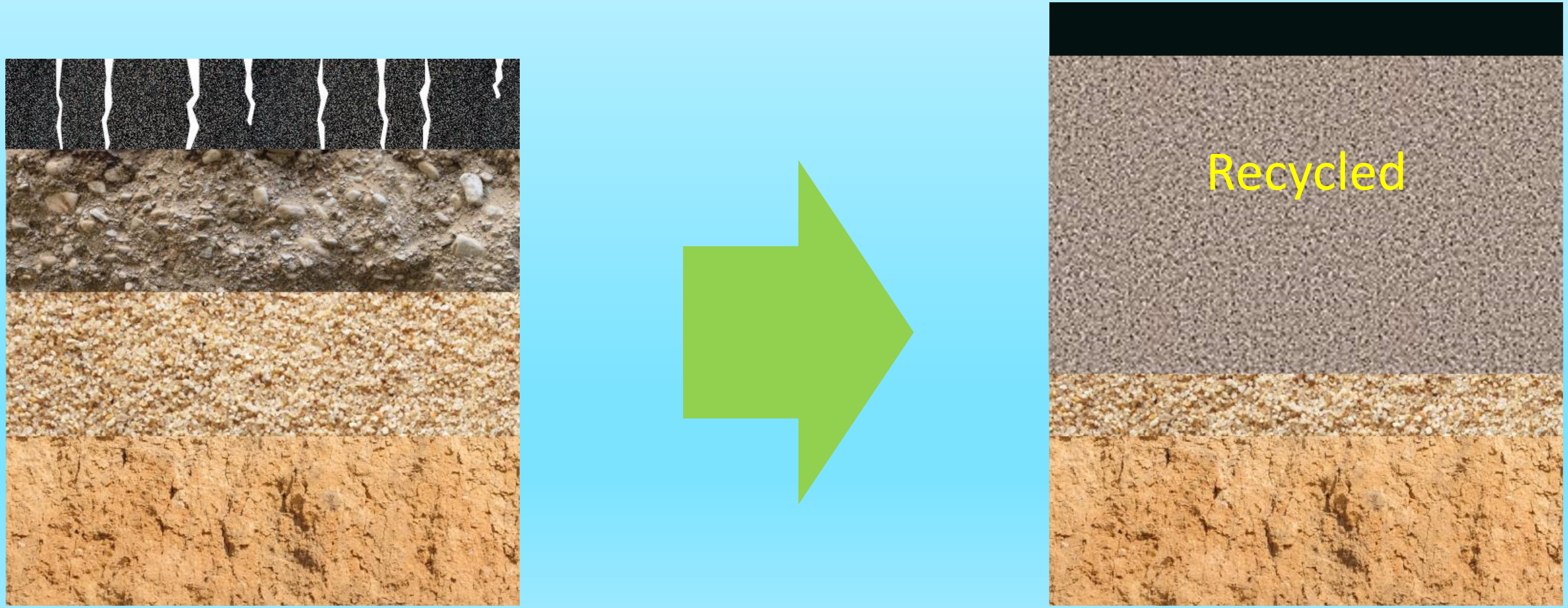
FDR-C Layer

Where to Use FDR

- Bottom-up distresses from the underlying layers
  - Bottom-up cracking (alligator A & B, block, shrinkage, etc.)
  - Thermal cracks
  - Base and/or subgrade rutting
  - Plus distresses usually addressed with PDR
- Recycles top 8 to 12in.
  - Milling teeth go through AC layers into underlying base
- 1 to 2 lane miles per day depending on recycle train
- Many PDR (CIR) projects should be FDR

Bottom-Up Distresses in Pavement Layers

- Use FDR-N, FDR-C or FDR-FA/EA depending on material properties and desired structural capacity



Bottom-Up Distresses from Subgrade

- Two additional options for increasing structural capacity:
  1. Add new RAP or AB material on top of existing road and recycle with FDR-FA or FDR-EA
     - Existing base becomes a subbase
  2. Use a two part process to build an inverted pavement
     - Mill surface and base and stockpile it
     - Stabilize subgrade with lime or cement
     - Process stockpiled material with EA or FA through CCP and place with paver

Recycling Methods

- Methods:
  - Single wheel-driven train
  - Tandem wheel-driven train
  - Single-unit track-driven train
  - Cold central plant
- Recycling Agents:
  - None
  - Emulsified or foamed asphalt
  - Cement or lime (or both)
  - Other proprietary

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Site Investigation

- Detailed site investigation is required to make informed decisions
  - Cost is negligible vs. extended life
- Investigation should include:
  - Visual assessment to identify and understand distresses and their cause and origin
  - Coring to determine optimal recycling depth, distress origin, variability, etc.
  - DCP tests through core hole
  - Sample of underlying material to approximate recycle depth
  - FWD and GPR if available
- Caltrans CR & site investigation guides
  - www.ucprc.ucdavis.edu/publications

Analysis Outline

- What do we have, what do we need to do?
  - ✓ Depth and origin of distresses are understood and CR will address them?
    - Target removing all distresses
    - Choose PDR (CIR) or FDR
  - ✓ Grade height can be raised?
    - 100% FDR still requires a surface
    - Can additional material be used for lane widening?
  - ✓ Sufficient material to recycle?
    - Including after pre-milling if grade height restrictions?
  - ✓ >15% underlying unbound material?
    - Fines improve gradation, density, strength and stiffness
    - Facilitates up-cut action / cools milling teeth
  - ✓ Drainage is functional?
    - Drainage-related problems will recur
  - ✓ USCS complete on unbound + combined materials?
    - Dictates choice of recycling agent

Choosing a Recycling Agent

- Asphalt and cementitious are mutually exclusive

	Material Type												
	AC + Good Base		AC + Marginal Base		Subgrade								
	Well Graded Gravel	Poorly Graded Gravel	Silty Gravel	Clayey Gravel	Well Graded Sand	Poorly Graded Sand	Silty Sand	Clayey Sand	Silt Or Silt With Sand	Lean Clay	Organic Silt/ Organic Lean Clay	Elastic Silt	Fat Clay, Fat Clay With Sand
USCS	GW	GP	GM	GC	SW	SP	SM	SC	ML	CL	OL	MH	CH
Foamed asphalt **P_{200} 5 – 15** **PI < 6**	■■■	■■■	■■■	■	■	■	■						
Emulsified asphalt **P_{200} 5 – 15** **PI < 6**	■■■	■■■	■■■	■	■	■	■						
Portland cement **P_{200} >20, PI < 20** **SO_4 < 3,000 ppm**	■	■	■■■	■■■	■■■	■■■	■■■	■■■	■■■	■■■			
Lime **P_{200} >25, PI > 20** **SO_4 < 3,000 ppm**								■■■		■■■		■■■	■■■

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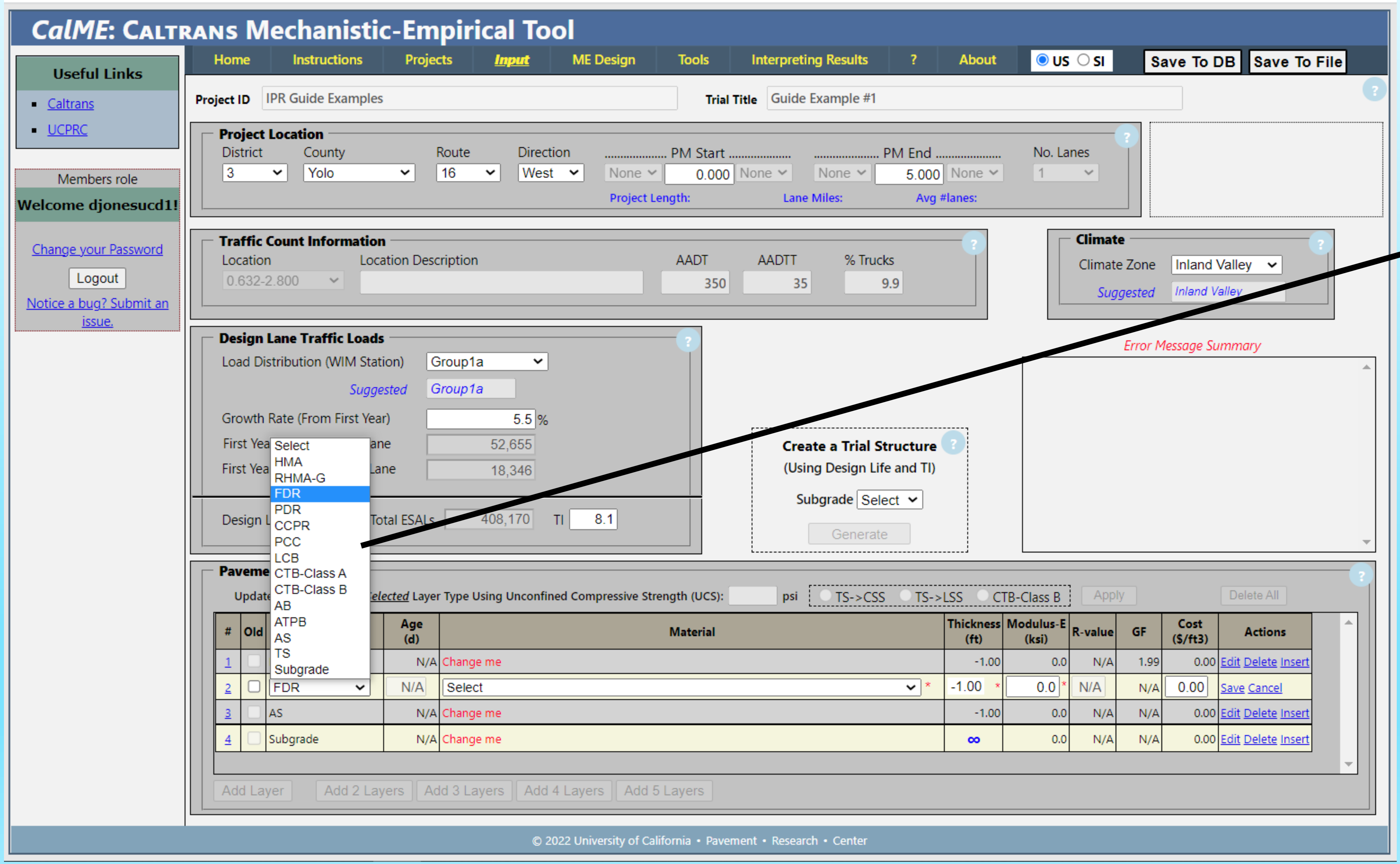
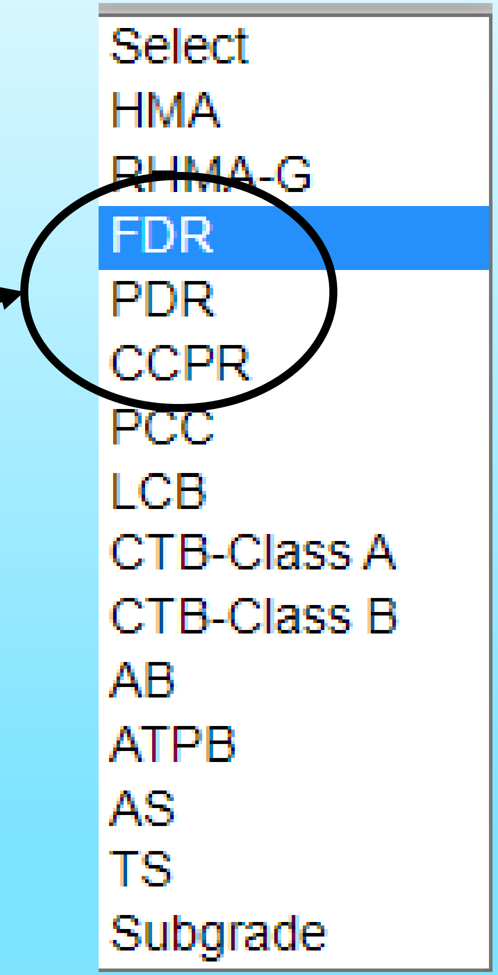
Pavement Design

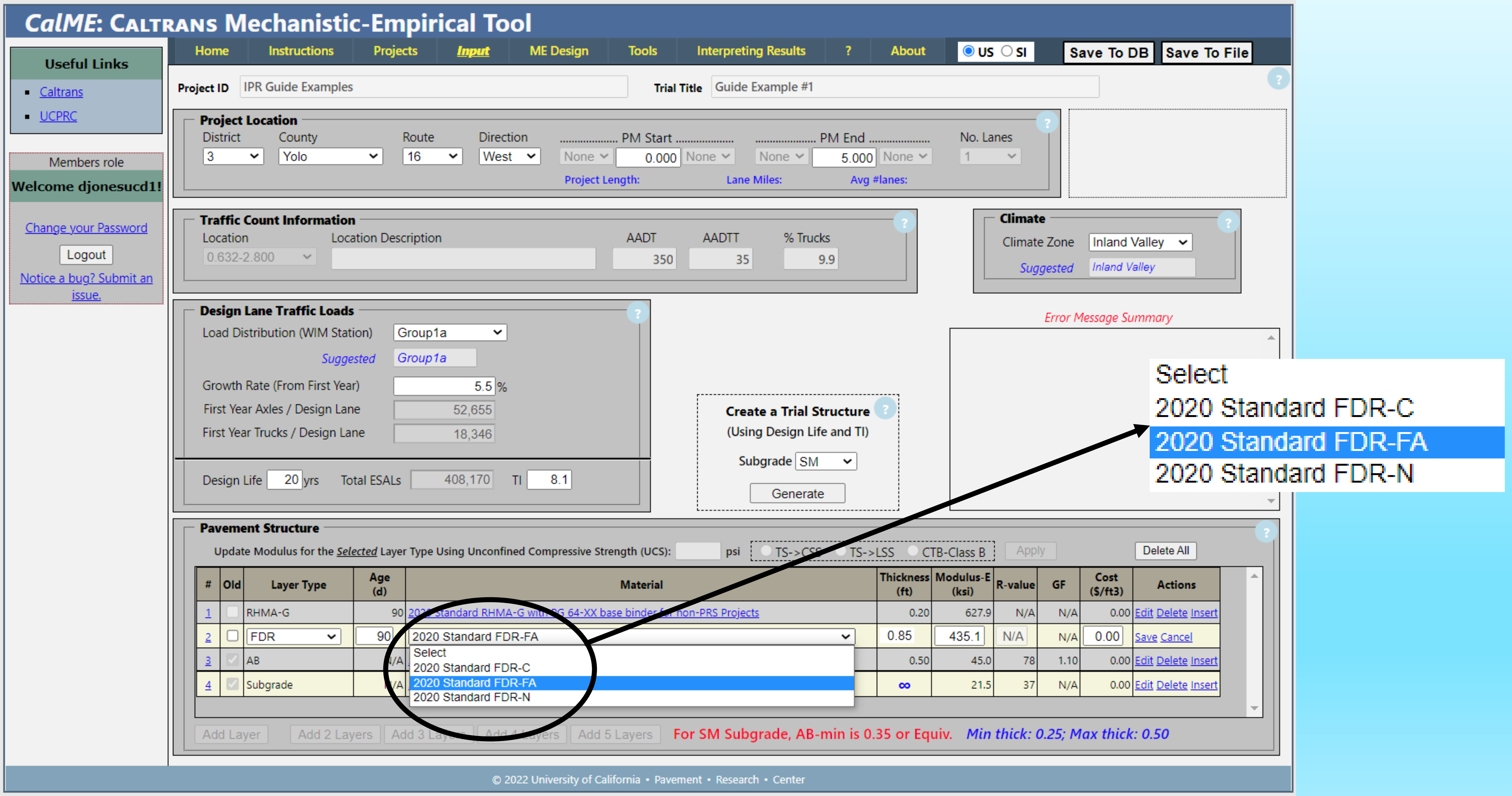
- Layer thicknesses
  - Base on available materials/target traffic
  - AASHTO 93 or ME?
    - Updated layer coefficients available for recycled layers
    - Limited representative CR performance models in most ME packages
      - Modeled as either AC or AB; neither is appropriate
    - AC thicknesses tend to be overly conservative

CalME Input: Layer Type





CalME Input: FDR Materials



Pavement Design

- Layer thicknesses
  - Based on available materials/target traffic
  - AASHTO 93 or ME
    - Updated layer coefficients available for recycled layers
    - Limited representative CR performance models in most ME packages
- Considerations
  - Choose recycle depth and recycling agent carefully
    - Cost difference between 10 & 12in. is relatively small
    - > 12in. can result in differential compaction, layer contamination, and shrinkage/block cracking

Mix Design

- Asphalt recycling agents (EA and FA)
  - Recommend ITS wet strength of 30psi (210kPa) based on modified Proctor or gyratory MDD
  - Marshall compaction and stability have issues when used on CR materials
- Cementitious
  - Use ICS + 1% as initial starting cement content
    - 1.5 hour pH test; good indicator of durability
    - Risk of modification-only and carbonation if not met
  - Target UCS of 250-450psi (1.7 to 3.1 MPa)
    - Risk of shrinkage crack at higher strengths

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Shrinkage Crack Mitigation on FDR-C

- Keep design strength between 250-450psi, based on ICS
- Spread cement accurately with no overlaps
- No dragging hoses
- Microcrack compacted surface
  - 48 to 56 hours after final compaction
  - 3 passes, 12 ton roller at max. vibration
  - Spray surface with water prior to start
- Microcracking works!

Shrinkage Crack Mitigation on FDR-C

- Mitigates, won't prevent cracks
- Introduces a network of fine cracks that do not have sufficient energy to reflect through AC surfacings
- Stiffness recovers quickly
- Extends fatigue life
- Cost is insignificant
- Increasing number of states require it in specifications

Paver-Laid FDR

- New generation CR equipment can recycle to 12in.
  - Asphalt or cement recycling agents
- Higher quality, faster, and cheaper FDR
- Requires high capacity paver, preferably with high compaction screed
- Appropriate rollers and roller weights

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Conclusions

- FDR is under-utilized method of rehabilitating/reconstructing distressed roads
- Versatile, fast, resilient and cost effective
- 100% use of already paid for in-place materials
- New CR developments include:
  - Focus on distress depth and origin
  - ME design procedures
  - Revised mix design procedures
  - New construction & QC procedures
  - Shrinkage-crack mitigation measures

Thank-you

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