RCC Design Future?
Results from LTRC's Accelerated Loading Facility

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LTRC Project 12-7P

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Outline

- Background
- Objectives
- Field construction results
- Load test results
- Conclusions
- Implementation efforts
- Questions

Why interested in RCC?

Background

- RCC for roadways started in the mid-1980's
- Successful RCC projects include:
  - U.S. 78 near Aiken, SC
    - 10" RCC – 1 mile 4 lane section completed in 2009
  - 2012 Arkansas completed a section in the Fayetteville Shale Play Area
    - 7" RCC over a reconstructed base course
    - 8" RCC placed as an overlay

Objectives of the Study

(1) to determine the structural performance with failure mechanism and load carrying capacity of **thin RCC** surfaced pavements

(2) to determine the applicability of using a **thin RCC** surfaced pavement structure (with cement treated or stabilized base) as a design option for low- and high-volume pavement design in Louisiana

Lab Materials and Test Methods

- Materials
  - No. 67 crushed limestone
  - Manufactured sand
  - Type I portland cement
- Test methods
  - ASTM C1557 Modified Proctor
  - ASTM C1435 for cylinders
  - ASTM C39
  - ASTM C6938 and ASTM C1040

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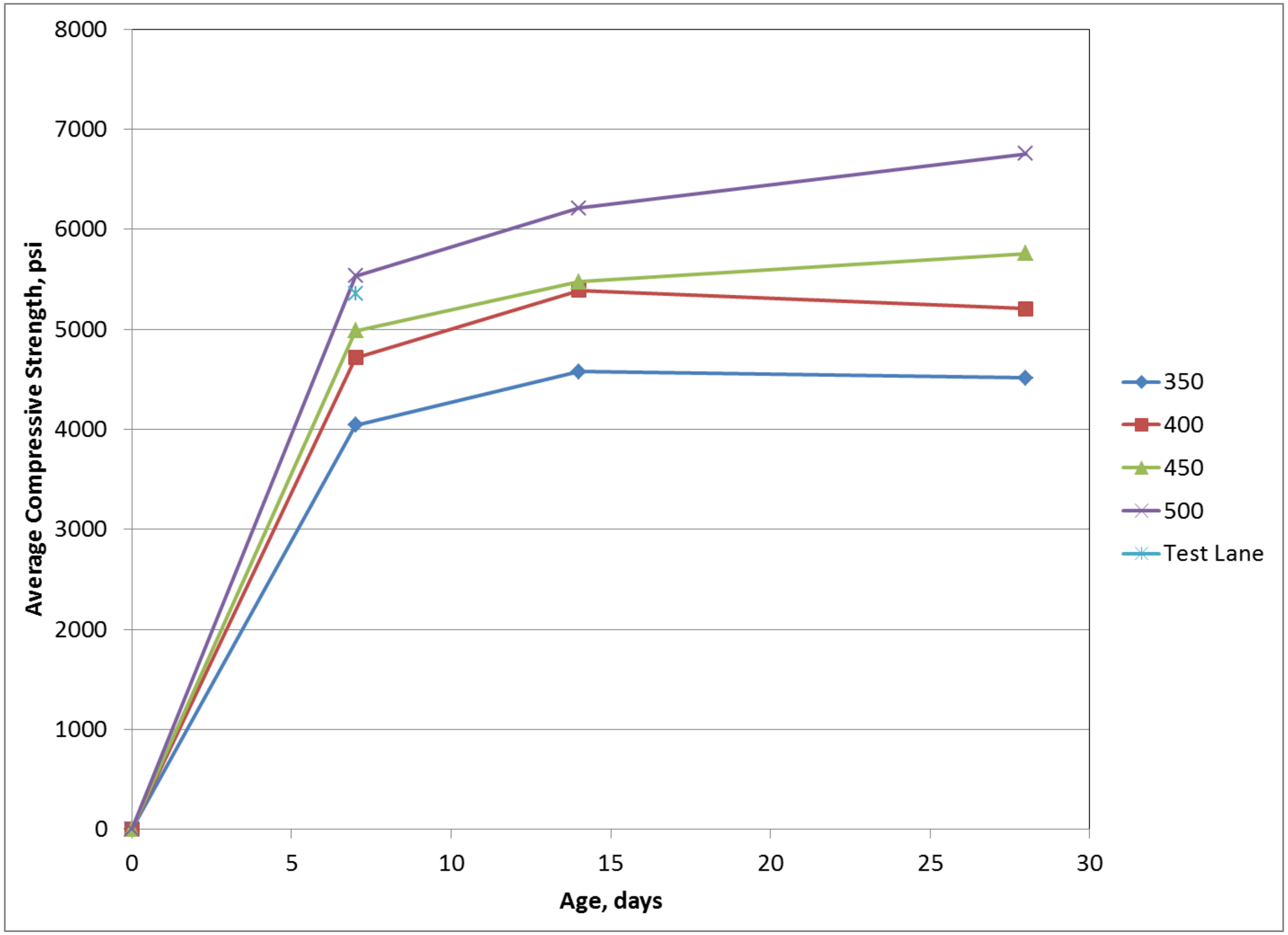
Laboratory Mixtures

- 350, 400, 450, and 500 PCY mixtures
- Tested for density first (Modified Proctor)
- Then tested for strength

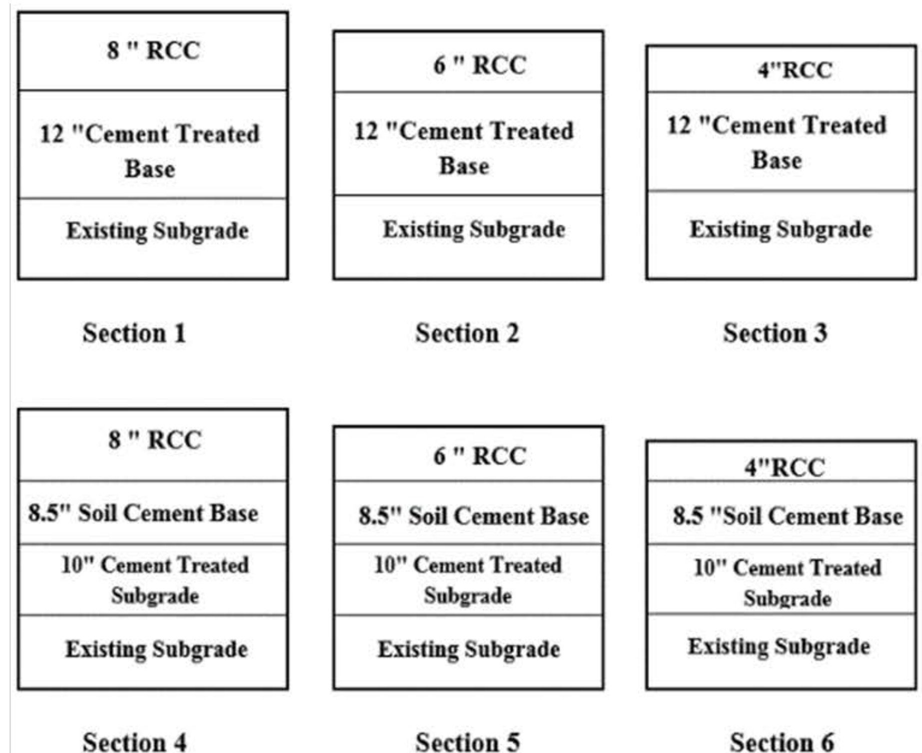
Mixture Results - Strength



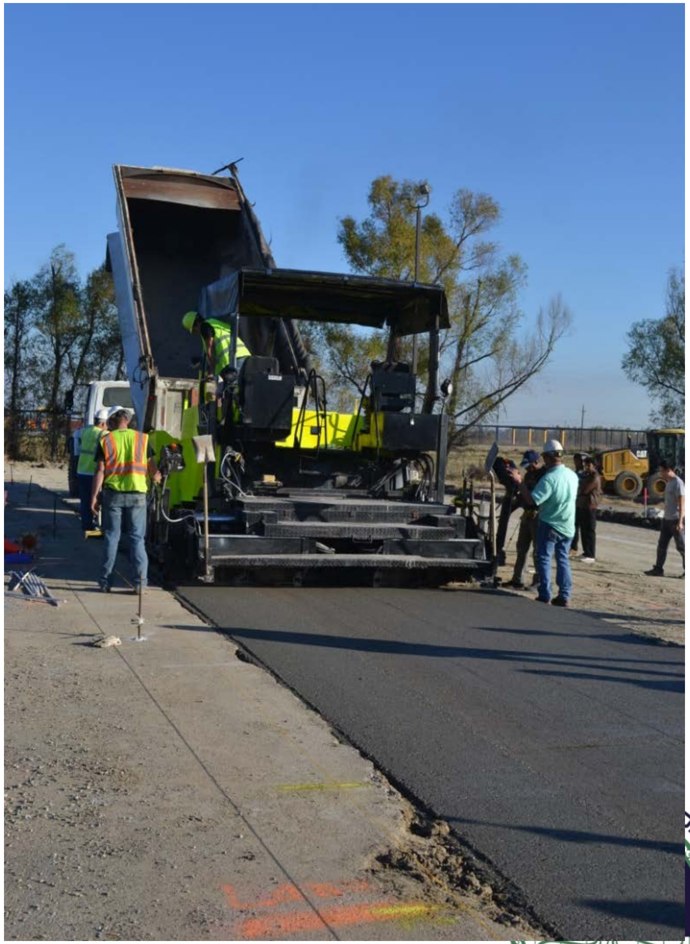
Mixture Proportion

Material	Quantity (pcy)
Cement	450
Coarse Aggregate	1521
Fine Aggregate	2017
Water	154

Constructed Sections



Pictures

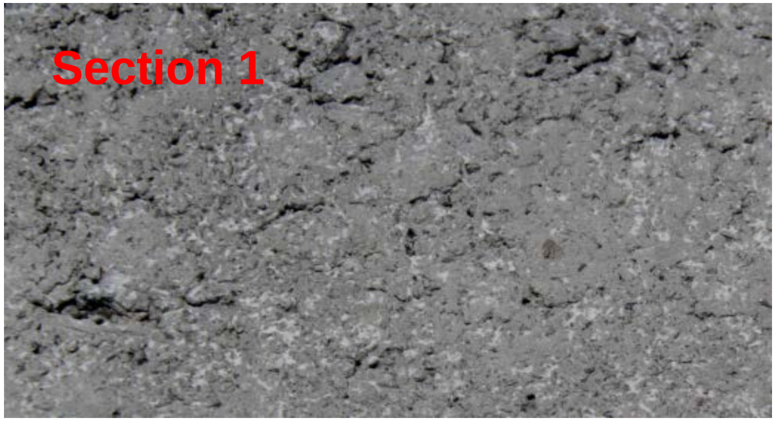



Section 3


Section 6


Section 2


Section 5


Section 1


Section 4

FWD Backcalculated Layer Moduli

8”RCC+12CT	6”RCC+12CT	4”RCC+12CT
E_{RCC}=3587ksi E_{base}=258ksi E_{sub} = 27ksi	E_{RCC}=2361ksi E_{base}=181ksi E_{sub} = 24ksi	E_{RCC}=2904ksi E_{base}=139ksi E_{sub} = 22ksi
Section 1	Section 2	Section 3

8”RCC+8.5SC	6”RCC+8.5SC	4”RCC+8.5SC
E_{RCC}=3767ksi E_{base}=418ksi E_{sub} = 31ksi	E_{RCC}=3763ksi E_{base}=352ksi E_{sub} = 28ksi	E_{RCC}=4384ksi E_{base}=305ksi E_{sub} = 26ksi
Section 4	Section 5	Section 6

Those backcalculated results consistent with FWD deflections obtained from individual layers

Field Results

- Density slightly lower in the bottom depth
- Strengths at 55 days of age
  - Lane 1 – 5192 psi
  - Lane 2 – 4422 psi
    - Due to lower densities

Section Number	**Thickness (in)**
1	9.65
2	6.05
3	4.90
4	8.01
5	6.36
6	4.10

Accelerated Pavement Testing - ATLaS30

Dual-tire load, 130psi
Load: up to 30 kips
Speed: 4~6 mph
Bi-directional loading
Effective length: 42-ft
About 10,000 passes/day

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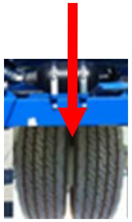
Accelerated Loading Testing

- Started on **Section 4**

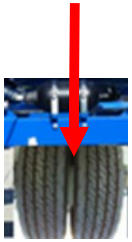
8 " RCC
8.5" Soli Cement Base
10" Cement Treated Subgrade
Existing Subgrade

- Roughly 78,000 reps. for each load level,

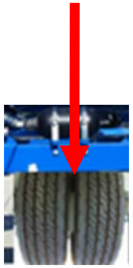
9,000 lb



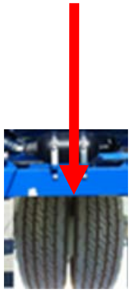
16,000 lb



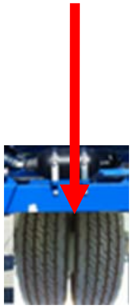
20,000 lb



22,000 lb

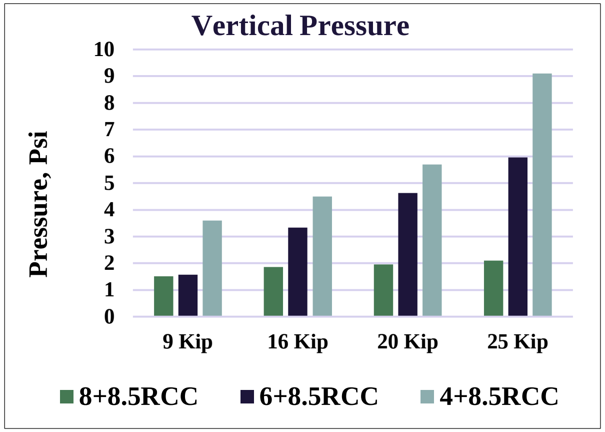


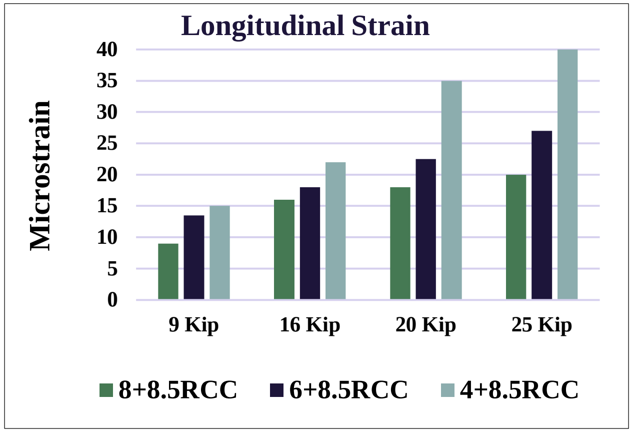
25,000 lb



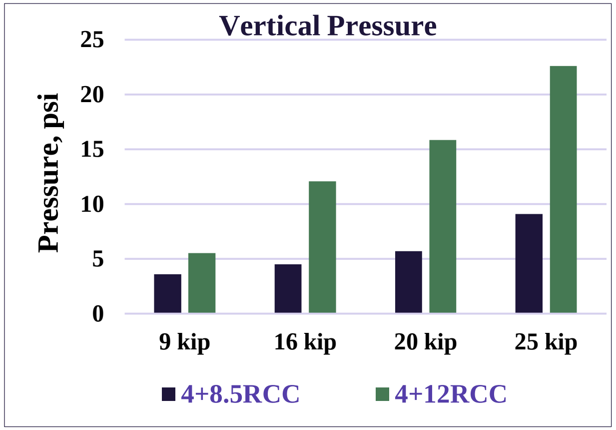
Instrumentation Response

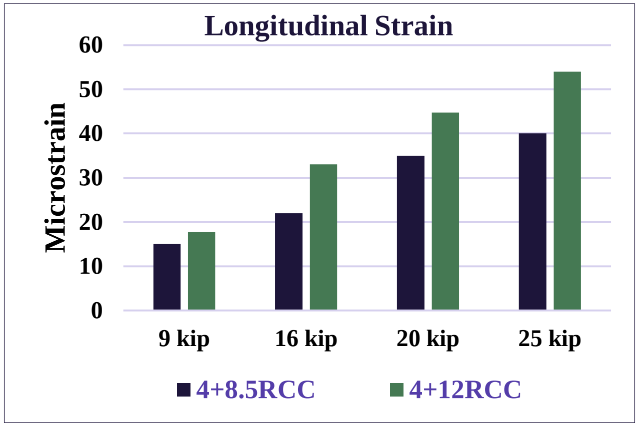
- Typical stress and strain measured at the bottom of RCC slabs with different thickness under APT loading





- Typical stress and strain measured at the bottom of RCC slabs over different base support under APT loading





Distress Observed (8+8.5RCC) – Section 4

- Approximately after 392,500 load repetition (11.28 million equivalent ESALs), no significant damage was observed
- Due to the high load repetitions received on section 6+8.5RCC to fatigue failure, the test was discontinued

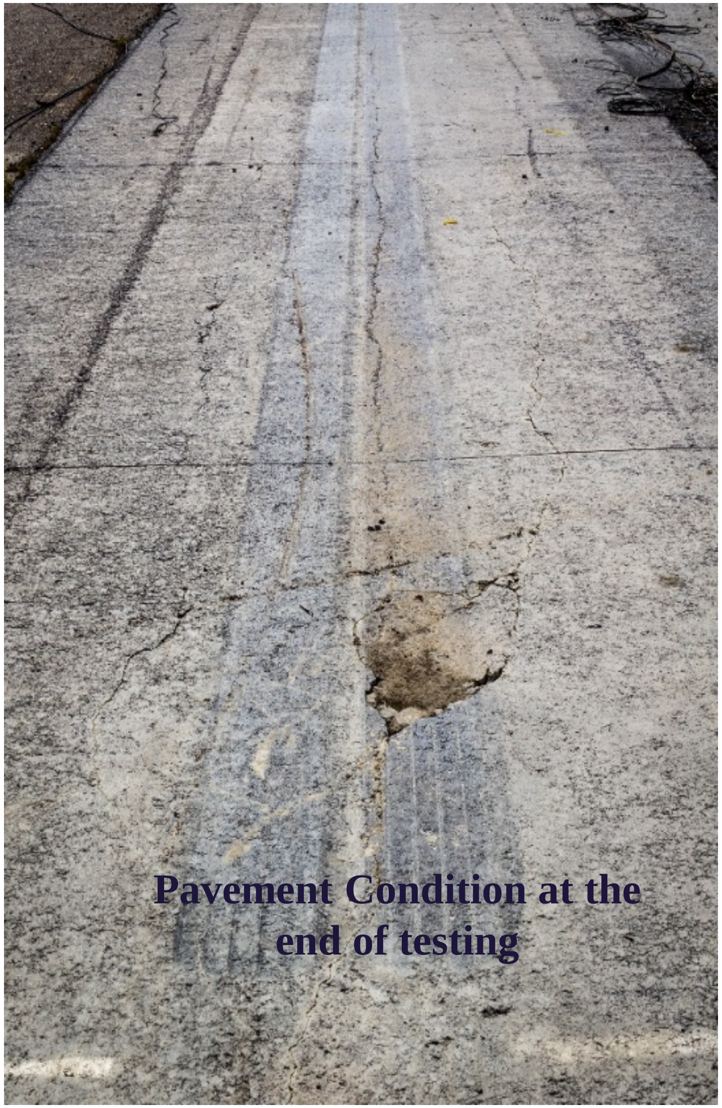
392,500 Passes

Current Pavement Condition

Distress Observed (6+8.5RCC) – Section 5

1.75 million Passes

- Visual Distresses
- Longitudinal cracks were observed along the wheel path and at the edge of the tire print
- Pumping action was observed through cracks and joints
- 87.4 million ESALs to failure
- ***1.9 million ESALs predicted***



Distress Observed (4+8.5RCC) – Section 6

- Visual Distresses
- Longitudinal cracks were observed along the wheel path and at the middle of the tire print
- Pumping action was observed through the cracks and joints
- 19.2 million ESALs to failure
- ***0.7 million ESALs predicted***

706,500 Passes

Pavement Condition at the end of testing

Distress Observed (4+12RCC) – Section 3

- Due to relatively weaker support, an early longitudinal crack was observed after 55,000 passes under 9 loading
- About 3 million ESALs to failure
- ***Predicted 0.7 million ESALs to failure***

196,000 Passes

Longitudinal crack along the wheel path

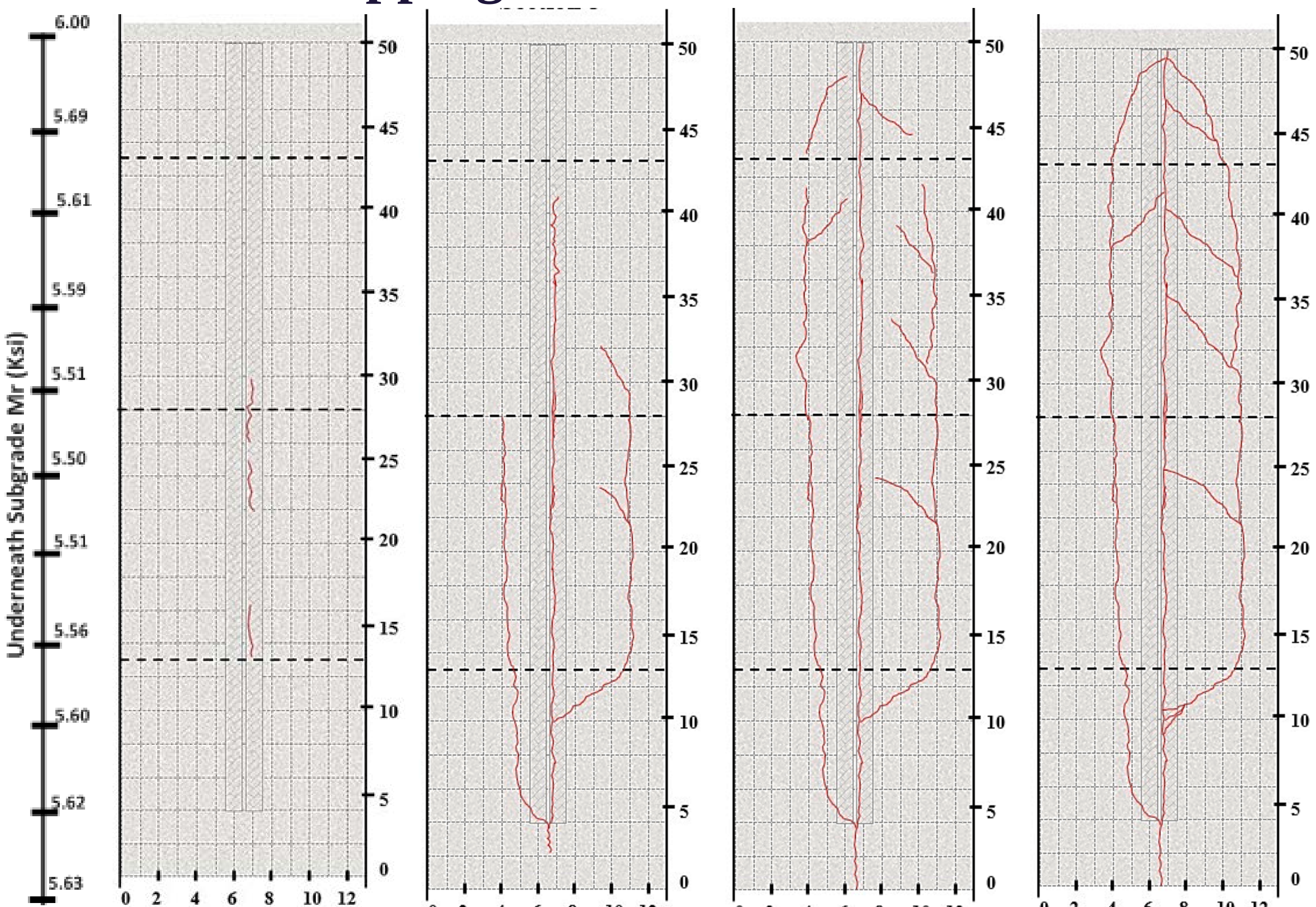
Distress Observed (6+12RCC) – Section 2

- Longitudinal cracks
- Pumping and Local failure
- About 19 million ESALs to failure
- ***Predicted 1.9 million***

637,000 Passes

Crack Mapping on (6+8.5RCC) – Section 5

- **Crack Mapping**



After 1,050,000 Load Repetition

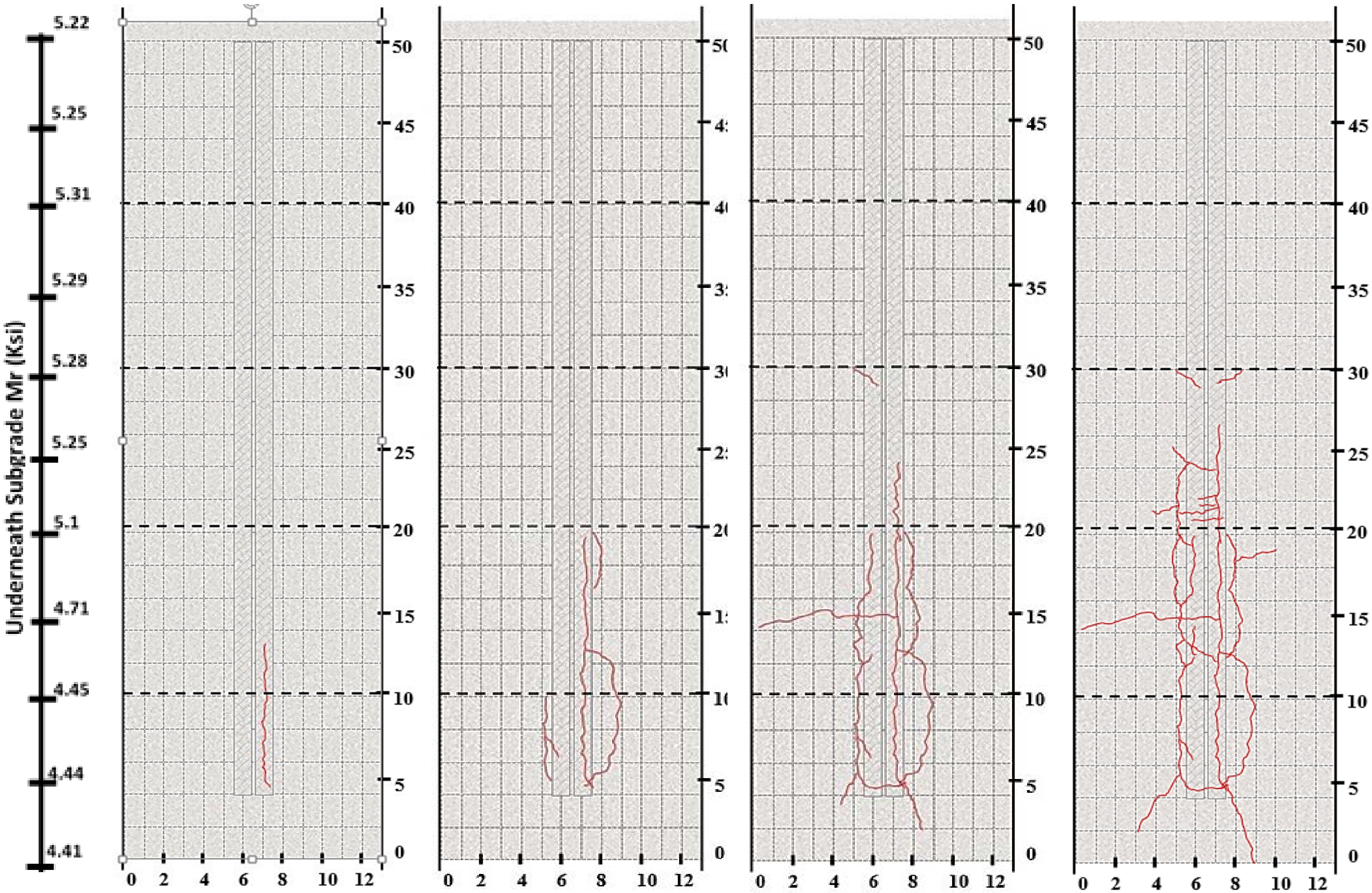
After 1,230,000 Load Repetition

After 1,500,000 Load Repetition

After 1,750,850 Load Repetition

Crack Mapping on (4+8.5RCC) – Section 6

- **Crack Mapping**



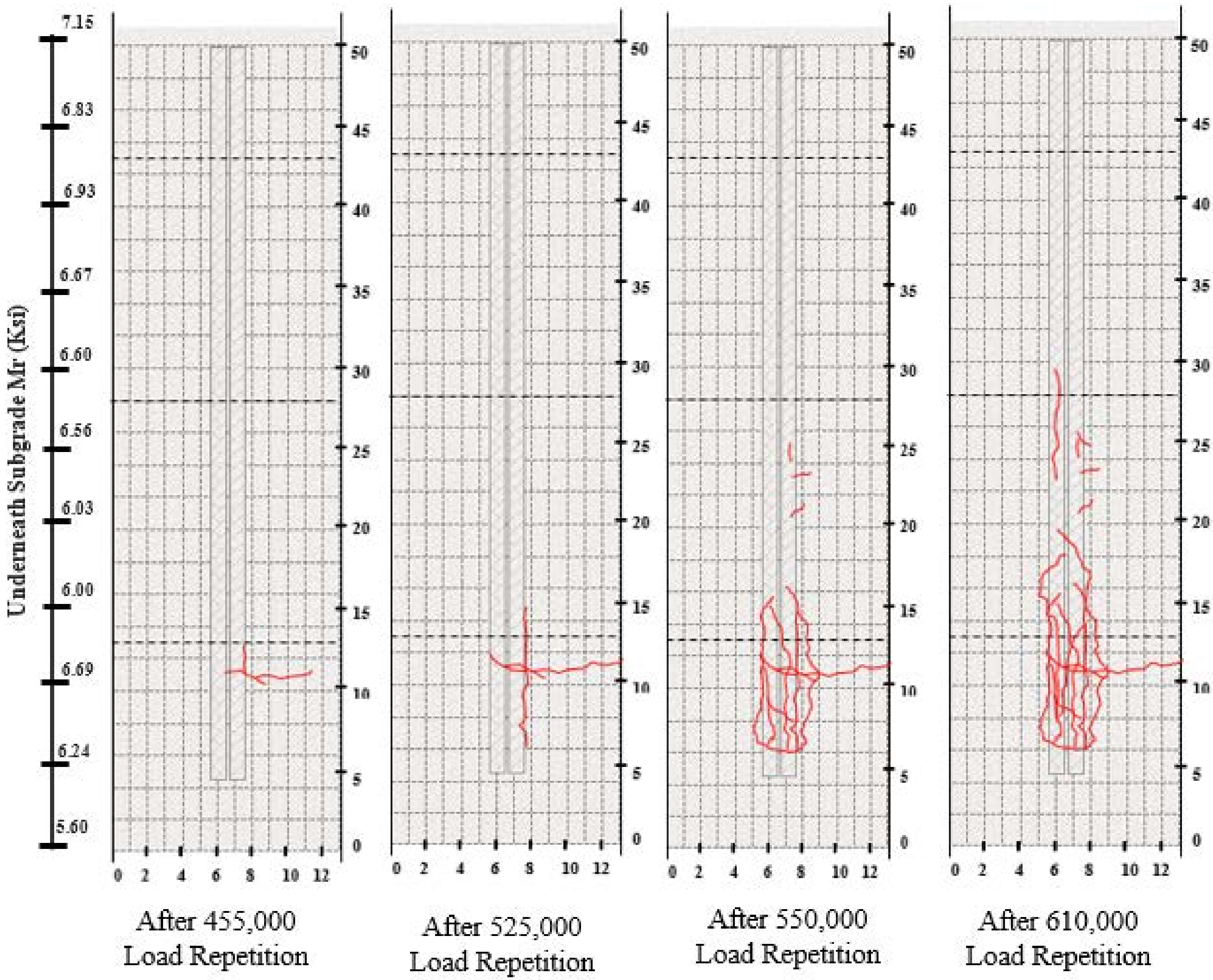
After 390,000 Load Repetition

After 480,000 Load Repetition

After 560,000 Load Repetition

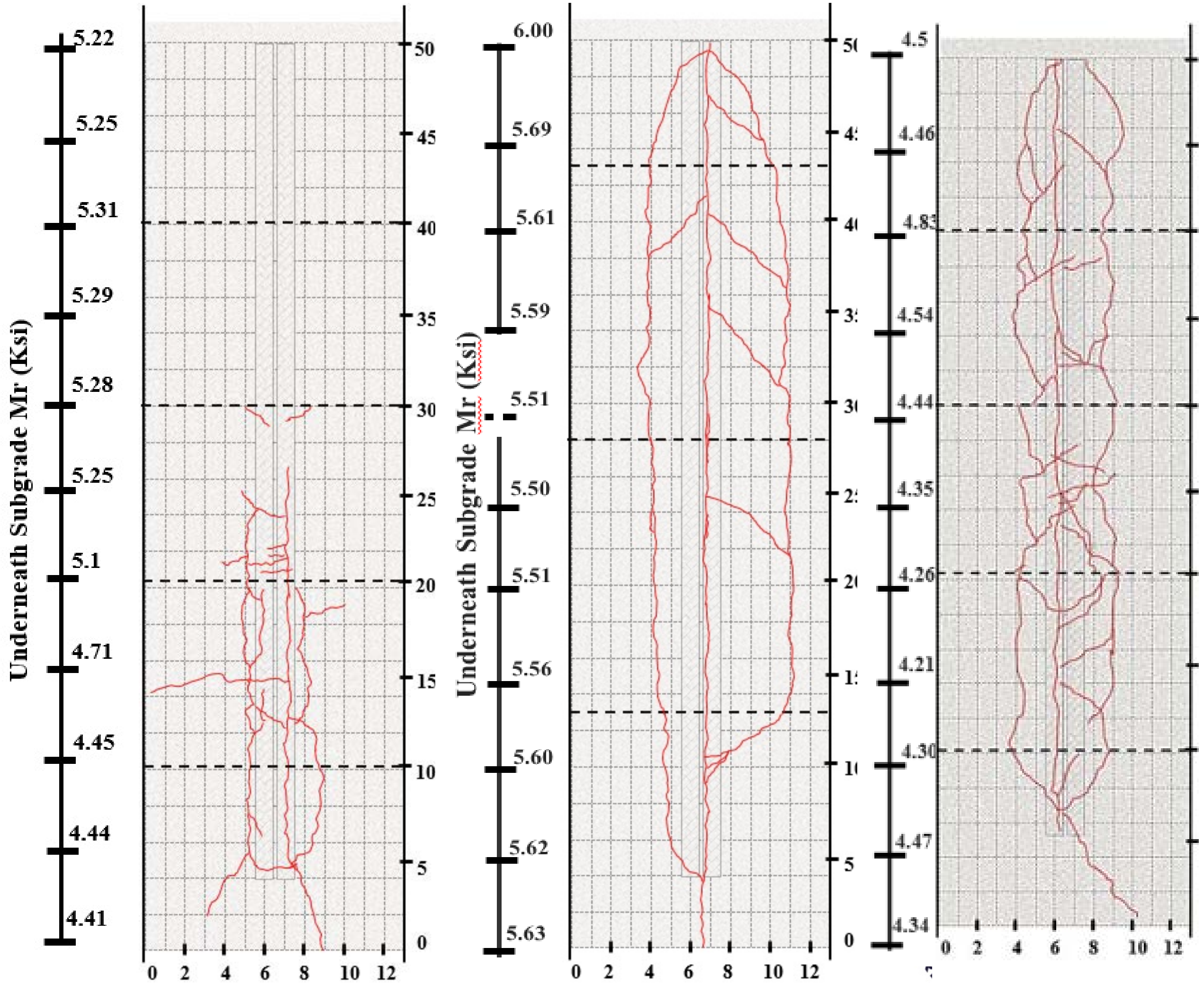
After 706,500 Load Repetition

Crack Mapping on (6+12RCC) – Section 2



Comparison of Cracking Pattern of Failed RCC Sections

- Crack initiated at the weakest subgrade location
- Cracking pattern for thicker section was much wider than the thinner section
- Uniform subgrade resulted in a final cracking failure covering the entire loading area for 6+8.5RCC & 4+12RCC



4+8.5RCC | 6+8.5RCC | 4+12RCC

Construction Cost Analysis

- 13-ft wide , 1 mile length
  - RCC = $198,082
  - HMA = $311,169
- Typical 2-lane, 10 mile long project
  - 5-in RCC vs. 7-in HMA
  - Total cost savings up to $2,261,740

Summary

- Except two 8” RCC test sections, the best performer is (6”RCC + 8.5” soil cement) section, with
  - Rideable surface and relatively low IRI;
  - Outstanding load carrying capacity, est. ESALs = 87.4 M;
  - Potential to be used for heavy-loaded, medium speed pavements;
- Sections (4”RCC+8.5” soil cement) and (6”RCC+12” cement treated) also performed very well
  - Both can carry large amounts of heavy traffic (half axle >20kips); Est. ESALs > 15 M
  - Surface IRI to be controlled during the construction
  - Potential to be used for low-volume roads with heavy truck traffic.

Summary (cont.)

- Four RCC sections failed under fatigue cracking. The observed fatigue cracks were initiated first either in the middle or at the edge of the tire print along a longitudinal direction;
- The width of fatigue cracking pattern was found much wider for 6-in RCC sections (e.g. 6+8.5RCC) than that for 4-in. RCC sections
- RCC-Pave fatigue models were found not suitable for the fatigue life prediction of thin RCC sections evaluated.
- Two preliminary fatigue models for thin RCC pavement fatigue analysis have been developed

RCC Implementation

- The ATLaS30 loading results generally indicate that
  - a thin-RCC over soil cement pavement structure has a superior load carrying performance
  - Recommendation to select and build several field RCC test sections on those Louisiana highways where the pavements are often encountered by heavy truck loading
    - To validate the APT performance and provide further implementation guidelines
  - ***Will not test the 8-inch sections to failure!***

Acknowledgements

- The construction of RCC test lanes was a joint effort between LTRC and its concrete industry partners:
  - CAAL was instrumental in arranging industry support through donations of manpower and materials for this project;
  - Gilchrest Contractors provided the manpower and equipment to construct the subgrade and base courses;
  - Holcim and LaFarge provided cement
  - Vulcan Materials provided aggregate
  - Rollcon in Houston, TX paved the test lanes; and
  - Cemex of Arizona setup and operated pugmill