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

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LTRC Project 12-7P

April 26, 2016

Spring TTCC/NCC Meeting, Columbus, OH

Outline

- Background
- Objectives
- Field construction results
- Preliminary load test results
- Conclusions

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

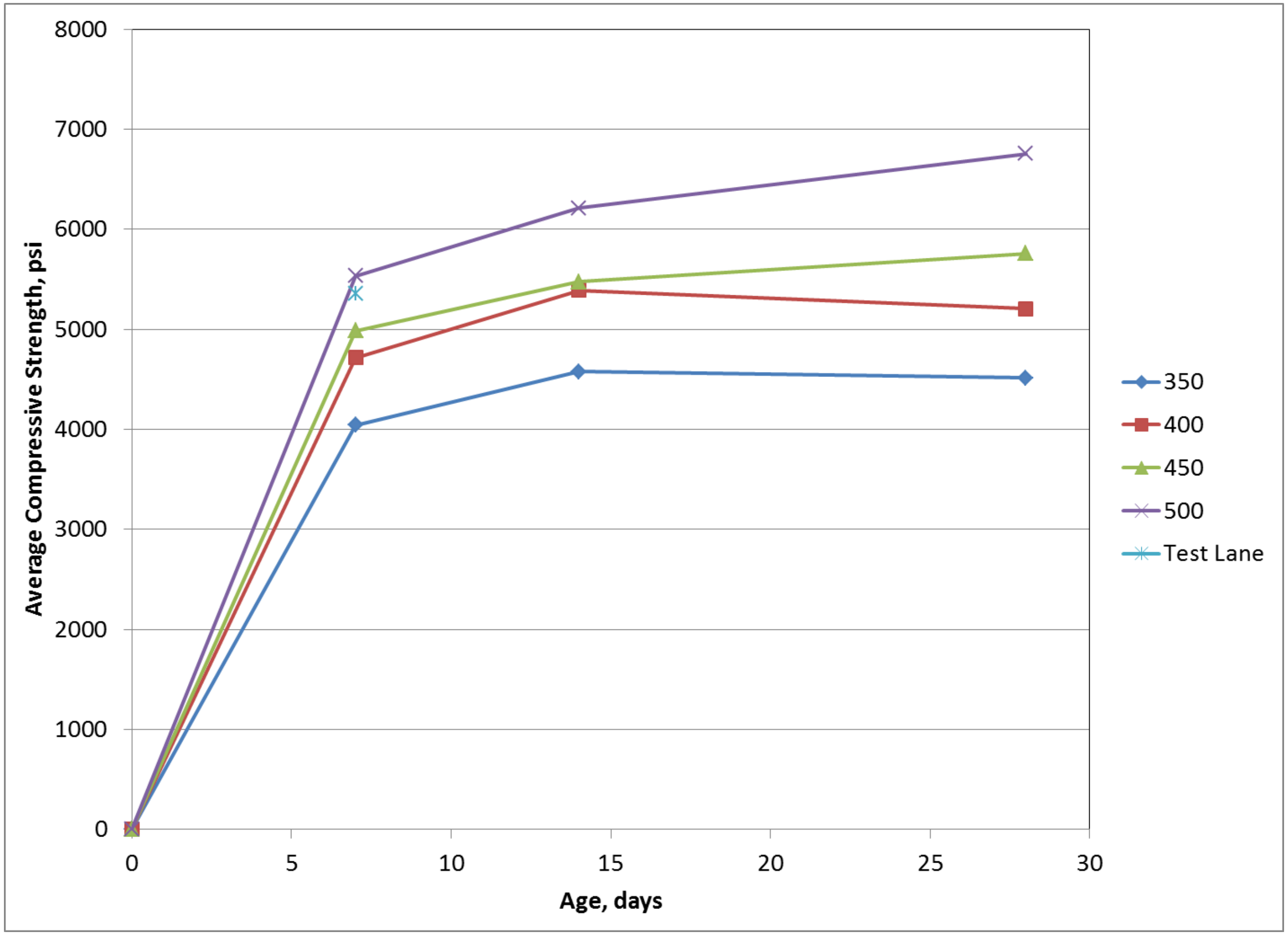
(1) to determine the structural performance with failure mechanism and load carrying capacity of **thin RCC** surfaced pavements

(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

Laboratory Mixtures

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

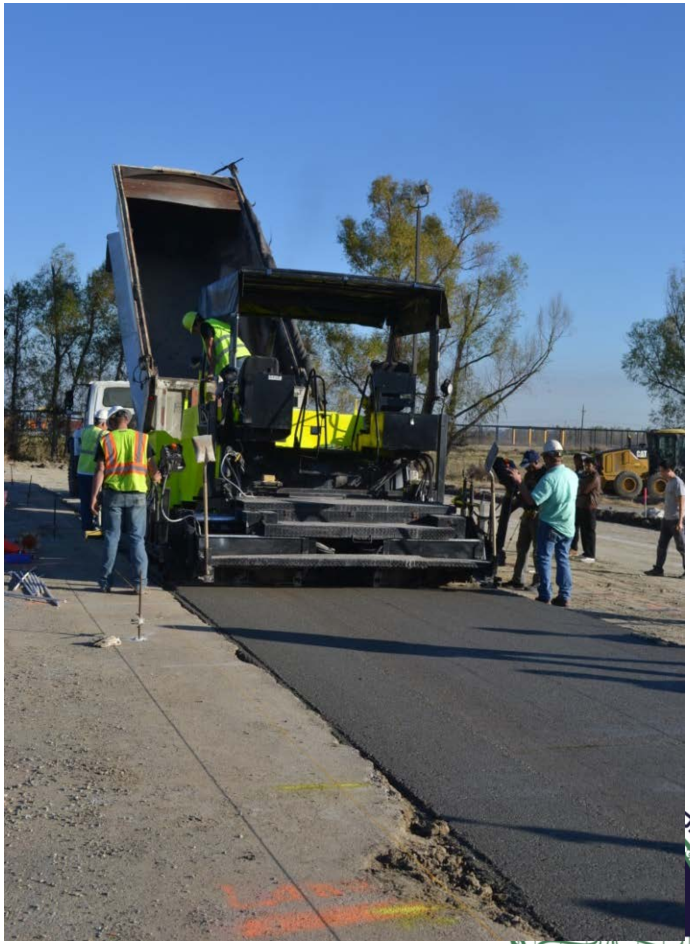
Mixture Results - Strength



Mixture Proportion

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

Pictures



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

Constructed RCC Test Sections

- Six full-scale RCC pavement test sections were constructed at Pavement Facility of Louisiana Transportation Research Center (LTRC)
  - Each section: 71.7-ft long and 13-ft wide

8 " RCC
12 "Cement Treated Base
Existing Subgrade

Section 1
(8+12RCC)

6 " RCC
12 "Cement Treated Base
Existing Subgrade

Section 2
(6+12RCC)

4"RCC
12 "Cement Treated Base
Existing Subgrade

Section 3
(4+12RCC)

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

Section 4
(8+8.5RCC)

6 " RCC
8.5" Soil Cement Base
10" Cement Treated Subgrade
Existing Subgrade

Section 5
(6+8.5RCC)

4"RCC
8.5 "Soil Cement Base
10" Cement Treated Subgrade
Existing Subgrade

Section 6
(4+8.5RCC)


Section 3


Section 6


Section 2


Section 5


Section 1


Section 4

FWD Backcalculated Layer Moduli

8"RCC+12CT
E_{RCC}=3587ksi
E_{base}=258ksi
E_{sub} = 27ksi

Section 1

6"RCC+12CT
E_{RCC}=2361ksi
E_{base}=181ksi
E_{sub} = 24ksi

Section 2

4"RCC+12CT
E_{RCC}=2904ksi
E_{base}=139ksi
E_{sub} = 22ksi

Section 3

8"RCC+8.5SC
E_{RCC}=3767ksi
E_{base}=418ksi
E_{sub} = 31ksi

Section 4

6"RCC+8.5SC
E_{RCC}=3763ksi
E_{base}=352ksi
E_{sub} = 28ksi

Section 5

4"RCC+8.5SC
E_{RCC}=4384ksi
E_{base}=305ksi
E_{sub} = 26ksi

Section 6

Those backcalculated results consistent with FWD deflections obtained from individual layers

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

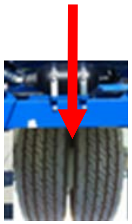
Accelerated Loading Testing

- Started on Section 4

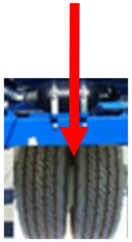
8 " RCC
8.5" Soli Cement Base
10" Cement Treated Subgrade
Existing Subgrade

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

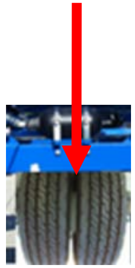
9,000 lb



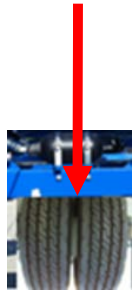
16,000 lb



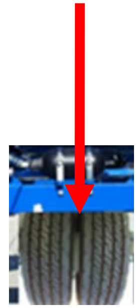
20,000 lb



22,000 lb

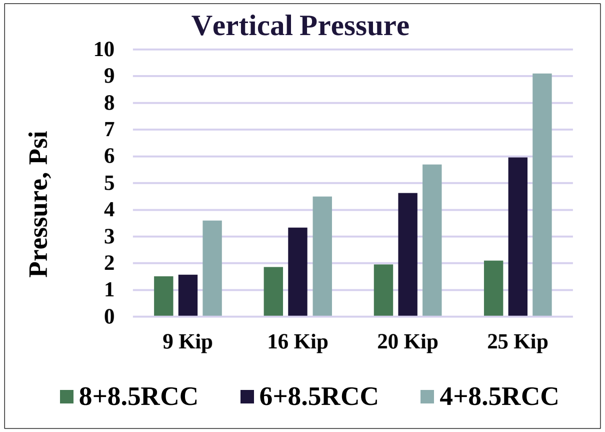


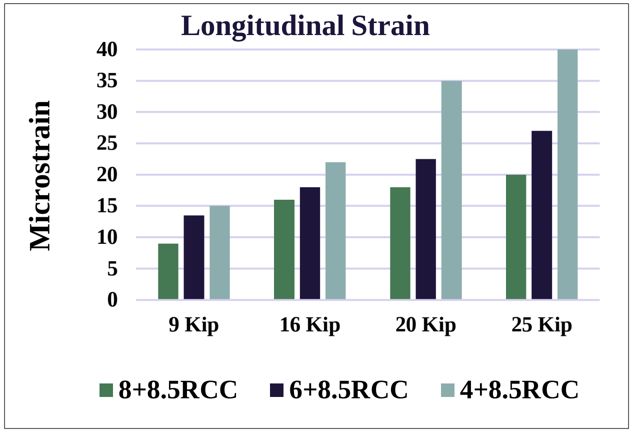
25,000 lb



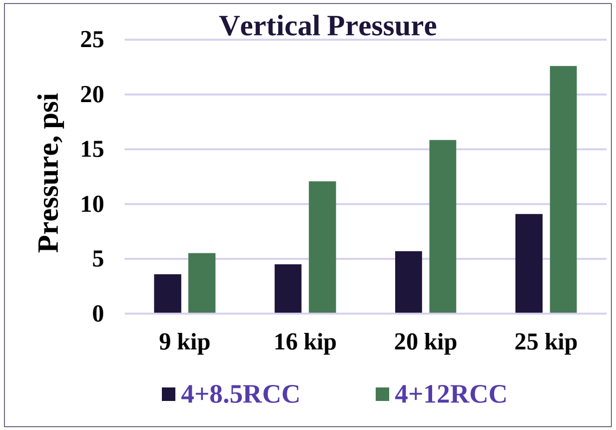
Instrumentation Response

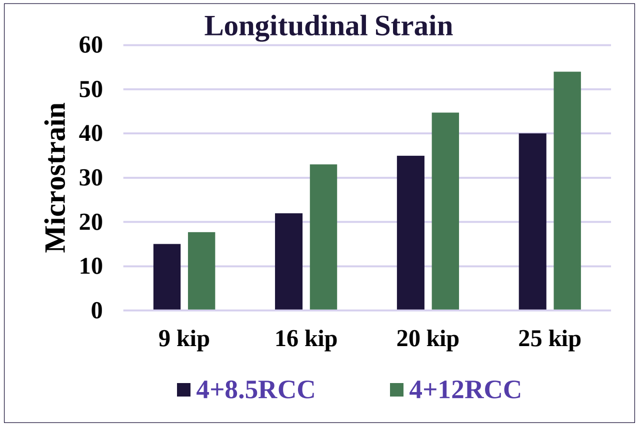
- Typical stress and strain measured at the bottom of RCC slabs with different thickness under APT loading





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





Loading Sequence and Passes

	Section 4	Section 5	Section 6	Section 3	Section 2
Loads	**8+8.5RCC**	**6+8.5RCC**	**4+8.5RCC**	**4+12RCC**	**6+12RCC**
9kip	78500	78000	78500	73000	78000
16kip	78500	78000	78500	73000	78000
20kip	78500	78000	78500	50000	78000
22kip	78500	78000	78500	-	78000
25kip	78500	78000	78500	-	78000
16kip	-	157000	314000	-	155000
9kip	-	34000	-	-	30000
16kip	-	32000	-	-	32000
20kip	-	30000	-	-	30000
22kip	-	30000	-	-	22000(Running)
25kip	-	84000	-	-	
16kip	-	137000	-	-	-
20kip	-	290000	-	-	-
25kip	-	325000	-	-	-
27.5kip	-	247000	-	-	-
Total Pass	392500	1756000	706500	196000	637000
Est. ESALs	11.3 M	87.4 M	19.2 M	2.7 M	16.8 M

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

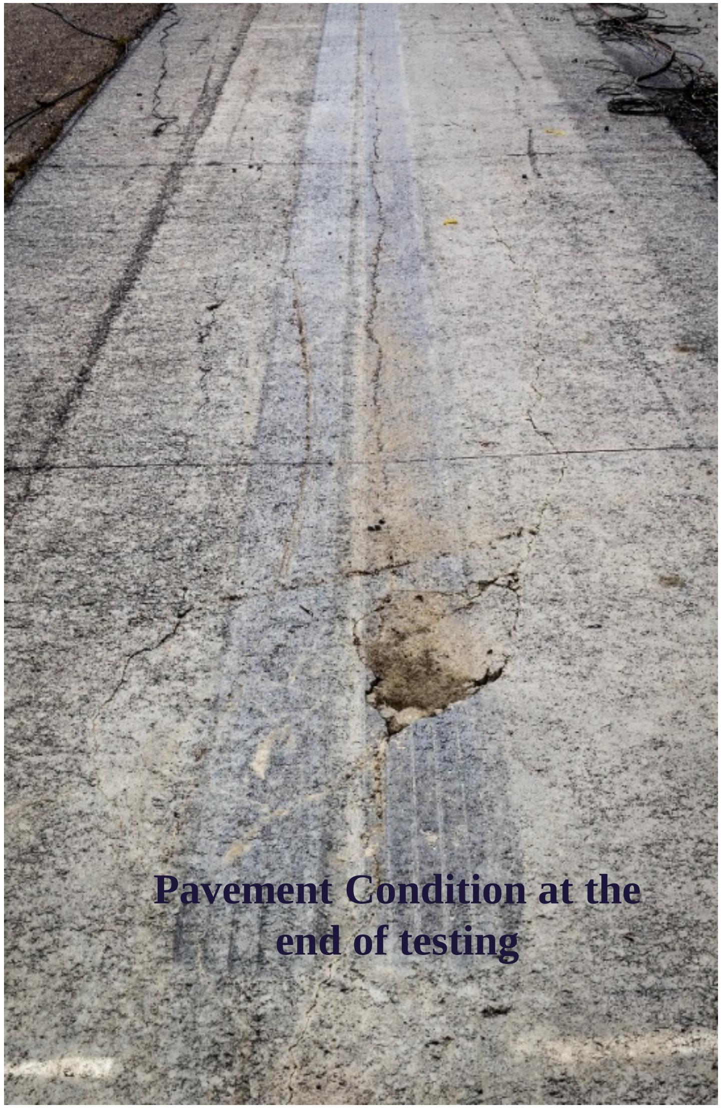
392,500 Passes

Current Pavement Condition

Distress Observed (6+8.5RCC) – Section 5

- **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***

1.75 million Passes



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
  - ***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 kip dual tire loading.
- This section failed at about 3-million ESALs of loading with extensive cracking
- ***Predicted 0.7 million ESALs to failure***

196,000 Passes

Longitudinal crack along the wheel path

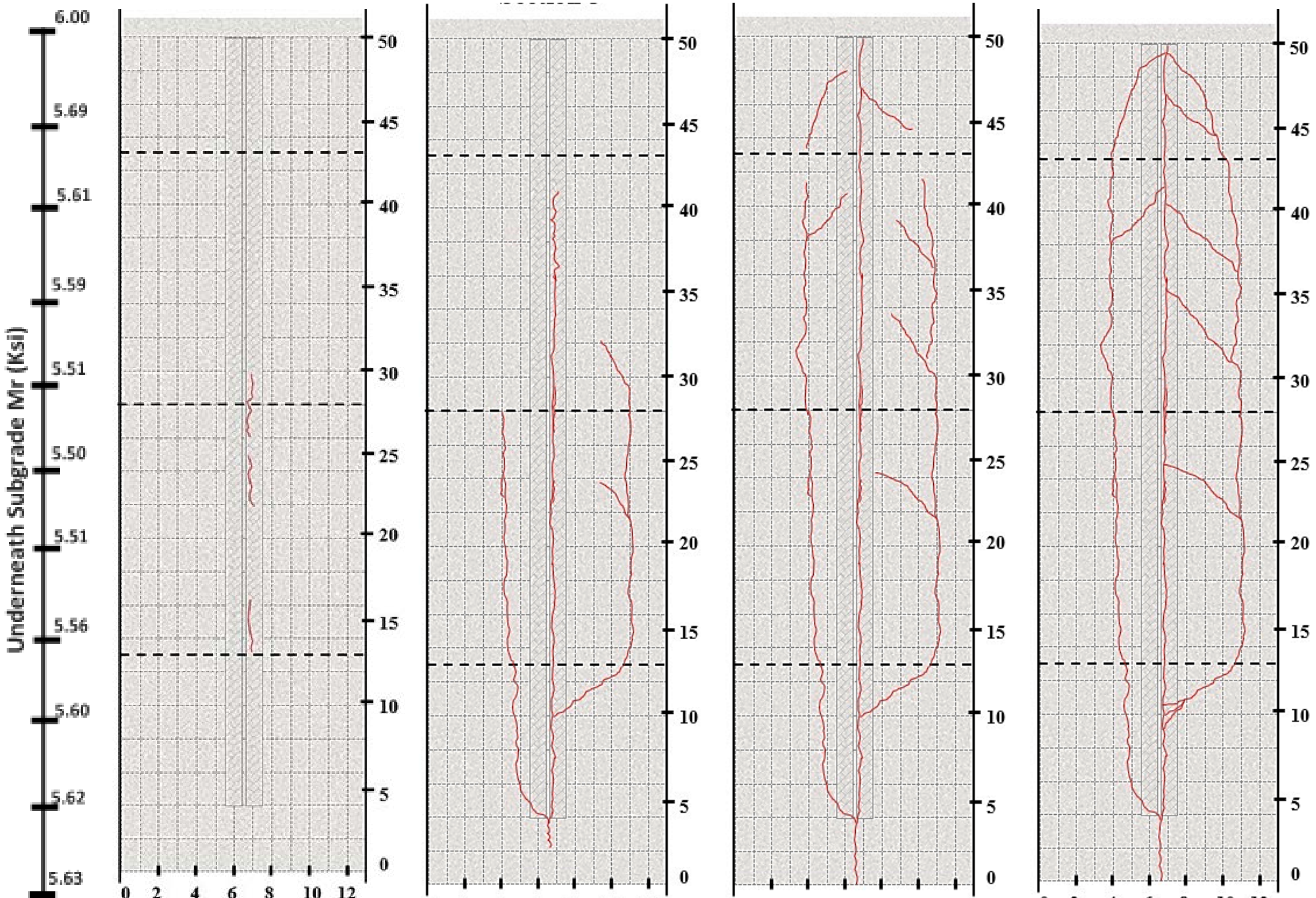
Distress Observed (6+12RCC) – Section 2

637,000 Passes

- Longitudinal cracks
- Pumping and Local failure
- **Completed now with about 19 million ESALs**
- ***Predicted 1.9 million***

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

- Crack Mapping



After 1,050,000 Load Repetition

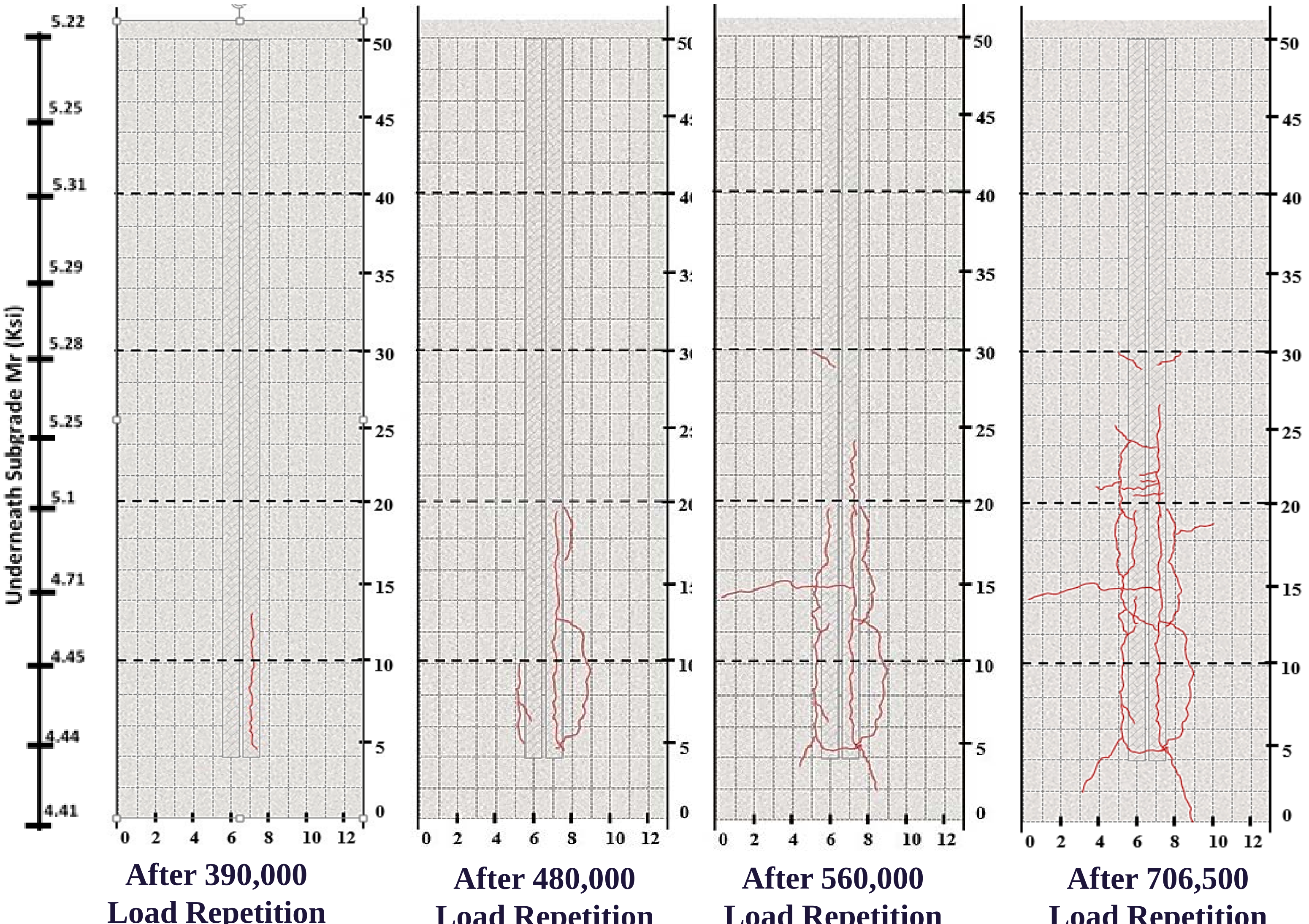
After 1,230,000 Load Repetition

After 1,500,000 Load Repetition

After 1,750,850 Load Repetition

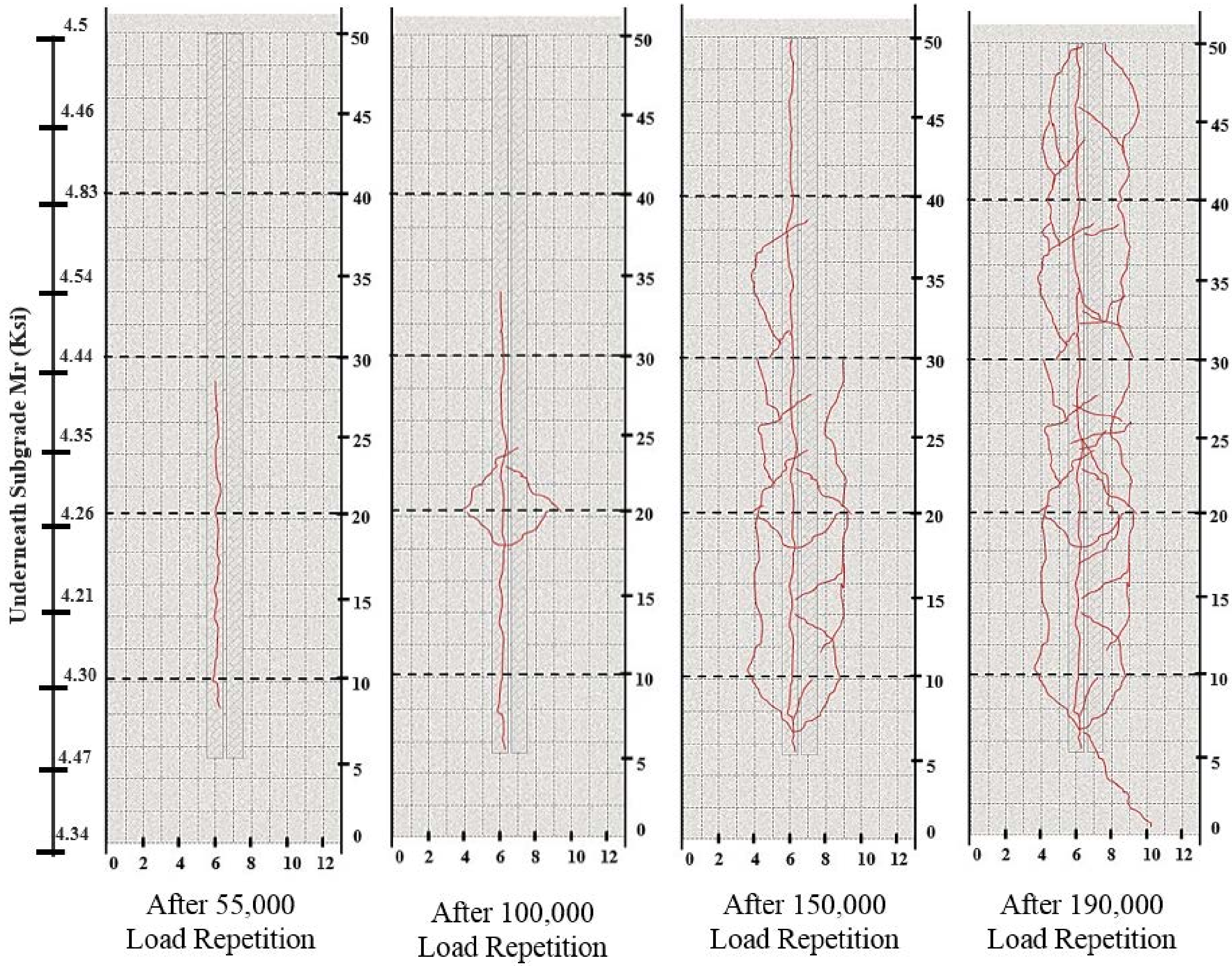
Crack Mapping on (4+8.5RCC) – Section 6

- Crack Mapping



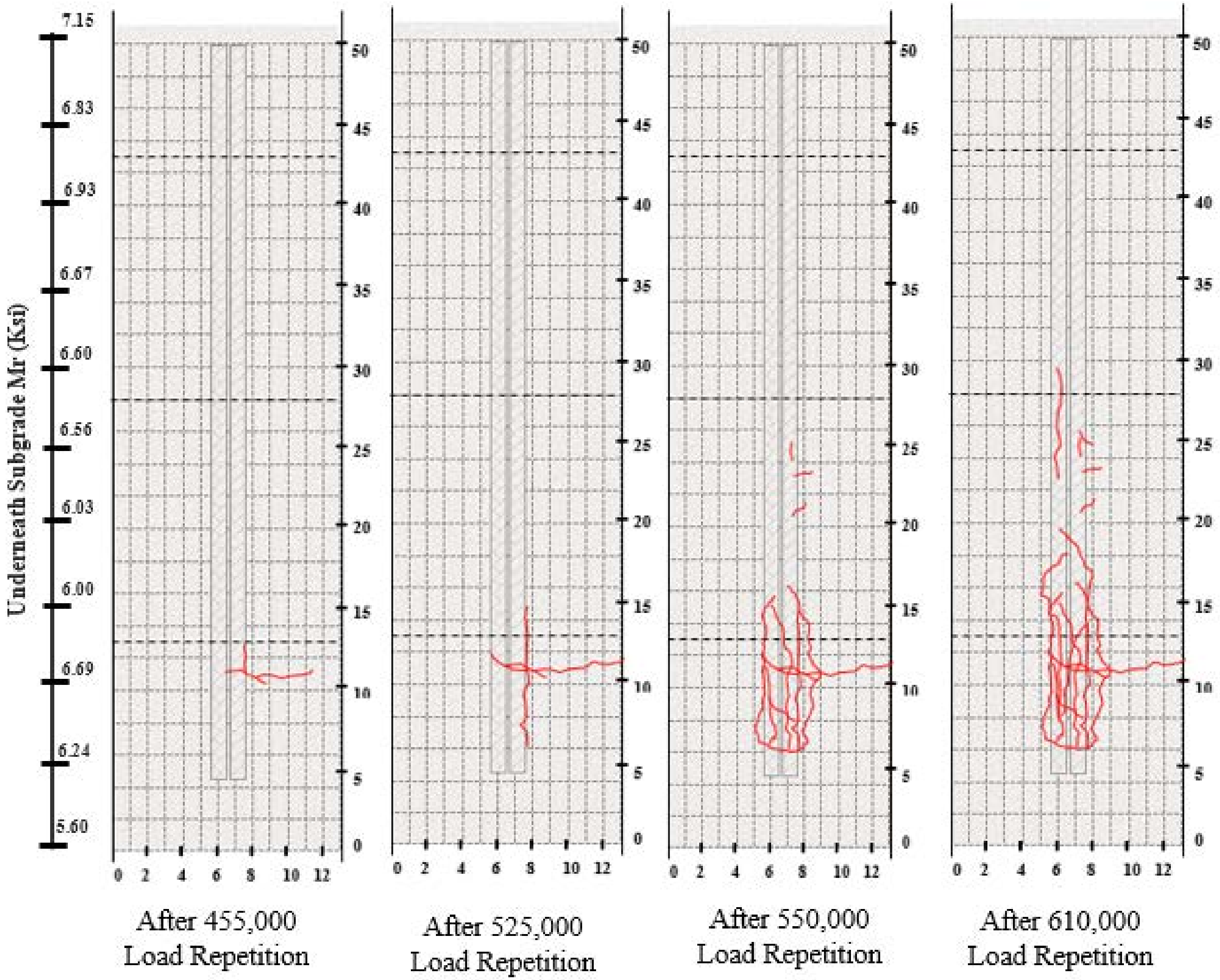
Crack Mapping on (4+12RCC) – Section 3

- Crack Mapping



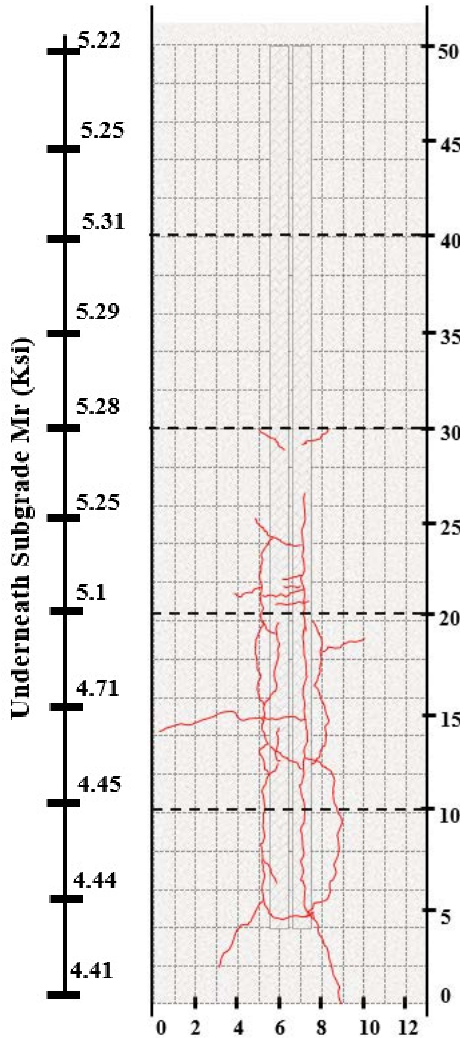
Crack Mapping on (6+12RCC) – Section 2

- On-going

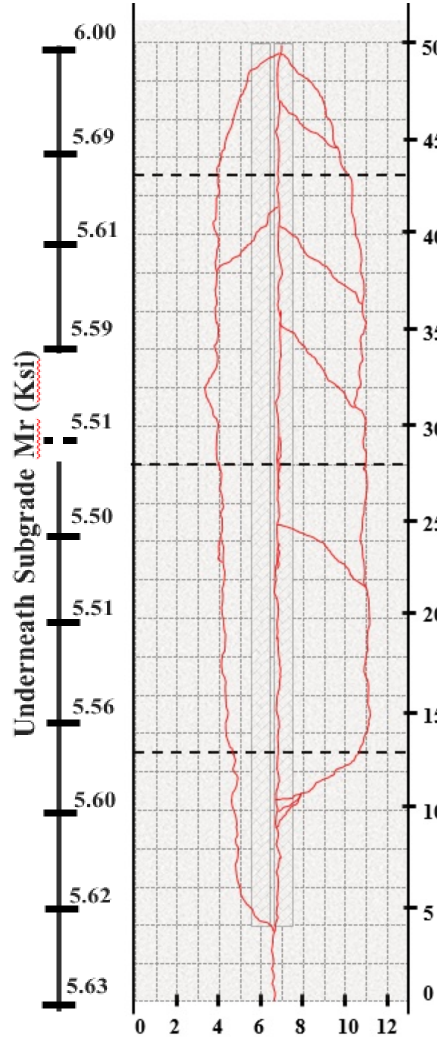


Comparison of Cracking Pattern of Failed RCC Sections

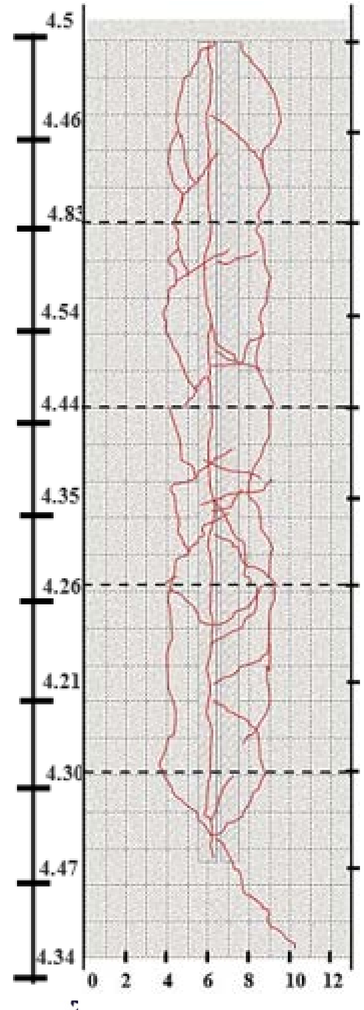
- Crack initiated at the weakest subgrade location
- Cracking pattern for thicker section was much wider than the thinner section
- Uniform subgrade resulted in a final cracking failure covering the entire loading area for 6+8.5RCC & 4+12RCC



4+8.5RCC



6+8.5RCC



4+12RCC

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
  - Will finalize the developed fatigue model
  - Will perform cost-benefit analysis
  - Will build a Finite element model to simulate thin-RCC pavement

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