National Center for Asphalt Technology NCAT AT AUBURN UNIVERSITY

Effect of Dwell Time and Lag Time on IDEAL-CT and IDEAL-RT Results – Expanded Study

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CAPRI CONSORTIUM FOR ASPHALT PAVEMENT RESEARCH AND IMPLEMENTATION

Concerns with Asphalt Mixture Storage

- NCHRP Project 552 – Research Gap
- Hypothesis
  - With more mixture oxidation in storage…
  - Mix Stiffness ↑
    - Cracking Results ↓
    - Rutting Results ↑
- How much does additional storage time actually matter for BMD test results?

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What are the Effects of Storage?

Lag Time
- The time between mixture sampling and specimen compaction
  - i.e. **Mixture Sample** Storage Time

Dwell Time
- The time between laboratory compaction of specimens and the time when those specimens are tested
  - i.e. **Compacted Specimen** Storage Time

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Original Work

- Testing performed at NCAT
  - Adam Taylor and Nathan Moore
- Small exploratory study
  - Funded by FHWA
- 2 x Alabama mix designs
  - Produced <1 hour from NCAT
  - IDEAL-CT and IDEAL-RT
- Limitation – Geography
  - Impetus for expanding the footprint of the study through CAPRI

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Expanded Lag and Dwell Time Study

- Funded through CAPRI
  - 6 additional participating labs provided data
    - Atlas (TX)
    - BATT (KY)
    - Brox Industries (MA)
    - Maryland DOT (MD)
    - Rowan University (NJ)
    - Wisconsin DOT (WI)
  - 8 additional mix designs
  - Participating labs instructed to following the original testing plan and framework

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Specimen Preparation

- Full presentation given to prospective participating labs (April 2024)
- Key Points
  - Specimen Homogeneity
  - Limit Specimen Aging in Shallow Pans
  - Compacting Specimens as quickly as possible
    - 2 people splitting/compacting
    - 1 person for G_{mb}/G_{mm}/conditioning specimens
  - **Stratified Random Specimen Selection**

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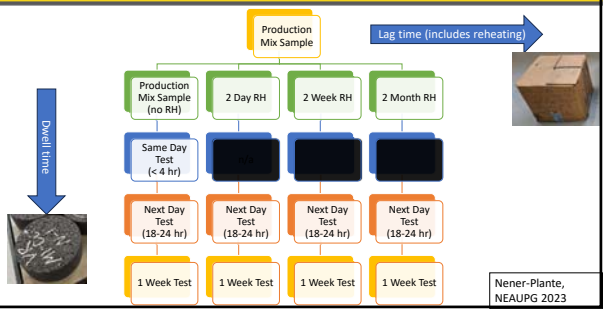
Testing Plan (IDEAL-CT and IDEAL-RT)



Expanded Lag and Dwell Time Study

- Data sent to NCAT for review, compilation, and analysis
- 10 mixes total included for analysis
  - Including the 2 original AL mixes tested at NCAT
    - 540 total CT Index Specimens (average CV ~ 15%)
      - 6 replicates/set x 9 sets/mix x 10 mixes
    - 360 total RT Index Specimens (average CV ~ 5.5%)
      - 4 replicates/set x 9 sets/mix x 10 mixes
    - 900 (!!!) total 62 mm specimens compacted to 7.0 ± 0.5 percent air voids

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Summary of Mix Design Information

Mix ID	AL-1	AL-2	KY-1	KY-2	NJ-1	NJ-2	MA-1	MD-1	TX-1	WI-1
NMAS (mm)	9.5	9.5	9.5	9.5	9.5	12.5	12.5	12.5	9.5	12.5
$P_{#8}$ (PCS)	62	53	41	36	38	36	44	30	41	56
Binder PG Grade	67-22	76-22	76-22	64-22	64-22	64-22	64E-28	64S-22	64-22	58S-28
RAP (%)	20	20	17	15	25	15	15	35	20	25
Ndes	60	60	65	65	75	75	75	65	50	75
Total AC (%)	5.9	5.5	6.3	5.9	5.9	5.3	5.0	4.9	5.4	5.7
Virgin AC (%)	4.9	4.6	5.4	5.2	4.7	4.6	4.1	3.0	4.5	4.5
VMA (%)	17.6	16.5	16.2	16.2	16.4	15.6	16.1	14.5	16.3	15.3
Air Voids (%)	4.7	4.2	3.7	3.6	4.0	4.0	4.1	4.0	4.0	3.0
CT Index (Production Day)	30	62	66	68	81	117	141	125	14	98
RT Index (Production Day)	111	88	152	101	107	55	85	106*	125	32

* = Lab ran HT instead of RT – Correlated using relationship developed at the Test Track

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Does Dwell Time Matter?

- Statistically compare all specimens tested at a given re-heating time for each mix
- Statistical Analysis (α = 0.05)
  - Production Group – ANOVA (3 groups)
  - Student's t-test - RH Groups (2 groups)

Separate Groups for Analysis

Re-heating (Lag) time	<4 hr. Dwell			18-24 hr. Dwell			1 Week Dwell		
	Avg.	St Dev.	CV (%)	Avg.	St Dev.	CV (%)	Avg.	St Dev.	CV (%)
Production (no RH)	29.9	4.0	13.6	29.0	4.3	14.8	32.0	3.5	11.0
2-day RH				25.6	2.9	11.4	25.5	4.1	16.0
2-week RH				29.5	4.4	14.8	29.2	5.1	17.6
2-month RH				24.7	2.2	8.9	25.2	2.0	7.8

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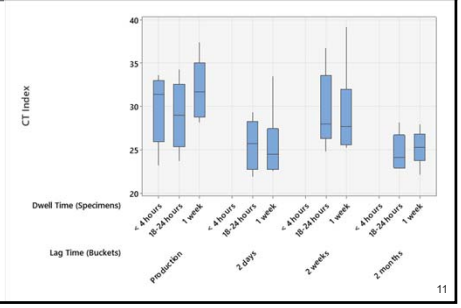
Example – No Dwell Effects

- AL Mix 1
  - CT Index
- No statistical effects of dwell time for this mix



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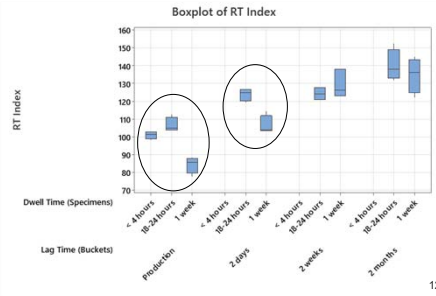
Example – Dwell Effects

- KY Mix 2
  - RT Index
- Some statistical effects for dwell time
  - Conflicting Trends



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CT – Dwell Time Statistical Analysis

- Only 4 of 40 comparisons showed a statistical impact (10%)
  - 3 of these 4 ran counter to the expected trend
  - i.e. CT Index increased with additional storage time

Mix ID	Lag Time			
	Production	2 days	2 weeks	2 months
AL-1	0.419	0.981	0.915	0.706
AL-2	0.576	0.448	0.005	0.434
KY-1	0.960	0.508	0.881	0.658
KY-2	0.093	0.891	0.249	0.793
NJ-1	0.791	0.538	0.891	0.729
NJ-2	0.737	0.348	0.851	0.985
MA-1	0.122	0.653	0.168	0.018
MD-1	0.535	0.292	0.151	0.393
TX-1	0.040	0.701	0.521	0.611
WI-1	0.074	0.956	0.491	0.021

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RT – Dwell Time Statistical Analysis

- 9 of 40 comparisons showed a statistical impact (22.5%)
  - 4 of these 9 ran counter to the expected trend
  - i.e. RT Index decreased with additional storage time

Mix ID	Lag Time			
	Production	2 days	2 weeks	2 months
AL-1	0.167	0.032	0.017	0.369
AL-2	0.110	0.482	0.409	0.029
KY-1	0.904	0.748	0.008	0.222
KY-2	0.000	0.003	0.392	0.455
NJ-1	0.799	0.919	0.875	0.745
NJ-2	0.013	0.002	0.164	0.638
MA-1	0.002	0.902	0.057	0.784
MD-1	0.151	0.996	0.334	0.392
TX-1	0.152	0.145	0.367	0.888
WI-1	0.169	0.752	0.127	0.464

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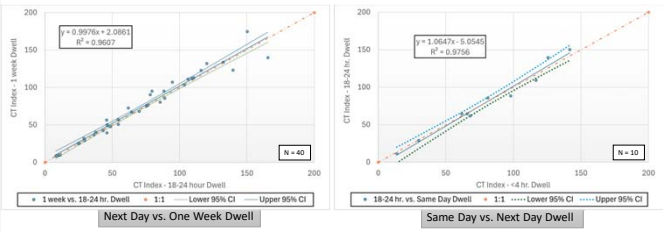
1:1 Plot – Dwell Time – IDEAL-CT



Next Day vs. One Week Dwell | Same Day vs. Next Day Dwell

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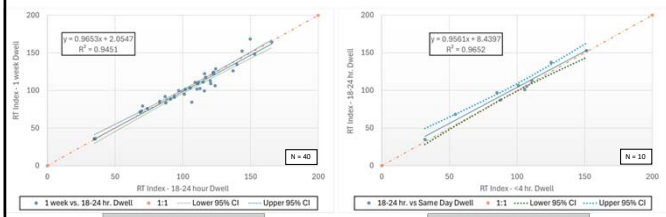
1:1 Plot – Dwell Time – IDEAL-RT



Next Day vs. One Week Dwell | Same Day vs. Next Day Dwell

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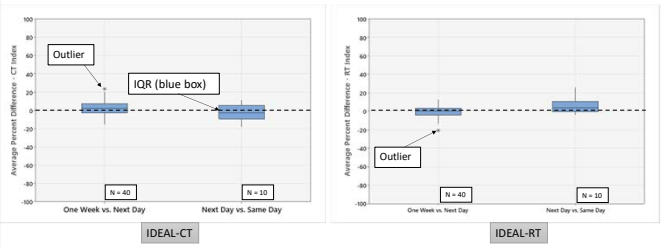
Dwell Time – Practical Differences



IDEAL-CT | IDEAL-RT

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Dwell Time Takeaways

- Low number of statistically significant comparisons (both CT and RT) and they trend in different directions
- Next Day vs. Same Day Specimens
  - RT Index increased an average of 6% from the day of production to the next day
  - CT Index decreased an average of less than 3%
- One week vs. Next Day Specimens
  - Minimal change on average for either CT or RT

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Lag Time Comparisons (AL Mix 1 CT example)

Reheating (Lag) Time	No Dwell Time			18-24 Hours Dwell			One Week Dwell		
	Average	St. Dev	CV (%)	Average	St. Dev	CV (%)	Average	St. Dev	CV (%)
No Reheating (Production)	29.9	4.0	13.6	29.0	4.3	14.8	32.0	3.5	11.0
Two Days				25.6	2.9	11.4	25.5	4.1	16.0
Two Weeks				29.5	4.4	14.8	29.2	5.1	17.6
Two Months				24.7	2.2	8.9	25.2	2.0	7.8

Single Group

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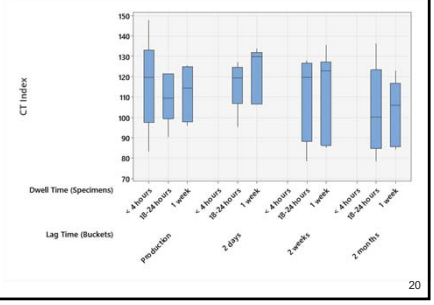
Example – No Effect of Lag Time

- NJ Mix 2
  - CT Index
- No statistical effects of lag time

Lag Time	N	NJ-2 Avg.	NJ-2 Grouping
Production	18	112.7	A
2 days	12	119.5	A
2 weeks	12	111.8	A
2 months	12	103.4	A



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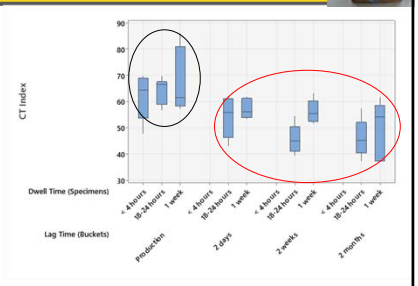
Example – Effect of Lag Time

- AL Mix 2
  - CT Index
- Production Group Statistically higher than RH Groups

Lag Time	N	AL-2 Avg.	AL-2 Grouping
Production	18	64.6	A
2 days	12	55.7	B
2 weeks	12	51.1	B
2 months	12	48.3	B



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CT – Lag Time Statistical Analysis

- Production Day
  - Always Highest Statistical Grouping
- Earliest Test (Production) vs. Latest Test (2-month RH)
  - 8 of 10 mixes showed a statistical reduction in CT Index over time
- Earliest RH (2-day) vs. Latest RH (2-month)
  - 9 of 10 mixes in same statistical grouping

Lag Time	N	AL-1	AL-2	KY-1	KY-2	NJ-1	NJ-2	MA-1	MD-1	TX-1	WI-1
Production	18	A	A	A	A	A	A	A	A B	A	A
2-day RH	12	B C	B	B	B	C	A	B C	B	B	C
2-wk. RH	12	A B	B	B	B	A B	A	B C	A	A B	A B
2-mo. RH	12	C	B	B	B	B	A	C	A B	B	B C

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RT Index –Lag Time Statistical Analysis

- Production Day
  - Usually lowest statistical grouping (excepting MD-1, TX-1)
- Earliest Test (Production) vs. Latest Test (2-month RH)
  - Increase = 5 of 10
  - Same = 4 of 10
- Earliest RH (2-day) vs. Latest RH (2-month)
  - Same = 6 of 10
  - Higher and Lower = 2 of 10 each (opposite trend)

Lag Time	N	AL-1	AL-2	KY-1	KY-2	NJ-1	NJ-2	MA-1	MD-1*	TX-1	WI-1
Production	12	B	C	B	C	B	B	B	A	A	A
2-day RH	8	A	B C	A	B	A	A	A	A	A B	A
2-wk. RH	8	A B	B	A B	A B	A	A B	A	B	B	A
2-mo. RH	8	B	A	B	A	A	A	A	B	A B	A

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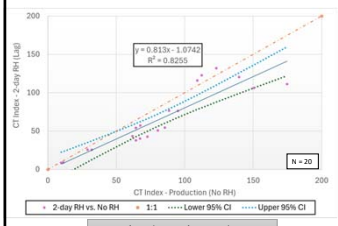
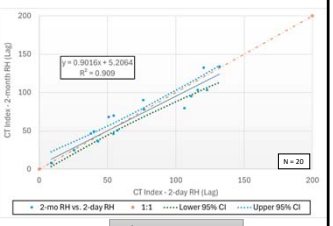
1:1 Plot – Lag Time – IDEAL-CT



No RH (Production) vs. Earliest RH



Earliest RH vs. Latest RH

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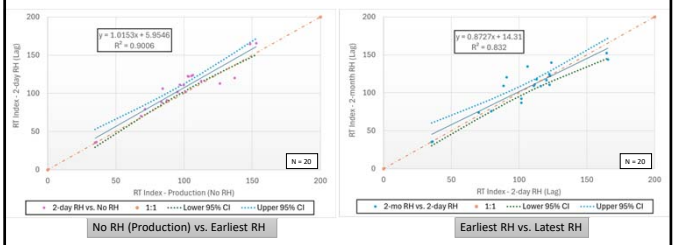
1:1 Plot – Lag Time – IDEAL-RT



No RH (Production) vs. Earliest RH | Earliest RH vs. Latest RH

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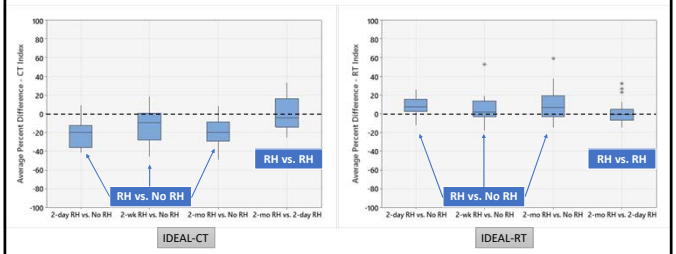
Lag Time – Practical Differences



IDEAL-CT | IDEAL-RT

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Lag Time Takeaways

- Earliest RH vs. Production Day (no RH)
  - Average CT Index decreased by 13 to 22 percent
  - Average RT Index increased by 5 to 10 percent
- Most of the effects of lag time appeared to come from the effects of re-heating more than the effects of additional storage time
- Example VDOT Production BMD Requirements
  - NAPA BMD Resource Guide
  - CT Index
    - ≥ 70 for RH specimens
    - ≥ 95 for non-RH specimens

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Overall Takeaways

- Treating Production tests (no RH) differently than re-heated tests is necessary
  - (and also common sense)
- Establish good standard organizational practices for sample and specimen handling
  - Examples
    - Either test all Production (no RH) specimens the same day or test them the next day
    - Don't treat Production day specimens and re-heated specimen data interchangeably in the same database
    - Control specimen time in the oven

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Research Limitations

- Do longer durations for lag and dwell time impact CT or RT?
  - For this study
    - Max Dwell = 1 week
    - Max Lag = 2 months
- Only 2 tests evaluated in this study (IDEAL-CT and IDEAL-RT)

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Special Thanks!

- Participating Labs
  - Atlas, BATT, Brox, Maryland DOT, Rowan, Wisconsin DOT
- Tyler Wollmuth
- Randy West
- Derek Nener-Plante
- Leslie Myers
- Nathan Moore

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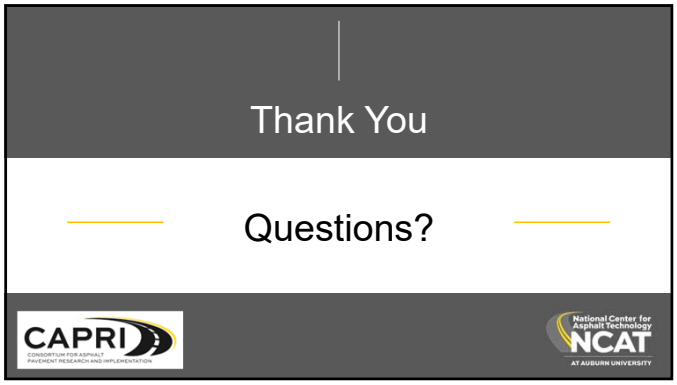
Thank You
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