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Validation of Short- and Long-Term Oven Aging Lab Procedures (Part 1)

Final Report

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1. INTRODUCTION

In 2023, the American Association of State Highway and Transportation Officials (AASHTO) Committee on Materials and Pavements (COMP) Technical Subcommittee 2C Task Force 2c-2022-02, in collaboration with NCHRP project 20-44(19), proposed a new AASHTO standard practice titled "*Long-Term Laboratory Conditioning of Asphalt Mixtures*." This document was developed to supersede the previous long-term aging (LTA) practice in the former AASHTO R 30-22 and to add four additional LTA methods based on recent relevant research (Newcomb et al., 2015; Kim et al., 2017; Bahia et al., 2018; Chen et al., 2018; Newcomb et al., 2019; Chen et al., 2020; Zhou et al., 2021). In 2024, COMP approved the document as AASHTO R 121-24.

AASHTO R 121-24 includes five LTA methods. Method A involves aging compacted specimens, whereas Methods B through E involve aging loose mixtures using different combinations of aging temperature and duration (Table 1). These methods are not intended to produce the same level of asphalt aging. Instead, they provide multiple options for state highway agencies (SHAs) to incorporate LTA into laboratory evaluations of cracking resistance for asphalt mixtures.

Table 1. Summary of LTA Methods in AASHTO R 121-24

LTA Method	Material Condition	Aging Temperature	Aging Duration
Method A	Compacted Specimen	85°C	5 Days
Method B	Loose Mixture (25 to 50 mm thickness)	85°C	5 Days
Method C	Loose Mixture (≤ NMAS thickness)	95°C	Varies depending on field aging maps
Method D	Loose Mixture (25 to 50 mm thickness)	100 to 125°C	20 Hours
Method E	Loose Mixture (≤ NMAS thickness)	135°C	6 or 8 Hours

Although AASHTO R 121-24 provides step-by-step procedures for each LTA method, certain operational details are not explicitly specified, which may hinder broader adoption by SHAs and the asphalt pavement industry. For example, Method A specifies that compacted specimens must cool to room temperature inside the oven after aging for 5 days at 85°C. This requirement, carried forward from the former AASHTO R 30-22, can create operational challenges because it prevents alternative use of the oven during the specimen cooling period. Allowing specimens to cool on a countertop after removal from the oven could improve laboratory efficiency; however, the effect of these two cooling approaches on laboratory cracking test results has not been evaluated.

Similarly, Methods B through E require that loose mixtures be cooled to room temperature after aging, then reheated for compaction. Although this workflow generally aligns well with typical laboratory schedules, some laboratory personnel may prefer to omit the cooling and reheating step by compacting loose mixtures after aging once the mixture reaches the compaction temperature. Therefore, research is needed to evaluate these procedural variations and quantify their potential impacts on laboratory cracking test results.

2. OBJECTIVES

The objectives of this research were to:

(1) Quantify the impacts of alternative post-aging material-handling approaches on the measured cracking resistance of asphalt mixtures for the LTA methods defined in AASHTO R 121-24; and
(2) Develop recommended revisions to AASHTO R 121-24 to further standardize operational procedures related to the post-aging handling of compacted specimens and loose mixtures.

Specifically, this research compared two compacted-specimen handling approaches for Method A and two loose-mixture handling approaches for Methods B through E. The effects of these approaches on the Indirect Tensile Asphalt Cracking Test (IDEAL-CT) results were evaluated using five plant-produced mixtures with distinct component materials and cracking potentials. For each LTA method, one approach followed AASHTO R 121-24, and the other represented an operationally practical alternative, as summarized below.

Compacted-Specimen Handling Approaches for Method A

- *Standard approach* (AASHTO R 121-24): After aging, turn off the oven and allow compacted specimens to cool to room temperature inside the oven.
- *Alternative approach*: After aging, remove compacted specimens from the oven and allow them to cool to room temperature on a countertop.

Loose-Mixture Handling Approaches for Methods B–E

- *Standard approach* (AASHTO R 121-24): After aging, cool loose mixtures to room temperature, reheat to compaction temperature, and then compact.
- *Alternative approach*: After aging, bring loose mixtures directly to compaction temperature and compact them without an intermediate cooling step.

3. EXPERIMENTAL PLAN

Figure 1 presents an overview of the experimental plan. Five plant-produced asphalt mixtures with different component materials and cracking potentials were selected. Each mixture was evaluated using the IDEAL-CT, one of the cracking tests most widely used by SHAs, under 10 testing conditions. These conditions corresponded to the five LTA methods in AASHTO R 121-24, with each method evaluated using both the standard and alternative post-aging material-handling approaches previously defined. Upon completion of IDEAL-CT testing, statistical analyses were performed to compare results between the standard and alternative approaches across all mixtures and LTA methods. Based on these findings, recommendations were developed regarding the acceptance of the alternative approaches and potential revisions to AASHTO R 121-24. Additional details of the experimental plan are provided below.

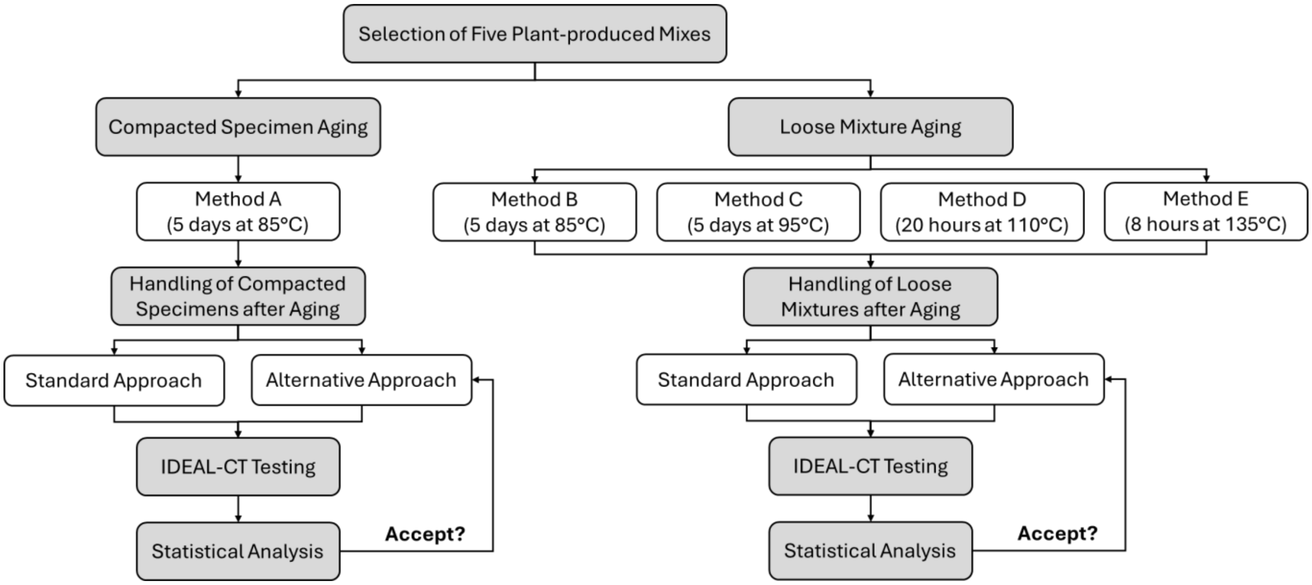

Figure 1. Overview of the Experimental Plan

3.1 Selection of Plant-Produced Asphalt Mixtures

Table 2 summarizes the five plant-produced mixtures selected for evaluation. The selected mixtures included two mix design methods and covered a wide range of component materials and proportions, including virgin binder grades, aggregate types, reclaimed asphalt pavement (RAP) contents, and additives. The mixtures also represented a broad range of cracking potential, as reflected by a cracking tolerance index (CT_{Index}) range of approximately 50 to 300 for hot-compacted (HC) or reheated (RH) plant-mixed, laboratory-compacted (PMLC) specimens tested in relevant NCAT studies.

Table 2. Selected Plant-Produced Asphalt Mixtures

Mixture ID	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
State	Minnesota	Virginia	Tennessee	Minnesota	Ohio
Mix Design Method	Superpave	Superpave	Marshall	Superpave	Marshall
NMAS	12.5 mm	12.5 mm	12.5 mm	12.5 mm	9.5 mm
Virgin Binder Grade	58H-28	64S-22	67-22	58V-34	64-22
Aggregate Type (Absorption Capacity)	Limestone, Sand (Low)	Granite (Low)	Gravel, Limestone, Sand (High)	Granite (Low)	Limestone (High)
RAP Content	25%	30%	15%	17%	10%
Additive	None	None	Rejuvenator, Warm mix asphalt	Wet plastic	None
CT_{Index}	~ 80 (RH)	~ 50 (RH)	~ 100 (HC)	~ 150 (RH)	~ 300 (RH)

3.2 Selection of LTA Conditions

For Methods A and B, aging conditions followed AASHTO R 121-24 and consisted of 5 days at 85°C. For Methods C through E, AASHTO R 121-24 allows different combinations of aging temperature and duration depending on the targeted field aging level. In this study, they were selected to represent comparable aging levels based on the binder stiffness-based kinetics model developed in NCHRP Project 09-54 (Kim et al., 2021): 5 days at 95°C for Method C, 20 hours at 110°C for Method D, and 8 hours at 135°C for Method E.

3.3 Post-Aging Material-Handling Details

For Method A, the alternative compacted-specimen handling approach required removing compacted specimens from the oven after aging and allowing them to cool to room temperature on a countertop. To reduce the risk of specimen damage during transfer, flat metal plates were placed beneath the specimens throughout the aging process to enable touch-free removal after aging.

For Methods B through E, loose mixtures were aged at the designated thicknesses specified in AASHTO R 121-24: 25 to 50 mm for Methods B and D, and the approximate mixture nominal maximum aggregate size (NMAS) for Methods C and E.

3.4 Specimen Preparation and IDEAL-CT Testing Details

To ensure material consistency between the standard and alternative handling approaches, split samples were prepared in accordance with AASHTO R 47-23. Specimens were then subjected to standardized aging, reheating, and compaction procedures following NAPA IS-145 guidelines (Moore and Taylor, 2023). A minimum of five replicate specimens were tested using the IDEAL-CT under each condition, defined as the combination of the LTA method and the post-aging material-handling approach, except for two sets with limited material availability: Mix 1 and Mix 2 under Method E with alternative handling. IDEAL-CT testing was conducted in accordance with ASTM D8225-19.

All IDEAL-CT testing was completed within one week after compaction to minimize potential impacts of specimen dwell time. Recent CAPRI research has shown that dwell time has minimal impact on IDEAL-CT results for specimens tested within one week after preparation (Taylor, 2026). For each IDEAL-CT test set, outlier analysis was performed in accordance with ASTM E178-19 to identify and exclude outliers among replicate results.

3.5 Analysis of IDEAL-CT Results

The primary analysis of the IDEAL-CT results focused on comparing the standard and alternative post-aging material-handling approaches. To support this comparison, Student's t-tests were first conducted between the two approaches for each combination of mixture and LTA method. In addition, a multi-way analysis of variance (ANOVA) was conducted using a general linear model (GLM) to evaluate the effects of the post-aging material-handling approach and its interactions with the mixture and LTA methods on IDEAL-CT results. Additional analyses were also conducted to compare the LTA methods under the specific aging conditions used in this study and to assess the effect of LTA on the maximum theoretical specific gravity (G_{mm}) of the mixtures.

4. TEST RESULTS AND DISCUSSION

4.1 Comparison of Post-Aging Material-Handling Approaches

Table 3 summarizes the average CT_{Index} results for all 50 sets of IDEAL-CT tests conducted in this study, representing 5 plant-produced mixtures × 5 LTA methods × 2 post-aging material-handling approaches. This dataset consisted of 303 individual IDEAL-CT specimens. A more detailed statistical summary of the CT_{Index} results is provided in Appendix A.

Table 3. Average CT_{Index} Values by LTA Method and Post-Aging Material-Handling Approach

LTA Method	Post-Aging Material-Handling Approach	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
Method A	Standard	33.6	10.0	23.0	104.5	129.1
	Alternative	34.9	12.8	20.7	103.8	127.8
Method B	Standard	33.5	16.5	19.0	107.4	96.3
	Alternative	27.8	14.5	19.5	99.0	107.2
Method C	Standard	17.5	10.4	9.4	71.7	57.7
	Alternative	17.6	9.1	11.3	78.4	61.6
Method D	Standard	35.1	17.5	22.8	98.7	89.0
	Alternative	31.7	17.5	24.4	90.7	93.9
Method E	Standard	27.4	10.9	14.5	76.6	93.8
	Alternative	26.2	9.6	16.7	70.2	74.3

Figure 2 illustrates the absolute change in average CT_{Index} when the standard and alternative handling approaches are compared for the same mixture and LTA method. For example, for Mix 1 under LTA Method B, the CT_{Index} change of -5.7 indicates that the alternative handling approach produced an average CT_{Index} that was 5.7 units lower than that obtained using the standard handling approach. Figure 3 presents the same data as the percent change in CT_{Index} relative to the standard handling approach. For the same comparison, Mix 1 under LTA Method B, the alternative handling approach produced a CT_{Index} that was 17.0% lower than that obtained using the standard handling approach.

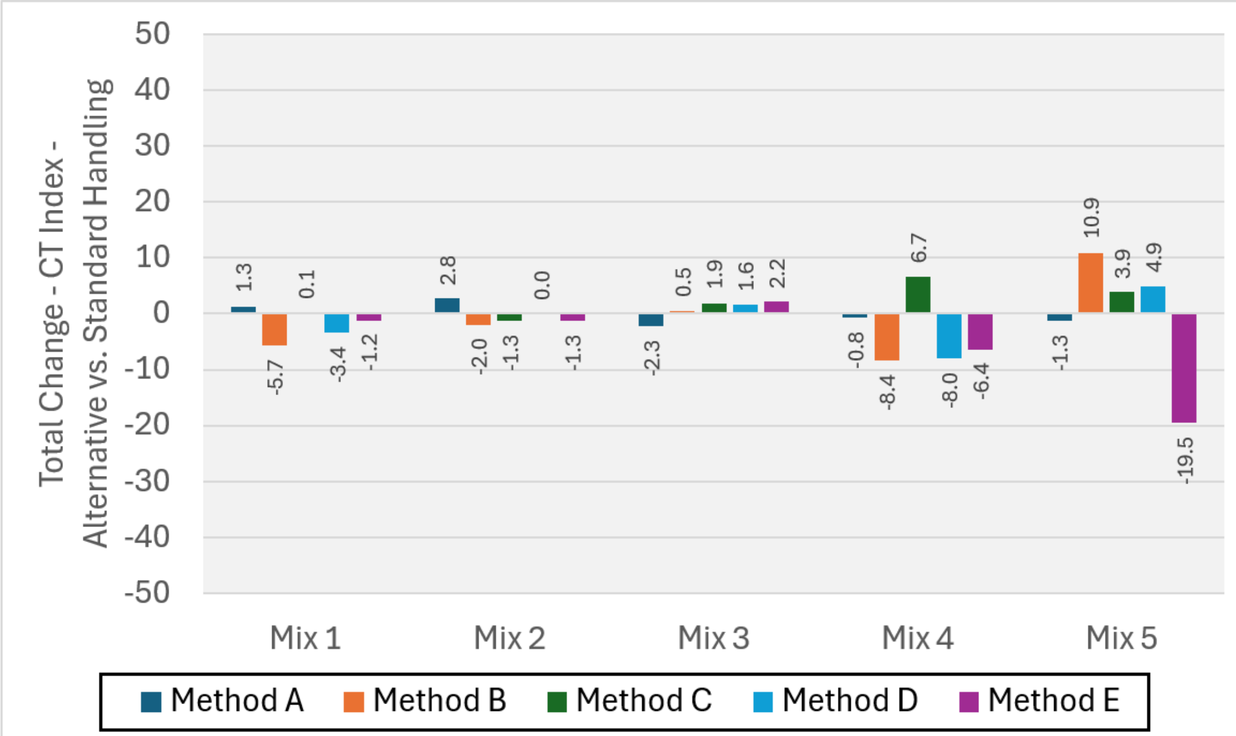

Figure 2. Change in Average CT_{Index} between Standard and Alternative Post-Aging Material-Handling Approaches

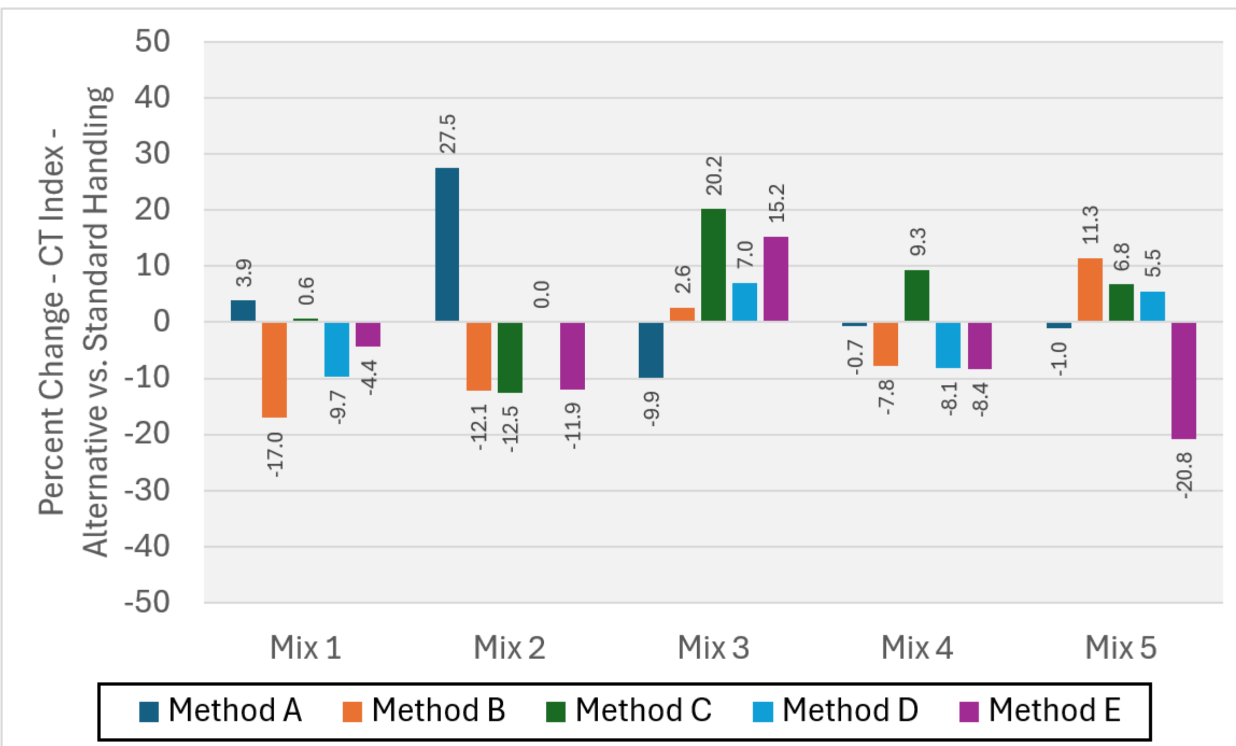

Figure 3. Percent Change in Average CT_{Index} between Standard and Alternative Post-Aging Material-Handling Approaches

For the 25 paired comparisons between the standard and alternative post-aging material-handling approaches (representing 5 mixtures × 5 LTA methods), 12 comparisons showed an increase in CT_{Index}, while 13 showed a decrease (Figures 2 and 3). The direction of change appeared random and did not show a consistent trend for any specific mixture or LTA method. Each of the five mixtures had at least one comparison showing an increase in CT_{Index} and at least one showing a decrease. Similarly, each of the five LTA methods had at least one comparison showing an increase in CT_{Index} and at least one showing a decrease. The largest CT_{Index} change magnitudes were observed for Mix 4 and Mix 5; however, these mixtures also had higher average CT_{Index} values than the other three mixtures evaluated in this study.

As shown in Figure 3, approximately two-thirds of the comparisons, 16 of 25, had a percent change in CT_{Index} of less than 10%, either increasing or decreasing, for the alternative handling approach relative to the standard handling approach. These differences are within the single-operator precision limit of 17.4% coefficient of variation (COV) specified in ASTM D 8225-26. Only three comparisons showed a percent change in CT_{Index} between 20% and 30%, including two increases and one decrease.

Student's t-tests ($\alpha = 0.05$) were performed for each paired set of CT_{Index} data to compare the standard and alternative post-aging material-handling approaches. The results are summarized in Table 4. None of the comparisons showed a statistically significant difference ($p\text{-value} < \alpha$) between the two handling approaches. In addition, only two of the 25 comparisons had p-values in the borderline or marginal range between 0.05 and 0.10. Overall, the results suggest that the post-aging material-handling approach (standard versus alternative) had no statistically significant effect on IDEAL-CT results after LTA.

Table 4. Student's t-Test Comparison of CT_{Index} Results Between Standard and Alternative Post-Aging Material-Handling Approaches (p-values)

LTA Method	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
Method A	0.628	0.245	0.368	0.907	0.914
Method B	0.067	0.401	0.801	0.442	0.405
Method C	0.922	0.094	0.157	0.441	0.425
Method D	0.351	0.993	0.684	0.182	0.551
Method E	0.797	0.327	0.260	0.408	0.156

To further evaluate whether the standard or alternative post-aging material-handling approach had a statistically significant effect on IDEAL-CT results across different LTA methods, a GLM analysis was performed at a significance level of $\alpha = 0.05$. This analysis was not intended to generate a predictive model, but rather to assess whether the main factors — mixture type, LTA method, and handling approach — and their interactions contributed significantly to the model.

The GLM results in Figure 4 showed that mixture type, represented by Mix ID, and LTA method, represented by aging method, made statistically significant contributions to the model ($p\text{-value} < \alpha$). However, the post-aging handling approach, represented by aging treatment (standard versus alternative), did not make a statistically significant contribution to the model, either as a main effect or through interactions with mixture type or aging method. These results provide additional evidence that the post-aging material-handling approach had minimal meaningful impact on IDEAL-CT results across the evaluated mixtures and LTA methods.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Mix ID	4	386843	96710.8	761.39	0.000
Aging Method	4	25241	6310.3	49.68	0.000
Aging Treatment	1	71	70.5	0.56	0.457
Mix ID*Aging Method	16	20416	1276.0	10.05	0.000
Mix ID*Aging Treatment	4	166	41.4	0.33	0.860
Aging Method*Aging Treatment	4	425	106.3	0.84	0.503
Mix ID*Aging Method*Aging Treatment	16	1927	120.5	0.95	0.514
Error	253	32136	127.0		
Total	302	465564			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
11.2703	93.10%	91.76%	90.31%

Figure 4. GLM Results for CT_{Index} Results Across Evaluated Mixtures, LTA Methods, and Post-Aging Material-Handling Approaches

4.2 Comparison of LTA Methods

The data from this study were also analyzed to evaluate differences in IDEAL-CT results among the five LTA methods for the evaluated mixtures. As discussed previously, certain LTA methods in AASHTO R 121-24 allow different aging temperatures and durations depending on the targeted field aging condition. Therefore, the comparisons presented herein apply specifically to the combinations of aging temperature and duration used in this study. Because no evidence was found to support a statistically significant difference between the standard and alternative handling approaches, the two sets of CT_{Index} results for each mixture and LTA method were pooled in the following analysis to increase replication.

For each mixture, the average CT_{Index} values were assigned a relative numerical ranking, with 1 indicating the highest average CT_{Index} and 5 the lowest. These rankings are summarized in Table 5, along with the average ranking across all five LTA methods. An ANOVA with Tukey's post hoc test (α = 0.05) was also performed for each mixture to assess whether differences in CT_{Index} were statistically significant.

Table 5. Relative Rankings of LTA Methods based on CT_{Index} Results (1 = Highest, 5 = Lowest)

LTA Method	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Average
Method A	1	3	2	1	1	1.6
Method B	3	2	3	2	2	2.4
Method C	5	5	5	4	5	4.8
Method D	2	1	1	3	3	2.0
Method E	4	4	4	5	4	4.2

The results of the Tukey statistical groupings are summarized in Table 6. A separate lettering system was used for each mixture to distinguish its statistical groupings: unprimed letters (A, B, C, etc.) correspond to Mix 1, letters with one prime mark (A', B', etc.) correspond to Mix 2, letters with two prime marks (A", B", etc.) correspond to Mix 3, and so forth. The prime marks therefore do not represent a numerical value, ranking, or level of statistical significance; they are used only to differentiate the lettering systems among the five mixtures. Within a given mixture, LTA methods sharing at least one common grouping letter were not statistically different in CT_{Index} at $\alpha = 0.05$. Conversely, LTA methods that did not share a common grouping letter had statistically different CT_{Index} results.

Table 6. Tukey Statistical Groupings of LTA Methods based on CT_{Index} Results

LTA Method	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
Method A	A	B’	A’’	A’’’	A’’’’
Method B	A, B	A’	A’’, B’’	A’’’	B’’’’
Method C	C	B’	C’’	B’’’	C’’’’
Method D	A, B	A’	A’’	A’’’	B’’’’
Method E	B	B’	B’’	B’’’	B’’’’

The relative rankings in Table 5 showed that Method A (compacted-specimen aging for 5 days at 85°C) had the highest average CT_{Index} ranking of 1.6. For four of the five mixtures, Method A was also included in the highest Tukey statistical grouping. Method C (loose-mixture aging for 5 days at 95°C), with an average ranking of 4.8, and Method E (loose-mixture aging for 8 hours at 135°C), with an average ranking of 4.2, generally produced the lowest CT_{Index} values among the LTA methods. Method C was consistently included in the lowest Tukey statistical grouping, while Method E was included in either the lowest or second-lowest grouping. In contrast, Method B (loose-mixture aging for 5 days at 85°C), with an average ranking of 2.4, and Method D (loose-mixture aging for 20 hours at 110°C), with an average ranking of 2.0, generally fell in the middle of the CT_{Index} rankings. In most cases, Methods B and D were included in either the highest or second-highest Tukey statistical grouping, along with Method A.

It is worth noting that, in addition to differences in aging temperature and duration, Methods B through E also differed in the thickness of the loose mixture used during aging. Specifically, Methods B and D required a loose-mixture thickness of 25 to 50 mm, whereas Methods C and E required a thickness approximately equal to the mixture NMAS. Figure 5 illustrates the different aging vessels used to age approximately 2,500 g of loose mixture at the specified thicknesses. For the same mass of loose mixture, spreading the material over a larger surface area would be expected to increase its exposure to heat and oxygen, potentially resulting in more severe aging. This factor may have contributed to the lower CT_{Index} rankings observed for Methods C and E relative to Methods B and D, although these methods also differed in aging temperature and duration.

Figure 5. Aging Vessels Used for AASHTO R 121-24 Methods B and D (Left) and Methods C and E (Right)

Overall, the comparison between Methods A and B suggests that loose-mixture aging is more severe than compacted-specimen aging due to increased exposure of the mixture to heat and oxygen. The comparison between Methods B and C suggests that increasing the aging temperature accelerates aging of the mixture. The rankings of Methods C, D, and E are consistent with the findings of Yin et al. (2026), which suggest that loose-mixture aging for 5 days at 95°C (Method C) is slightly more severe than loose-mixture aging for 8 hours at 135°C (Method E) and that both conditions are significantly more severe than loose-mixture aging for 20 hours at 110°C (Method D), based on the aging conversion relationships developed using the IDEAL-CT.

4.3 Effect of LTA on G_{mm}

The data collected in this study were also analyzed to evaluate the effect of LTA method on G_{mm}. Specifically, the analysis examined whether the changes in G_{mm} resulting from LTA differed between mixtures containing highly absorptive aggregates, such as Mixes 3 and 5, and those with lower aggregate absorption. A unique G_{mm} value was determined for each combination of mixture and LTA method and was subsequently used to calculate the air void content of the IDEAL-CT specimens.

For Method A, LTA was conducted on compacted specimens. Therefore, G_{mm} was determined on the reheated loose mixtures prior to aging. This condition, designated as “RH PMLC”, served as the baseline for comparison with the other four LTA methods, for which G_{mm} was determined using loose mixtures after LTA. Table 7 summarizes the 25 G_{mm} values obtained across the five mixtures and five LTA methods.

Table 7. G_{mm} Values by LTA Methods

LTA Method	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5
Method A (RH PMLC)	2.493	2.513	2.325	2.469	2.417
Method B	2.496	2.518	2.333	2.473	2.421
Method C	2.503	2.520	2.338	2.464	2.431
Method D	2.498	2.518	2.328	2.472	2.427
Method E	2.501	2.524	2.335	2.487	2.424

Figure 6 illustrates the change in G_{mm} for each mixture and LTA method relative to the corresponding RH PMLC G_{mm} value. In general, G_{mm} is expected to increase following aging. An increase in G_{mm} was observed for 19 of the 20 comparisons between the RH PMLC condition and the LTA methods. Furthermore, 18 of the 20 comparisons fell within the difference two-sigma (d2s) limit of 0.0131 for G_{mm} specified in AASHTO T 209-25. These results indicate that, although LTA generally increased G_{mm}, the magnitude of the increase was typically within the expected within-laboratory variability of the test.

It is also noteworthy that the mixtures containing highly absorptive aggregates (Mixes 3 and 5) exhibited increases in G_{mm} following LTA that were comparable to those observed for mixtures with lower aggregate absorption. This finding suggests that aggregate absorption had little apparent influence on the magnitude of G_{mm} change resulting from the LTA methods evaluated in this study.

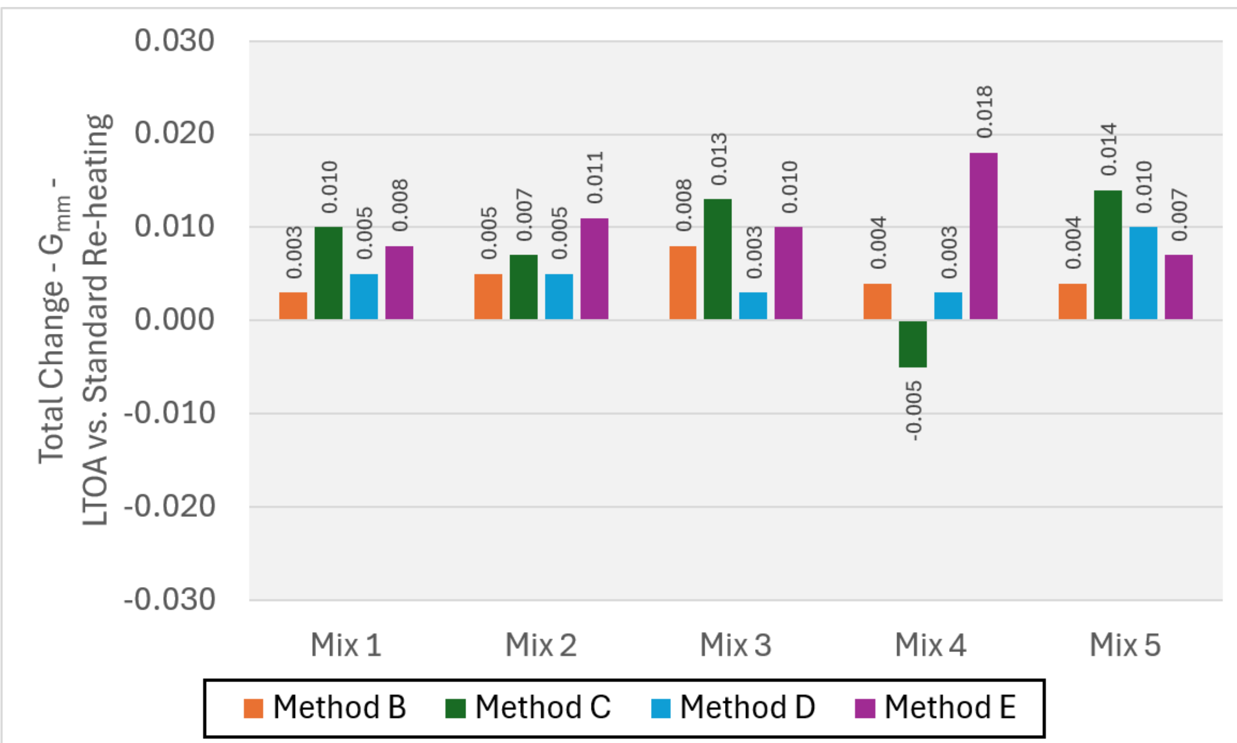

Figure 6. Change in G_{mm} by LTA Methods

5. CONCLUSIONS AND RECOMMENDATIONS

A standard and an alternative post-aging material-handling approach were evaluated for each of the five LTA methods in AASHTO R 121-24, based on IDEAL-CT testing of five plant-produced asphalt mixtures representing a wide range of component materials and cracking potentials. Based on the results of this study, the following conclusions and recommendations are provided:

- Across all LTA methods, the post-aging material-handling approach did not have a consistent or statistically significant effect on the CT_{Index} results. Approximately half of the 25 comparisons (combinations of mixture and LTA methods) yielded higher CT_{Index} values with the standard handling approach, whereas the remaining comparisons yielded higher CT_{Index} values with the alternative handling approach. No consistent trend was observed, indicating that neither handling approach systematically increased or decreased CT_{Index} for a particular mixture or LTA method. Statistical analyses, including Student's t-tests and a GLM analysis, showed no significant differences in CT_{Index} between the standard and alternative handling approaches. These findings support the adoption of the alternative post-aging material-handling approach in future revisions of AASHTO R 121. Recommended revisions are provided in a redlined version of AASHTO R 121-24, which is submitted with this report.
- For the specific LTA conditions evaluated in this study, Method A (compacted-specimen aging for 5 days at 85°C) generally yielded the highest CT_{Index} values, indicating the least severe aging. Methods C and E (loose-mixture aging for 5 days at 95°C and 8 hours at 135°C, respectively) generally produced the lowest CT_{Index} values, indicating the most severe aging conditions and the greatest reductions in cracking resistance. Methods B and D (loose-mix aging for 5 days at 85°C and 20 hours at 110°C, respectively) produced intermediate CT_{Index} values and generally exhibited aging severities between those associated with Methods A and C/E. The observed differences in aging severity among these methods are attributable to a combination of factors, including aging temperature, aging duration, material condition during aging (compacted specimen versus loose mixture), and exposure area of the mixture to heat and oxygen.
- Loose-mixture aging specified in AASTHO R 121-24 Methods B through E consistently increased the G_{mm} of the mixtures evaluated in this study. However, most of the observed increases were within the d2s precision limit for G_{mm} specified in AASHTO T 209-25. In addition, the magnitude of the G_{mm} increase did not vary substantially across mixtures with different aggregate absorptions, suggesting that aggregate absorption had little apparent influence on LTA's effect on G_{mm} in the mixtures evaluated in this study.

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APPENDIX A. DETAILED STATISTICAL SUMMARY OF CT_{INDEX} RESULTS FOR INDIVIDUAL MIXTURES

Table A1. CT Index – Statistical Summary - Mix 1 (MN Superpave – 12.5 mm NMAS – 25% RAP - PG 58H-28)

R121 Aging Method	Aging Treatment	N	Air Voids (%)	Fracture Energy (J/m²)	Slope (kN/mm)	L_{75} (mm)	CT Index		
			Avg.	Avg.	Avg.	Avg.	Avg.	St. Dev.	CV (%)
Method A	Standard	6	7.1	6,991	5.274	3.762	33.6	5.3	15.8
	Alternative	5	7.1	7,109	5.020	3.686	34.9	3.2	9.0
Method B	Standard	6	6.8	7,549	6.171	4.077	33.6	4.8	14.2
	Alternative	6	6.8	7,269	6.447	3.635	27.9	4.8	17.2
Method C	Standard	6	6.9	7,692	9.875	3.307	17.5	3.3	18.6
	Alternative	6	7.1	6,931	7.939	3.009	17.6	2.4	13.8
Method D	Standard	5	7.0	7,462	5.290	3.724	35.1	2.0	5.7
	Alternative	6	6.9	7,493	6.331	3.887	31.7	7.9	24.8
Method E	Standard	5	7.1	7,358	6.644	3.537	27.4	10.0	36.4
	Alternative	4	7.2	7,160	6.548	3.585	26.2	1.3	5.1

Table A2. CT Index – Statistical Summary - Mix 2 (VA Superpave – 12.5 mm NMAS – 30% RAP - PG 64S-22)

R121 Aging Method	Aging Treatment	N	Air Voids (%)	Fracture Energy (J/m²)	Slope (kN/mm)	L_{75} (mm)	CT Index		
			Avg.	Avg.	Avg.	Avg.	Avg.	St. Dev.	CV (%)
Method A	Standard	5	7.1	7,352	12.328	2.459	10.0	2.6	25.6
	Alternative	5	7.1	7,792	11.670	2.753	12.8	4.1	32.3
Method B	Standard	6	6.9	8,377	10.371	2.925	16.5	4.3	26.1
	Alternative	6	6.9	8,153	10.224	2.666	14.5	3.2	22.2
Method C	Standard	6	6.9	7,708	12.280	2.457	10.4	0.9	8.7
	Alternative	7	6.9	7,873	15.300	2.593	9.1	1.6	17.9
Method D	Standard	6	6.9	8,604	9.747	2.914	17.5	2.8	16.1
	Alternative	6	7.0	8,666	9.793	2.894	17.5	3.7	21.3
Method E	Standard	5	7.3	7,945	12.515	2.524	10.9	2.3	20.7
	Alternative	4	7.2	7,823	13.109	2.373	9.6	1.6	16.3

Table A3. CT Index – Statistical Summary - Mix 3 (TN Marshall – 12.5 mm NMAS – 15% RAP - PG 67-22 + RA/WMA)

R121 Aging Method	Aging Treatment	N	Air Voids (%)	Fracture Energy (J/m^2)	Slope (kN/mm)	L_{75} (mm)	CT Index		
			Avg.	Avg.	Avg.	Avg.	Avg.	St. Dev.	CV (%)
Method A	Standard	6	7.2	8,024	7.470	3.121	23.0	5.4	23.6
	Alternative	6	7.2	7,964	7.520	2.923	20.7	1.9	9.2
Method B	Standard	6	7.1	7,968	8.952	3.099	19.0	4.6	24.4
	Alternative	7	6.8	8,202	8.679	3.056	19.5	3.1	15.8
Method C	Standard	6	7.2	7,384	13.273	2.470	9.4	1.4	15.5
	Alternative	7	7.0	7,804	12.804	2.709	11.3	3.0	26.6
Method D	Standard	6	6.5	8,611	8.975	3.518	22.8	4.7	20.5
	Alternative	6	6.5	8,596	8.541	3.467	24.4	7.8	31.9
Method E	Standard	5	6.7	7,463	9.339	2.630	14.5	3.6	24.6
	Alternative	6	6.6	8,178	9.533	2.908	16.7	2.2	13.2

Table A4. CT Index – Statistical Summary - Mix 4 (MN Superpave – 12.5 mm NMAS – 17% RAP - PG 58V-34 + Wet Plastic)

R121 Aging Method	Aging Treatment	N	Air Voids (%)	Fracture Energy (J/m²)	Slope (kN/mm)	L_{75} (mm)	CT Index		
			Avg.	Avg.	Avg.	Avg.	Avg.	St. Dev.	CV (%)
Method A	Standard	6	6.6	6,150	1.985	5.008	104.5	13.8	13.2
	Alternative	6	6.6	6,131	1.962	4.970	103.8	6.9	6.7
Method B	Standard	6	6.9	6,734	2.172	5.124	107.4	20.7	19.2
	Alternative	6	7.0	6,655	2.304	5.096	99.0	15.0	15.1
Method C	Standard	7	6.6	7,541	3.385	4.655	71.7	15.7	21.9
	Alternative	7	6.5	7,479	3.081	4.734	78.4	15.7	20.0
Method D	Standard	7	6.9	6,521	2.217	5.005	98.7	11.0	11.1
	Alternative	7	6.9	6,596	2.413	4.933	90.7	10.2	11.2
Method E	Standard	7	7.3	6,797	2.872	4.731	76.6	13.2	17.2
	Alternative	7	7.1	6,881	3.045	4.519	70.2	14.4	20.6

Table A5. CT Index – Statistical Summary - Mix 5 (OH Marshall – 9.5 mm NMAS – 10% RAP - PG 64-22)

R121 Aging Method	Aging Treatment	N	Air Voids (%)	Fracture Energy (J/m²)	Slope (kN/mm)	L_{75} (mm)	CT Index		
			Avg.	Avg.	Avg.	Avg.	Avg.	St. Dev.	CV (%)
Method A	Standard	6	7.0	8,213	2.296	5.347	129.1	23.0	17.8
	Alternative	6	7.0	8,198	2.434	5.638	127.8	17.0	13.3
Method B	Standard	6	6.7	8,928	3.183	5.062	96.3	15.8	16.5
	Alternative	7	6.9	9,196	3.040	5.143	107.2	28.5	26.6
Method C	Standard	6	7.2	8,892	4.739	4.548	57.7	8.4	14.6
	Alternative	7	7.2	8,717	4.252	4.480	61.6	8.6	13.9
Method D	Standard	7	6.9	8,354	3.137	4.957	89.0	11.9	13.3
	Alternative	7	7.1	8,494	3.125	5.088	93.9	17.6	18.8
Method E	Standard	6	7.2	9,076	3.475	5.082	93.8	26.9	28.7
	Alternative	7	7.0	8,818	3.872	4.823	74.3	14.3	19.3