

STORAGE OF ASPHALT CONCRETE

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The effect of asphalt concrete storage on asphalt cement properties and on the variability of gradation and asphalt content was determined. One mix stored in inert gas and 2 stored in normal atmospheres (all for 18 hours) were sampled before and after storage. In addition to these, 1 stored for 48 hours in an inert gas and another stored for 24 hours in a normal atmosphere were sampled solely to determine changes in asphalt cement properties. Four mixes were resampled from pavements after 1 year for further comparison of properties of asphalts from stored and control mixes. Properties of asphalt cement extracted from fine mixes were not altered by storage in either inert gas or normal atmospheres. Coarse mixes stored in normal atmospheres hardened significantly. For the 4 mixes resampled after 1 year in pavements, all initial similarities and differences were maintained. Gradation variability of all mixes, both fine and coarse, was increased by storage. Fine mix cores taken shortly after construction, however, show stored mix to be no more variable than mix directly from the pug mill.

●THE FLEXIBILITY of operation and economic benefits accorded by asphalt concrete storage bins have led to a marked increase in their use. With this have come numerous types of facilities manufactured for storing asphalt concrete. This combination of increased use and varying facilities has generated concern about the effects of storage on asphalt concrete gradation, asphalt content, and asphalt cement properties. Several studies have been initiated to determine the effects of storage on mix and asphalt characteristics.

Many factors may influence the effects of storage on asphalt concrete. Table 1 gives some and the mix component they might affect. A number of investigators have attempted to determine the significance of various combinations of these factors. However, because of the variety of possible combinations, no single study gave definitive answers to all questions.

The effects of storage fall into 2 main areas—asphalt cement and gradation (asphalt content included). Table 2 gives the correspondence between studies that have dealt with measurement of change in asphalt cement characteristics. Methods of sampling, sample sizes, and numbers of samples differed from study to study.

Tuttle (1) concluded that asphalt cement hardens significantly if asphalt concrete is stored in the temperature range of 250 to 350 F (121.1 to 162.8 C) for prolonged periods; neither segregation nor asphalt migration was investigated. Middleton, Goodknight, and Eaton (2) stored fine-graded asphalt concrete for 4 days, sampling the mix periodically to the point of final discharge from the storage bin. Although a marked change in the asphalt cement occurred during mixing in the pug mill, negligible change resulted from storage. Again, segregation and asphalt migration were not specifically studied, although past problems with asphalt migration were cited, which led to regular use of a silicone additive. Thus, silicone was incorporated into their work not to prevent oxidizing but to prevent nonuniform asphalt content. Pavements placed with mix from Middleton, Goodknight, and Eaton's study and with mix placed at the same time but not subjected to storage were cored after 1 year in service (3). No significant difference was found between asphalt cement penetrations from the 2 sets of cores; both pavements had hardened approximately 20 penetration points since the original sampling.

Table 1. Factors affecting hot-mix storage.

Factor	Mix Property Influenced		
	Gradation Variability	Asphalt Content Variability	Asphalt Cement Consistency
Storage system			
Type of loading device	/	/	
Bin shape	/	/	
Presence or absence of insulation and/or heating system			/
Normal or inert atmosphere			/
Asphalt concrete mix			
Gradation and asphalt content	/	/	/
Composition and inherent properties of asphalt cement		/	/
Presence or absence of silicone or other antioxidant		/	/
Situation-specific variables			
Duration	/	/	/
Temperature		/	/

Table 2. Effect of storage on asphalt cement.

Reference	Bin			Storage Duration (hours)	Additive	Gradation	Asphalt Content (per-cent)	Asphalt Penetration Grade ^a	Decrease in Asphalt Cement Penetration ^b (percent)
	Description	Atmosphere	Temperature (deg F)						
1	Fully insulated, hot-oil heated, cylindrical silo	Normal	300	17	None	Fine	6.5	85-100 (60)	38
				66				85-100 (57)	39
				19				85-100 (78)	22
				66				85-100 (60)	25
2	Fully insulated, lower third hot-oil heated (cone), cylindrical silo	Normal	≈300	22.5	Silicone	Fine	7.5	85-100 (69)	None
				71.5					16
				95.0					3
4	Not given	Normal	Not given	24	None	Fine	≈5.0	85-100 (68)	42
				24				85-100 (74)	16
				72					49
5	Fully insulated, hot-oil heated, cylindrical silo	Normal	≈300	24	Silicone	Fine	4.9	85-100 (73)	23
				72					59
		Normal	≈300	24	None	Fine	4.9	85-100 (68)	46
				24				40-50 (29)	None
		Normal	320	72	Proprietary	Fine	4.2		None
				72					None
		Normal	≈300	24	None	Fine	4.2	40-50 (32)	None
				72					47
6	Fully insulated, hot-oil heated, oval bin	Inert	≈300	24	Silicone	Coarse	4.9	— (48)	None
				72					None
		Normal		24			5.2	— (59)	24
				72					None
		Inert		24	None	Coarse	5.0	— (55)	7
				72					23
		Normal		24			5.0	— (54)	41
				72					30
7	Fully insulated, hot-oil heated, cylindrical silo	Inert	≈300	168	None	Coarse-fine	5.4	85-100 (79)	23
8	Fully insulated, hot-oil heated, cylindrical silo	Inert	≈315	24	None	Fine	—	AC-20 (42)	25
				72					21
		Inert	≈300	24		Coarse	3.6	AC-20 (48)	19
				72					21
9	Fully insulated, hot-oil heated, cylindrical silo	Normal	—	23	—	Fine	≈5.0	— (51)	10
				47					18

Note: 1°C = 5/9 (°F - 32).

^aNumbers in parentheses are penetrations of asphalt at 77 F (25 C) extracted immediately before storage.^bChanges in penetration measured as percent decrease from penetration after pug mill mixing but before bin loading; all values are for penetrations at 77 F (25 C).

Table 3. Storage installations sampled.

Installation	Year	Bin			Atmosphere	Temperature (deg F)	Loading Device	Gradation ^a	Asphalt Content (per-cent)	Asphalt Grade	Duration (hours)
		Num-ber	Description	Capacity							
1	1971	2	Fully insulated, hot-oil heated, cylindrical silo	160 tons	Inert gas	300	Slat conveyor	Fine (1A top)	6.0	85-100	18
				160 tons							
2	1972	2	Fully insulated, hot-oil heated, cylindrical silo	150 tons	Inert gas	310	Slat conveyor	Fine (1A top)	6.4	AC-20	48
				150 tons							
3	1973	2	Fully insulated, unheated, rectangular bin	200 tons	Normal	300	Skip hoist	Fine (1A top)	6.2	AC-20	24
4 ^b	1971	2	Fully insulated, unheated, rectangular bin	140 tons	Normal	275	Skip hoist	Coarse (1A binder)	4.5	85-100	18
				180 tons							
5 ^b	1971	2	Fully insulated, unheated, rectangular bin	140 tons	Normal	275	Skip hoist	Coarse (1A base)	3.7	85-100	18
				180 tons							

Note: 1°C = 5/9 (°F - 32). 1 U.S. ton = 0.907 metric ton.

^aNo additives are used. New York State specifications are given in parentheses.^bTwo mixes sampled at different times at the same location.

Vallerga and White (4) attempted to assess the merits of silicone as an antioxidant during storage. They reported that the hardening rate was significantly decreased by adding silicone. In cases with and without silicone there was no asphalt cement migration or mix segregation.

Foster (5) also found silicone to be a means of extending storage time. He stated nothing conclusive about segregation and migration; he found them to have occurred in some of his investigations but not in others. Another study by Foster (6) concerned the effects of an inert gas atmosphere on storage of coarse mixes. A combination of a silicone additive and inert gas resulted in no change in asphalt cement penetration after 3 days of storage. Even without silicone, however, inert gas provided a significant improvement over normal atmosphere in preventing asphalt hardening. Segregation and changes in asphalt content occurred, but asphalt content variations were shown to be related to variations in mix gradation and were attributed to segregation.

Two other studies involving inert gas systems were conducted by Parr and Brock (7) and Kandahl and Wenger (8). In neither case was silicone present. Parr and Brock found a statistically significant decrease in asphalt cement penetration after 7 days of storage. They stated, however, that the percent of retained penetration after storage still conformed to many thin-film-oven-loss test specifications. Segregation within trucks occurred as the mix was unloaded from the bin. Kandahl and Wenger found that both fine and coarse mixes hardened at similar rates. After 72 hours, each experienced a 21 percent increase in penetration. They also stated that only the normal variation inherent in asphalt concrete production was evident in mix gradation and asphalt content.

In a recent Louisiana study, Hearld and Lay (9) stored a fine-graded mix in a normal atmosphere and found 10 and 18 percent decreases in penetration after 1 and 2 days respectively.

Because of the large number of factors involved, no one study answered all questions involved with storage. However, several points are evident from past work. First, both inert gas and silicone can extend storage times for asphalt concrete beyond those possible with normal atmospheres and untreated asphalt cements. Second, the degree of hardening of asphalt cement is situation specific, that is, no all-encompassing statements can be made for different times and temperatures about how hard asphalts will become because of storage in various systems. Third, little work has been done to determine whether effects on asphalt cement consistency are transitory or lasting; only 1 study involved resampling a stored mix that had been in place for an extended period. Fourth, experience with mix segregation has differed from study to study; limited work has been directed toward determining whether asphalt concrete variability increased by storage is negated by the laydown process, that is, the remixing in the paver.

The objectives of the study reported here were to determine the following for each installation sampled:

1. Effect of storage on variability of aggregate gradation and asphalt content;
2. Whether increased variability that may be detected remains after stored mixes are placed and compacted;
3. Effect of storage on penetration, viscosity, and ductility of asphalt cement; and
4. Whether storage effects on asphalt cement are transitory or lasting.

The situation of storage systems available for study in New York State made choosing specific combinations of system and mix factors (the first 2 groups in Table 1) impossible. This investigation, which seeks to clarify the issue of the effects of storage on asphalt concrete, should be viewed as a replication and expansion of previous research of others.

SAMPLING AND TESTING

Storage systems were studied as they began operating on state contracts. In 1971, only 2 were available for sampling and testing. Although the number of installations in New York increased markedly beginning in 1972, only 2 more were sampled—1 in 1972, another in 1973. These installations were the only 2 both operating on state contracts and offering a combination of factors different from the 2 sampled in 1971.

All installations were studied for changes in asphalt cement properties, but only installations 1, 4, and 5 (Table 3) were studied for changes in gradation variability. For each of these 3, sampling was a 2-day operation. On the first day, mix going directly from the pug mill to the pavement was sampled from trucks immediately after discharge from the pug mill. Storage bins at each of these locations were loaded on the first day with mix sampled from the loading device before storage. On the second day the storage bin was emptied into trucks for hauling to the job site. Mix was sampled from each truck immediately after discharge from the bin; cores were taken once the mix was in place. Cores also were taken from a section of road containing mix directly from the pug mill that was placed the first day.

Installations tested only for asphalt cement properties were sampled by coring sections paved with mix that came directly from the pug mill and with mix that came out of storage bins. The numbers of samples taken from the 5 installations are given in Table 4.

All loose mix samples were of a 1-gal (3.8-dm³) size; cores were 6 in. in diameter. Cores were not quenched or packed in dry ice, but they were stored at 20 F (-6.7 C) until testing. Asphalt was extracted from all samples according to ASTM D2172-67 (Method B: trichlorethylene solvent). Asphalt cement was recovered by using the Abson method (ASTM D1856-69). Recovered asphalts were tested by using the following procedures:

1. ASTM D5-65 at 77 F (25 C) for penetration;
2. ASTM D2171-66 at 140 F (60 C) with a Cannon-Manning vacuum viscometer and ASTM D2170-67, 275 F (135 C) with a Zeitfuchs cross-arm viscometer for viscosity; and
3. ASTM D113-69 at 60 F (15.6 C) for ductility.

Aggregate was sieved according to New York State Materials Method 5.

ASPHALT CEMENT PROPERTIES

Summaries of results of tests on recovered asphalt cements are given in Tables 5 and 6 and Figure 1. Ductility results are presented as histograms because of the impossibility of computing statistics from data often reported as 100+ cm rather than as discrete values. The following hypothesis was tested for all properties given in Tables 5 and 6:

$$H_0 : \mu_{\text{stored}} \leq \mu_{\text{control}}$$

$$H_1 : \mu_{\text{stored}} > \mu_{\text{control}}$$

where μ = mean (asphalt cement property).

The t-distribution was used at the 0.01 significance level. Acceptance of the hypothesis H_0 indicates that there is no evidence showing asphalt cement to be harder after storage than from mix directly out of the pug mill. Rejection of H_0 indicates that a change has occurred—that a real difference was caused by storage.

Inert Gas

Storage of fine mixes in an inert gas atmosphere for periods of 18 and 48 hours did not significantly alter their asphalt cement properties (penetration and viscosity) when compared to a control mix placed directly from the pug mill. Although asphalt cements from both stored and control mixes increased in consistency from their original state, there is no experimental evidence to consider the stored asphalts harder. Figure 1 shows no change in ductility at 60 F (15.6 C) for the mix stored for 18 hours. After 1 year, asphalt cements can be seen to have hardened; both stored and control mixes harden at the same rate. Thus, a fine mix stored in inert gas appears to have suffered no detrimental effects. No data were generated on coarse mix storage.

Table 4. Sample size.

Installation	Loose Mix			Cores From Road	
	After Pug Mill	From Loading Device	After Storage Bin	At Construction	After 1 Year
1	72	To bin 1: 25 To bin 2: 25	72	72 (36 stored, 36 control)	30 (18 stored, 12 control)
2	—	—	—	22 (13 stored, 9 control)	20 (14 stored, 6 control)
3	—	—	—	31 (22 stored, 9 control)	—
4	75	To bin 1: 22 To bin 2: 28	75	72 (36 stored, 36 control)	30 (18 stored, 12 control)
5	75	To bin 1: 22 To bin 2: 28	75	72 (36 stored, 36 control)	19 (10 stored, 9 control)

Table 5. Asphalt cement properties in mixes stored in normal atmosphere.

Mix	Number of Samples	Penetration at 77 F ^a		Viscosity at 140 F		Viscosity at 275 F	
		Mean	Standard Deviation	Mean (poises)	Standard Deviation (poises)	Mean (centistokes)	Standard Deviation (centistokes)
Sampled at Construction							
Fine, top course, stored 24 hours							
Stored	22	40	3	6 110	1 100	625	113
Control	9	40	4	6 600	1 900	710	70
Coarse, binder course, stored 18 hours							
Stored	36	38	3	12 560	2 370	840	58
Control	34	59	6	3 830	940	520	48
Coarse, base course, stored 18 hours							
Stored	30	46	5	6 375	1 065	615	40
Control	32	63	6	2 970	770	445	45
Sampled After 1 Year in Place ^b							
Coarse, binder course, stored 18 hours							
Stored	18	35	5	17 600	5 160	970	105
Control	12	52	3	4 870	470	585	25
Coarse, base course, stored 18 hours							
Stored	10	50	5	5 250	1 475	555	75
Control	9	62	6	2 880	450	450	35

Note: 1°C = $\frac{5}{9}$ (°F - 32).^a0.1 mm, 100 g, 5 s.^bTop course placed in 1973; no data available.

Table 6. Asphalt cement properties in mixes stored in inert gas atmosphere.

Mix	Number of Samples	Penetration at 77 F ^a		Viscosity at 140 F		Viscosity at 275 F	
		Mean	Standard Deviation	Mean (poises)	Standard Deviation (poises)	Mean (centistokes)	Standard Deviation (centistokes)
Sampled at Construction							
Fine, top course, stored 18 hours							
Stored	33	56	5	2 760	325	460	28
Control	35	55	6	2 835	580	455	27
Fine, top course, stored 48 hours							
Stored	13	54	6	3 990	910	590	50
Control	9	55	1	3 320	180	555	10
Sampled After 1 Year in Place							
Fine, top course, stored 18 hours							
Stored	—	36	4	5 280	1 070	590	40
Control	—	36	4	6 255	1 000	590	33
Fine, top course, stored 48 hours							
Stored	14	46	6	5 030	1 080	655	70
Control	6	41	6	5 355	110	640	7

Note: 1°C = $\frac{5}{9}$ (°F - 32).^a0.1 mm, 100 g, 5 s.

Figure 1. Asphalt cement ductilities at 60 F at construction.

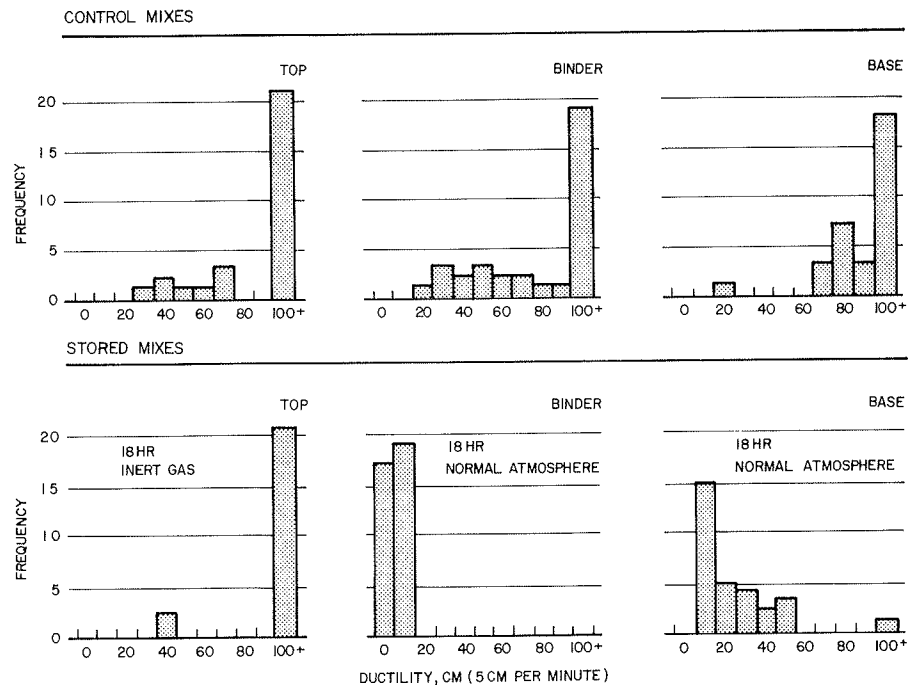


Table 7. Gradation variances on a sieve basis at different sampling locations.

Sieve	Pug Mill	Bin 1		Bin 2		In Place		Specification
		In	Out	In	Out	Pug Mill	Stored	
Fine Mix, Top Course, Cylindrical Bin								
1/2 in.	0.00	0.00	0.00	0.00	0.06	0.00	0.00	6.25
3/4 in.	9.67	4.30	7.04	3.93	29.96	9.80	9.92	12.25
1 in.	4.59	0.94	5.60	1.99	12.03	7.90	5.95	12.25
No. 20	1.51	1.65	2.10	0.32	3.31	3.88	3.24	12.25
No. 40	0.83	0.45	0.45	0.22	0.63	3.28	0.48	12.25
No. 80	0.27	0.14	0.44	0.04	0.30	0.19	1.61	4.00
No. 200	0.10	0.11	0.14	0.04	0.18	0.10	0.20	1.00
Percent AC	0.04	0.07	0.03	0.02	0.05	0.41	0.36	0.04
Total samples	70	22	35	24	34	36	36	—
Coarse Mix, Binder Course, Rectangular Bin								
1 in.	0.04	0.00	0.00	0.06	0.00	—	—	6.25
3/4 in.	6.45	7.67	8.59	4.62	15.73	—	—	9.00
1/2 in.	5.38	1.77	5.87	0.90	9.24	—	—	4.00
3/8 in.	2.56	0.32	1.34	0.45	2.94	—	—	2.25
Percent AC	0.20	0.04	0.08	0.02	0.05	—	—	0.04
Total samples	71	21	33	28	40	—	—	—
Coarse Mix, Base Course, Rectangular Bin								
1 to 2 in.	0.00	0.00	0.00	0.00	0.00	—	—	12.25
1 in.	43.96	31.93	49.41	16.82	23.16	—	—	16.00
3/4 in.	30.91	13.35	40.94	5.23	29.02	—	—	12.25
1/2 in.	7.08	6.60	13.26	2.56	7.14	—	—	9.00
3/8 in.	2.50	1.65	2.47	5.28	1.82	—	—	4.00
Percent AC	0.16	0.03	0.14	0.13	0.75	—	—	0.04
Total samples	68	22	32	28	33	—	—	—

Note: 1 in. = 25.4 mm.

Normal Atmosphere

Results of storage of a fine mix in a normal atmosphere paralleled those for storage in inert gas. After 24 hours of storage, asphalt cement extracted from a fine mix was not significantly harder than a control mix. Because stored and control mixes were both placed in 1973, they have yet to be recored to determine asphalt hardening rate.

Both coarse mixes (binder and base) stored for 18 hours in normal atmospheres experienced significant changes in asphalt cement consistency and ductility. The consistency differences have been maintained for a 1-year period, but neither has hardened as much as the fine (top course) mixes stored in inert gas. The base course, covered by both binder and top course mixes, has been protected from the effects of exposure to air and sunlight. The binder course has benefited from the cover provided by the top course. The very slow hardening rate of subsurface courses indicates that although storage caused a significant change in asphalt cement consistency, the change possibly could be tolerated. Observations of pavement condition where these mixes are in place bear this out.

VARIABILITY OF GRADATION AND ASPHALT CONTENT

Gradation variances for each of the 3 mixes sampled are given in Table 7, which also gives specification variances for each sieve and for asphalt content. Specification tolerances are based on 2 standard deviations as determined in previous studies of mix variability in New York State. The tolerances were halved, then squared, to determine the specification variances given in Table 7.

Mean gradations can be found in Table 8. No inferences were attempted about the effect of storage through use of the mean values. If sampling of the storage process is done to characterize all material entering and leaving a bin, mean comparisons should always result in statistical equality. When statistically significant differences in mean values are found, either of the following has happened: The aggregate has undergone some physical change (degradation), or more likely, sampling at either the loading or discharge points (or both) was inadequate to characterize the material in question.

Mean comparisons, therefore, do have some value because they can indicate the adequacy of sampling procedures. However, if the purpose is to compare all material before storage to all after storage, variability should be considered.

A multivariate approach was used to compare gradation variability at different points (10). Covariance matrices were computed at each production point given in Table 7 (except the pug mill) and compared as follows:

$$H_0 : \Sigma \text{ into bin} \geq \Sigma \text{ out of bin}$$

$$H_1 : \Sigma \text{ into bin} < \Sigma \text{ out of bin}$$

where Σ = covariance matrix (overall gradation).

In addition, for top course mix, in-place comparisons were made between pug mill and stored mixes.

Asphalt content variability was compared using the univariate F-test as follows:

$$H_0 : \sigma^2 \text{ into bin} \geq \sigma^2 \text{ out of bin}$$

$$H_1 : \sigma^2 \text{ into bin} < \sigma^2 \text{ out of bin}$$

where σ^2 = variance (asphalt content). Both covariance and variance comparisons used the F-distribution at the 0.01 significance level.

All mixes—fine and coarse—changed in overall gradation variability because of the storage process. For the fine mix (top course) the greatest change was in $\frac{1}{4}$ - and $\frac{1}{8}$ -in. (6- and 3-mm) material leaving the bin. The 2 coarse mixes were most affected on the $\frac{1}{2}$ - and $\frac{1}{4}$ -in. (13- and 6-mm) materials. The 1 additional gradation comparison, between in-place fine mixes stored and direct from the pug mill, showed no difference in

Table 8. Gradation statistics.

Sieve	Pug Mill	Into Bin 1	Out of Bin 1	Into Bin 2	Out of Bin 2	Pug Mill in Place	Stored in Place
Top Course							
1/2 in.							
Mean	99.94	99.99	99.99	99.99	99.89	99.99	100.00
Standard deviation	0.08	0.02	0.02	0.01	0.25	0.00	0.00
3/4 in.							
Mean	74.03	75.50	75.42	77.30	72.38	78.24	78.48
Standard deviation	3.11	2.07	2.65	1.98	5.47	3.13	3.15
1 in.							
Mean	49.15	50.67	50.62	51.24	48.08	51.96	53.12
Standard deviation	2.14	0.97	2.37	1.41	3.47	2.81	2.44
No. 20							
Mean	30.77	30.37	30.77	32.42	30.06	31.05	30.95
Standard deviation	1.23	1.28	1.45	0.57	1.82	1.97	1.80
No. 40							
Mean	14.73	14.75	14.25	15.32	14.48	15.90	16.56
Standard deviation	0.91	0.67	0.67	0.46	0.79	1.81	0.69
No. 80							
Mean	3.27	3.65	3.27	3.38	3.15	4.44	5.01
Standard deviation	0.52	0.37	0.67	0.21	0.55	0.44	1.27
No. 200							
Mean	1.93	2.26	1.93	2.00	2.18	2.62	2.91
Standard deviation	0.31	0.33	0.37	0.20	0.43	0.31	0.45
Percent AC							
Mean	6.17	6.16	6.10	6.12	5.93	6.53	6.40
Standard deviation	0.21	0.26	0.17	0.15	0.23	0.64	0.60
Total samples	70	22	35	24	34	36	36
Binder Course							
1 in.							
Mean	99.98	100.00	100.00	99.92	100.00	—	—
Standard deviation	0.19	0.00	0.00	0.25	0.00	—	—
3/4 in.							
Mean	61.30	65.12	60.69	62.42	63.32	—	—
Standard deviation	2.54	2.77	2.93	2.15	3.97	—	—
1/2 in.							
Mean	25.11	24.19	28.23	24.04	24.24	—	—
Standard deviation	2.32	1.33	2.42	0.95	3.04	—	—
3/8 in.							
Mean	15.60	17.70	18.21	17.75	18.03	—	—
Standard deviation	1.60	0.57	1.16	0.67	1.71	—	—
Percent AC							
Mean	4.30	4.42	4.42	4.40	4.59	—	—
Standard deviation	0.14	0.21	0.28	0.14	0.23	—	—
Total samples	71	21	33	28	40	—	—
Base Course							
1 to 1/2 in.							
Mean	100.00	100.00	100.00	100.00	100.00	—	—
Standard deviation	0.00	0.00	0.00	0.00	0.00	—	—
1 in.							
Mean	59.68	66.56	64.18	64.21	63.77	—	—
Standard deviation	6.63	5.65	7.03	4.10	4.81	—	—
3/4 in.							
Mean	23.23	33.72	31.47	32.35	31.08	—	—
Standard deviation	5.56	3.65	6.40	2.29	5.39	—	—
1/2 in.							
Mean	11.89	18.49	19.13	16.16	16.57	—	—
Standard deviation	2.66	2.57	3.64	1.60	2.67	—	—
3/8 in.							
Mean	9.93	11.92	12.68	8.79	8.30	—	—
Standard deviation	1.58	1.28	1.57	2.30	1.35	—	—
Percent AC							
Mean	3.13	3.46	3.63	3.44	3.80	—	—
Standard deviation	0.40	0.17	0.39	0.37	0.50	—	—
Total samples	68	22	32	28	33	—	—

Note: 1 in. = 25.4 mm.

overall variability. Apparently, the construction procedures produced enough remixing of material to counteract any variability increase caused by storage of the fine mix.

Asphalt content variability comparisons were of questionable value when the changes in gradation were found. Although changes in asphalt content variability occurred in 2 cases (binder from bin 2, base from bin 1), past research has shown that such changes may result from variations in gradation (6). Therefore, no conclusions were reached about the effect of storage on variations in asphalt content.

Gradation variability data were analyzed in 1 other manner. Comparisons were made to the variability allowed by New York specification tolerances rather than to overall variability between production points:

$$H_0 : \sigma^2 \text{ mix} \leq \sigma^2 \text{ specification}$$

$$H_1 : \sigma^2 \text{ mix} > \sigma^2 \text{ specification}$$

where $\sigma^2 \equiv$ variance (sieve).

All comparisons were done on a sieve-by-sieve basis by using the χ^2 /degrees of freedom distribution at the 0.01 significance level. This test is commonly used when comparison to a standard (in this case, mix specification) is necessary (11).

This analysis showed only the following material to have been altered beyond variability that is normally allowed by specifications:

1. A $\frac{1}{4}$ -in. (6-mm) top course out of bin 2;
2. A $\frac{1}{2}$ - and $\frac{1}{4}$ -in. (13- and 6-mm) binder out of bin 2;
3. A $\frac{1}{2}$ -in. (13-mm) base out of bin 1; and
4. A $\frac{1}{2}$ -in. (13-mm) base out of bin 2.

The 1-in. (25-mm) base course coming out of bin 1 was also beyond the variability allowed as was the 1-in. (25-mm) material going into bin 1. Therefore, nonconformance of the 1-in. (25-mm) material out of the bin did not necessarily indicate a storage effect.

CONCLUSIONS

Storage of a fine asphalt concrete mix in an inert gas atmosphere for 18 and 48 hours had no significant effect on asphalt cement consistency.

Fine asphalt concrete mix stored in a normal atmosphere for 24 hours did not experience any significant change in asphalt cement consistency.

Storage of 2 coarse asphalt concrete mixes for 18 hours in a normal atmosphere resulted in significant increases in asphalt cement consistency.

For 4 mixes resampled after 1 year in place, all initial similarities or differences between asphalt cements from control mixes (direct from the pug mill) and stored mixes persisted.

Overall gradation variability was increased by storage for both fine and coarse mixes. However, on a sieve-by-sieve basis, most material for all mixes was still within the variability permitted by specifications.

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