STUDY OF MINERAL FILLERS FOR SHEET-ASPHALT MIXTURES

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Three fillers, fly ash, hydrated lime, and quarry dust, were evaluated on the basis of simple beam tests that reflect the viscous resistance of the mix. Indian standard sand and asphalt of standard specification were used. The 10-in. long test specimen was supported on mild-steel rollers 20 cm (8 in.) apart and allowed to deflect under its own weight only. The deflection was measured at different time intervals until the specimens failed. A generalized form of creep law was used in estimation of the resistance offered by the different mixes to deformation. For a given percentage of binder with increasing concentration of filler, the resulting mix becomes stiff with decreasing deformation characteristics in the creep curve. The optimum F-A ratio is that at which creep constants are minimum. A measure of the greatest resistance is described, and fly ash is rated highest.

•AMONG the various tests available to study the flow properties of sheet-asphalt mixtures, the tensile and beam tests are most common. It is well known that the main influence of mineral fillers is on the rheological properties of asphalt mixes. An attempt is made in this study to evaluate three mineral fillers on the basis of simple beam tests that reflect the viscous resistance of the mix.

The three fillers studied were fly ash, hydrated lime, and quarry dust, which were sifted through a No. 200 mesh sieve. The fly ash contained 62 percent silica and 16 percent calcium oxide; the hydrated lime contained 60 percent calcium oxide and no silica. The quarry dust contained 93 percent silica with a trace of calcium oxide. The physical properties of the fillers are given in Table 1.

Indian standard sand was used throughout the investigation. Asphalt of 80 to 100 penetration grade, conforming to The Asphalt Institute's specification for 85 to 100 paving asphalt, was used as a binder, and its percentage was kept at 9 percent for all mixes, which is within the recommended limits of The Asphalt Institute's specifications (1).

The test specimens were 10 in. long, 2 in. wide, and 1 in. deep and were similar to those used by Lee and Rigden in their tensile strength studies (2). The design of the asphalt mixture was based on the recommendations made in The Asphalt Institute manual series. The hot mix was spread evenly inside the hot mold, and a static load of 12 tons was applied for 2 min. The specimens were air-cured for 7 days before test. Curing and testing was done at 30 ± 1 C. The bulk density of the test specimens using the three types of fillers is given in Table 1.

The test specimen was simply supported on mild-steel rollers 20 cm (8 in.) apart and allowed to deflect under its own weight only. The central deflection was measured at different time intervals until the specimen failed. The deflection was measured every 6 sec during the first minute and thereafter every ½ min. From the measured deflections, the maximum tensile strains were computed; the derivation of this relation is given in the Appendix. Typical strain-time curves are shown in Figures 1, 2, and 3.

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Table 1. Physical properties of the fillers and test beam.

Filler	Specific Gravity	Bulk Density in Toluene (g/cc)	Specific Surface (cm^2/g)	Voids in the Dry Compacted Filler	Bulk Density of Test Beam[a] (lb/ft^3)
Fly ash	2.13	0.500	4,184	0.520	116 to 119
Hydrated lime	2.56	0.220	11,760	0.644	112 to 115
Quarry dust	2.67	0.833	1,959	0.400	125 to 131

[a] 10- by 2- by 1-in. beam.

Figure 1. Typical experimental creep curve, fly ash.

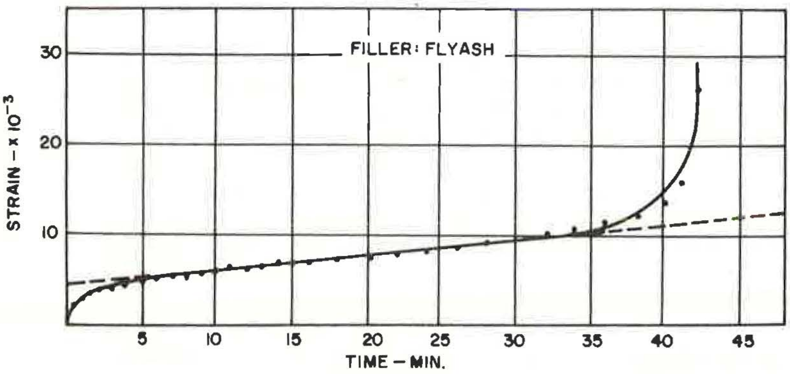


Figure 2. Typical experimental creep curve, hydrated lime.

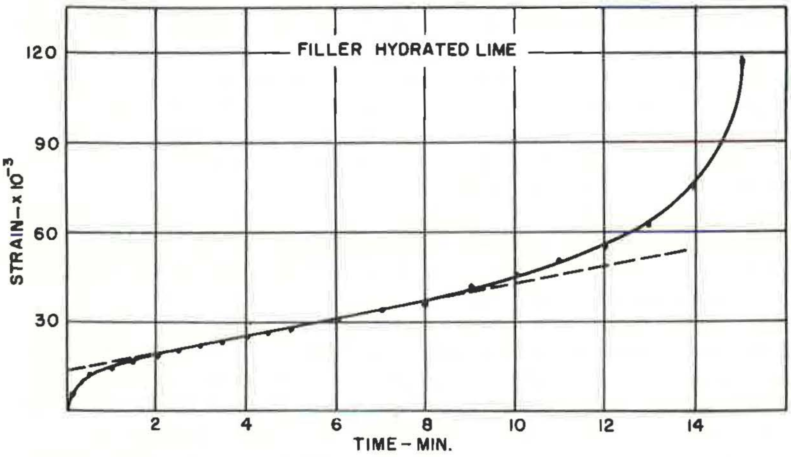
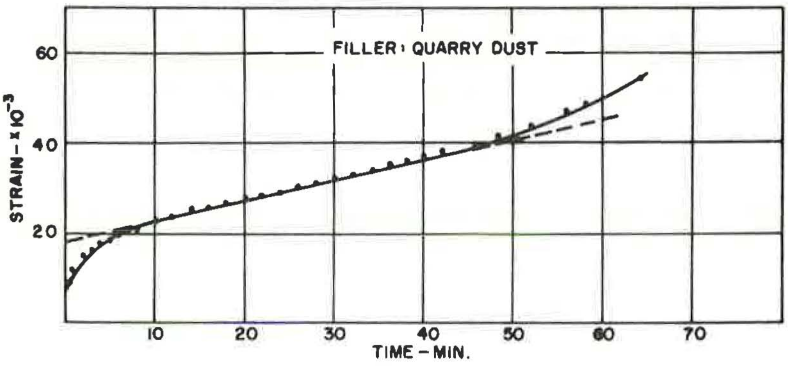


Figure 3. Typical experimental creep curve, quarry dust.



EVALUATION OF MINERAL FILLERS FROM AN ANALYSIS OF CREEP DEFORMATION

Based on Seth's (3) generalized strain measure, Rao (4) has developed a generalized form of creep law that deals with the strains in the initial transient stage and the subsequent steady-state deformation. The total strain ϵ at any time t can be expressed as

$$\epsilon = Kt_s^{1/m} + \alpha(t - t_s)$$

where K and 1/m are material constants characterizing the transient state deformation, t_s is time for limiting transient strain, t is total time, and α is constant rate of strain in the steady-state deformation.

The values of α, K, and 1/m, derived from the experimental curves, give a measure of the resistance offered by the different mixes to deformation. The strains during the transient state of deformation are plotted on log-log scale in Figures 4 through 6. The straight-line relation seems to justify the use of the transient-state creep relation given in the preceding equation. The material constants K and 1/m computed from Figures 4 through 6 for different filler-asphalt (F-A) ratios are given in Tables 2 through 4. The variation of these material constants with different F-A ratios for the three fillers investigated is shown in Figures 7 through 9.

The material constants K and 1/m indicate definite trends with different F-A ratios, and their critical values are obtained for the optimum F-A ratio. An analysis of the data shows that the logarithmic law of transient creep holds good in the first minute, after which the steady-state creep conditions tend to dominate. Furthermore, the transient condition is not ordinarily a critical factor in the design, as it is for the comparative evaluation of the fillers. The minimum rate of strain during the steady-state creep α was considered more significant and was taken as a measure of the viscous resistance of the mix to deformation.

In general, it can be seen that, for a given percentage of binder with increasing concentration of filler, the resulting mix becomes stiff with decreasing deformation characteristics in the creep curve. The F-A ratio at which these creep constants are minimum can be taken as the optimum F-A ratio for the particular filler. These optimum values are 1.01, 0.425, and 1.33 for fly ash, hydrated lime, and quarry dust respectively. The filler having the lowest among the minimum values of α can be considered to exhibit the greatest resistance. Accordingly, the fillers may be rated in the order of fly ash, hydrated lime, and quarry dust (from the standpoint of resistance to deformation under the steady-state condition). This conclusion also appears to be justifiable from physical properties of the filler as given in Table 1.

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Table 2. Material constants with varying F-A ratios, fly ash.

Filler by Weight of Total Mix (percent)	F-A Ratio by Volume	Material Constants		
		$\alpha \times 10^{-6}$	$k \times 10^{-4}$	1/m
12	0.62	5.52	104.0	0.532
14	0.72	4.53	83.0	0.445
16	0.83	0.335	25.0	0.354
18	0.91	0.083	7.5	0.306
20	1.01	0.046	5.4	0.384
22	1.12	0.133	13.2	0.268
24	1.24	2.74	28.0	0.384

Table 3. Material constants with varying F-A ratios, hydrated lime.

Filler by Weight of Total Mix (percent)	F-A Ratio by Volume	Material Constants		
		$\alpha \times 10^{-6}$	$k \times 10^{-4}$	1/m
6	0.26	33.30	138	0.589
8	0.35	0.83	82	0.466
10	0.43	0.33	36	0.296
12	0.52	0.71	32	0.306
16	0.68	5.00	14	0.374

Table 4. Material constants with varying F-A ratios, quarry dust.

Filler by Weight of Total Mix (percent)	F-A Ratio by Volume	Material Constants		
		$\alpha \times 10^{-6}$	$k \times 10^{-4}$	1/m
26	1.076	7.64	135	0.5095
28	1.160	2.77	100	0.4142
30	1.240	2.36	58	0.4986
32	1.320	1.45	44	0.4987
38	1.570	7.33	73	0.5206

Figure 4. Log time and strain during transient creep, fly ash.

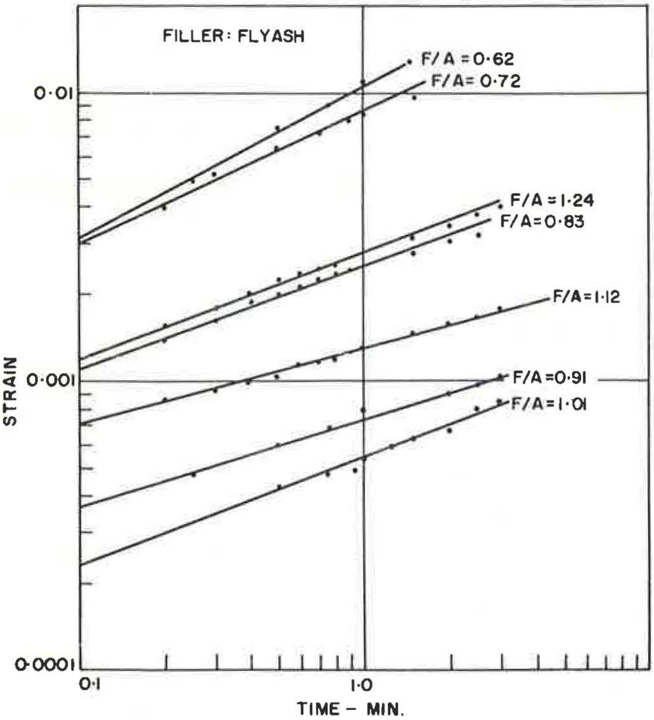


Figure 5. Log time and strain during transient creep, hydrated lime.

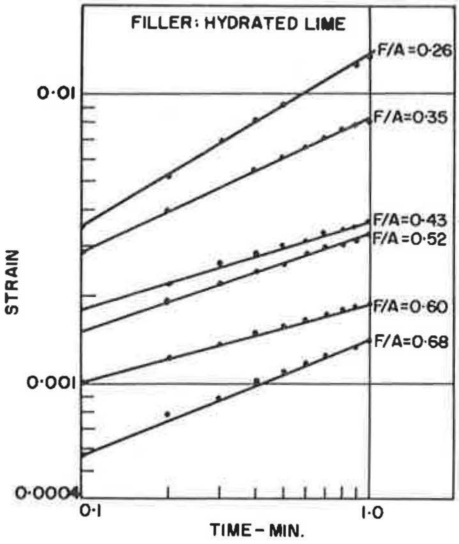


Figure 6. Log time and strain during transient creep, quarry dust.

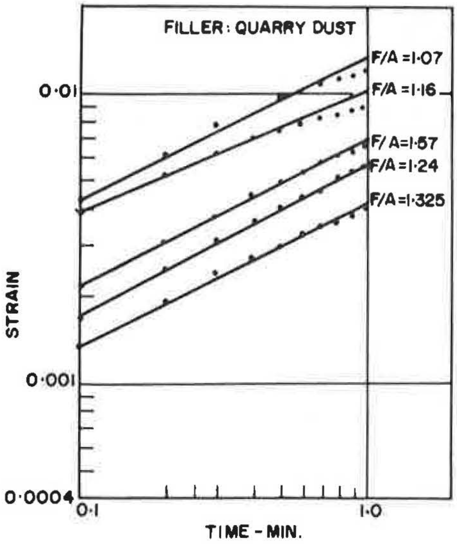


Figure 7. Relation between K under transient creep conditions and F-A ratio for different fillers.

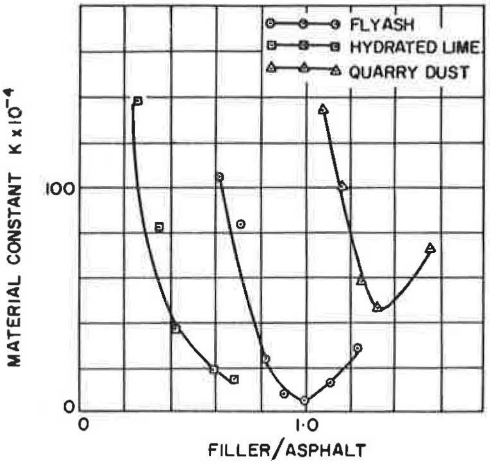


Figure 8. Relation between l/m under transient creep conditions and F-A ratio for different fillers.

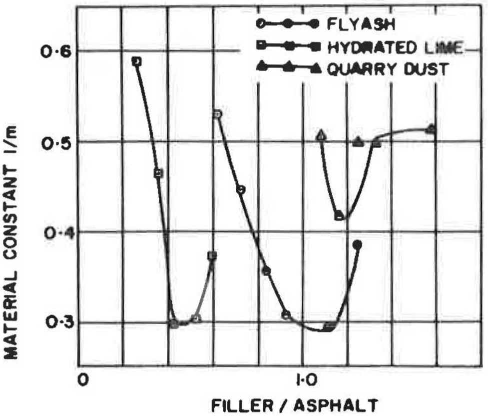
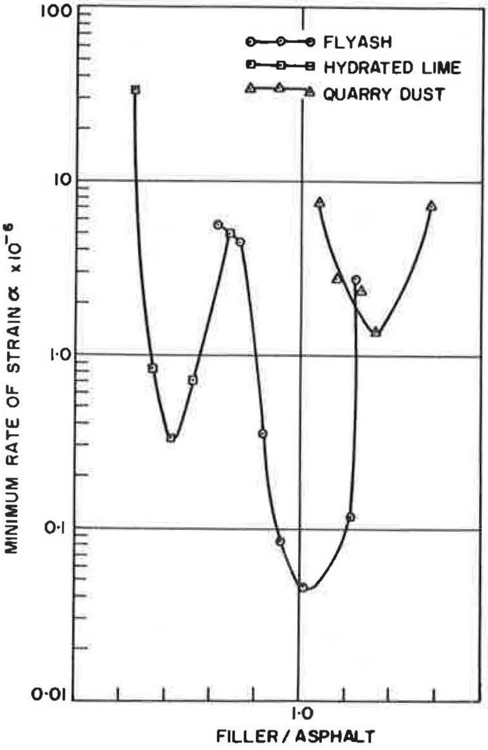


Figure 9. Relation between minimum rate of strain and F-A ratio for different fillers.



APPENDIX

DERIVATION OF MAXIMUM TENSILE STRAINS

From the theory of simple bending of beams, which does not follow Hooke's law (5),

$$\epsilon = \frac{y}{R}$$

where

ϵ = strain of the fiber considered,
y = depth of the fiber considered below the neutral axis, and
R = radius of curvature of the neutral axis of the deflected beam.

Secor and Monismith (6) have observed that the neutral axis is above the geometrical axis; Lee and Markwick (7) have experimentally verified that the neutral axis is very near the top of the deflected beam. Hence, the tensile strain of the bottom fiber can be approximately taken as

$$\epsilon \approx \frac{h}{R}$$

where h = the depth of the beam. The actual strain shall be less than the estimated strain, depending on the position of the neutral axis above the geometrical axis of the beam.

From the geometry of the deflected beam, assuming it to be an arc of a circle, it is evident that

$$R_b = L^2/8\,\delta$$

where

R_b = radius of curvature of the bottom fiber,
L = simply supported span, and
δ = observed deflection of the bottom fiber.

Because the span is 20 cm in the present study,

$$R_b = 50/\delta$$

Because the depth of the beam is very small compared to the radius of curvature, it can be safely assumed that

$$R = R_b = 50/\delta$$

Hence,

$$\epsilon = \frac{h}{50/\delta} = \frac{h\delta}{50}$$

In about 50 specimens tested in the study, it was found that the minimum radius of curvature observed was so large in comparison with the thickness of the specimen that the error involved in the assumption $R = R_b$ was less than 2 percent.