EFFECT OF MODIFIED RECLAIMED RUBBER AND GROUND VULCANIZED RUBBER ON THE PHYSICAL PROPERTIES OF BITUMINOUS PAVEMENTS AS EVALUATED BY THE GYRATORY TESTING MACHINES

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ABRIDGMENT

•THE purpose of this research was to develop a realistic model of field conditions for an asphaltic concrete pavement. A gyratory testing machine (GTM) was modified and programmed to impart cyclic loading at temperatures encountered during hot compaction and under traffic (Fig. 1).

Generally in line with the approach suggested by Ruth and Schaub (1), using the GTM compressible air roller system, specimens were subjected to 12 revolutions at 290 F to simulate field placement and then by 200 revolutions of cyclic loading at 140 F to simulate accelerated hot weather traffic. Following the densification process, GTM shear tests were conducted. Pertinent physical properties of the mixes containing small amounts of 2 rubber additives (derived from discarded tires) were measured and compared with a control mix of straight asphalt.

MATERIALS

The bituminous mix used in this investigation was a fairly well-graded sand asphalt with ⅜-in. top size gravel aggregate. The asphalt was 85 to 100 penetration grade. Two types of dry rubber additives were used: a minus 4 mesh powdered reclaimed and a minus 20 mesh ground vulcanized rubber.

DYNAMIC RECOVERY

Rubber treatment was found to improve the ability of a bituminous mix to recover from an imposed shear strain. To demonstrate this, specimens first densified by the gyratory compaction process were subsequently subjected to gyratory loading by using the air roller at reduced pressure so that any tendencies for the specimen to experience shear strain recovery could be measured by the gyrograph. Shear strain recovery would show up as a reduction in the gyrograph band width. Typical results are shown in Figure 2.

Figure 3 shows density versus revolutions of cyclic loading (hot compaction at 290 F followed by traffic simulation at 140 F) for a straight asphalt mix and 2 rubber-treated mixes. There is a significant difference in resistance to reduction in voids between treated and untreated mixes.

Figure 4 shows the gyrographs for the cyclic loading to simulate hot weather traffic. The gyrograph for the straight asphalt or control mix progressively widens, whereas neither mix containing rubber experiences this phenomenon. Because this is a laboratory simulation of traffic, it indicates that the addition of either of these rubber additives enhances the ability of the mix to resist failure caused by rutting and shoving; i.e., the rubber additive functions as a desensitizer in this regard.

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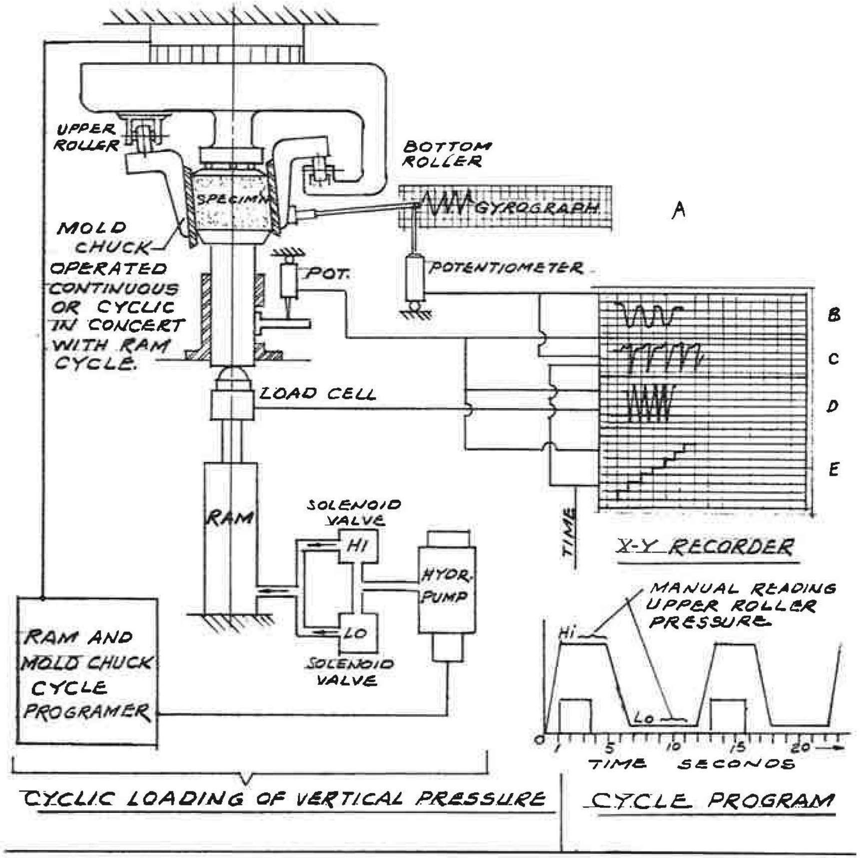
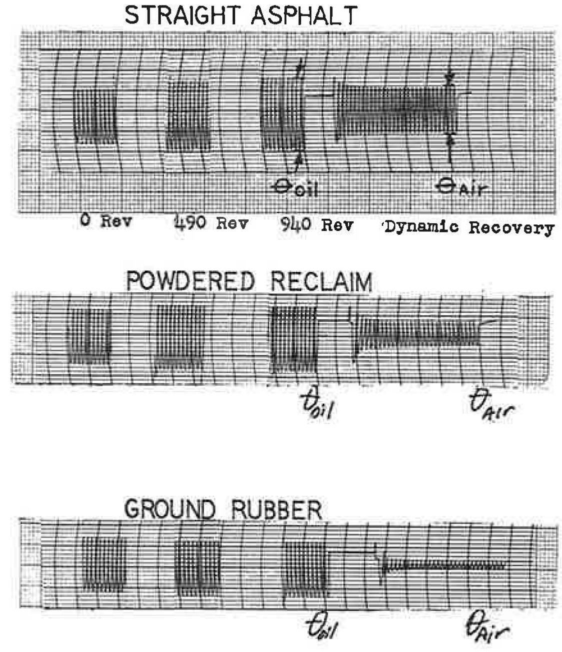


Figure 1. Schematic of GTM operation and instrumentation.



$$\text{RECOVERY INDEX} = \frac{\theta_{oil} - \theta_{Air}}{\theta_{oil}}$$

Vertical Pressure: 100 PSI
$\theta_0 = 1^\circ = 1.75\%$ (Oil Roller)
Air Roller: 10 PSIG
60 Revolutions @ 290°
940 Revolutions @ 140°
Total Binder: 7.0%

Figure 2. Gyratory compaction and dynamic recovery from continuous kneading at 140 F.

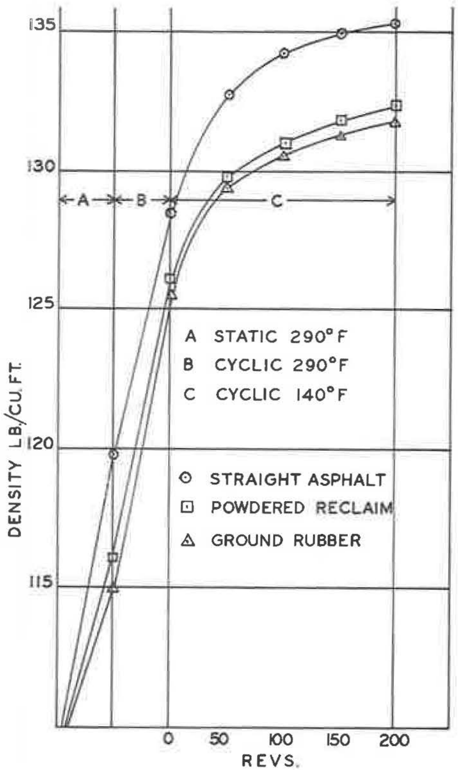


Figure 3. Density versus revolutions of cyclic loading.

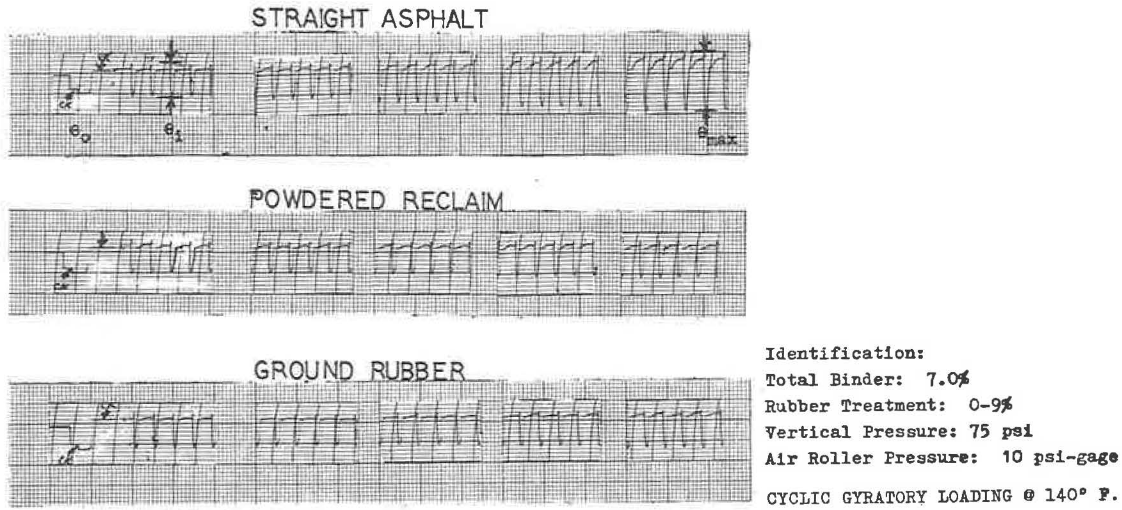


Figure 4. GTM-simulated accelerated traffic at 140 F.

Figure 5 shows composite data for the 3 mixes investigated. The stability index (θ_{max}/θ_0) for the untreated asphalt mix rises rapidly for binder contents in excess of that which coincides with the normally recommended voids for this type of mix, while the recovery index, (θ oil - θ air)/ θ oil, shows a rapid loss in value over the corresponding range. The increase in the stability index indicates increased shear deformation, while the loss in the recovery index confirms that the strain is permanent plastic yield.

By using a combination of light vertical pressure and a small gyratory angle, it was possible to generate an exudation phenomenon in the GTM so that bitumen bled from the mix. This "bleeding" test demonstrates the beneficial effects of rubber in eliminating bleeding as shown in Figure 6. The specimen on the right containing powdered reclaimed rubber showed no evidence of exudation, while the specimen on the left showed considerable bleeding. Elimination of bleeding by use of reclaimed rubber additives has been demonstrated in actual practive (2, 3).

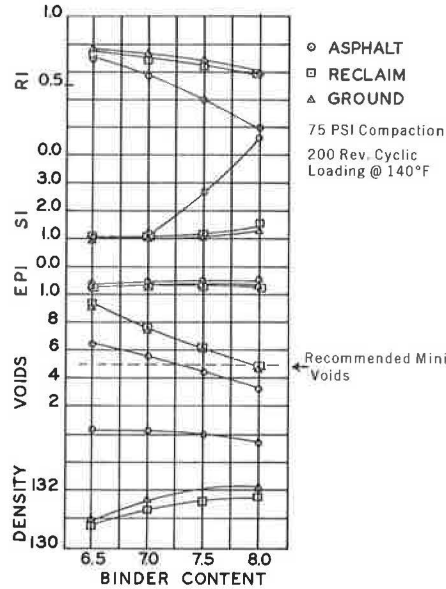
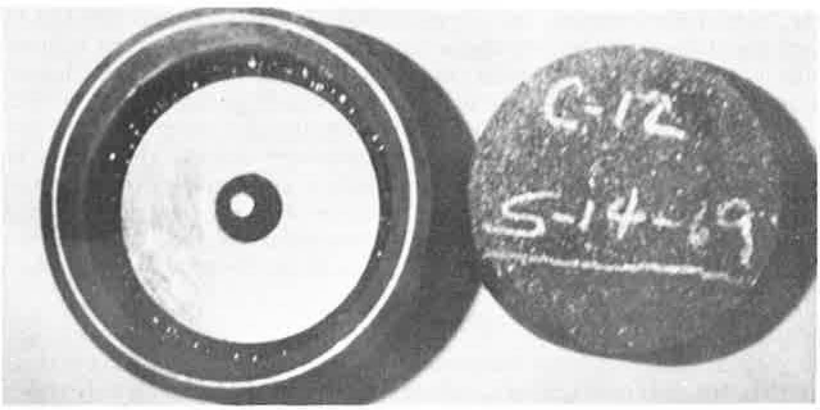


Figure 5. Binder content versus density and various indexes.

SHEAR TEST RESULTS

GTM shear was conducted on specimens subsequent to simulated hot placement and traffic compaction. In GTM shear, the matter of limited deflection is dealt with by finding the effective cohesion and internal friction values from Mohr's envelopes for various limiting degrees of shear strain. The Prandtl bearing value calculated from these values of C and ϕ thus becomes a bearing resistance associated with a limited permissible degree of shear strain that is in turn related to some limiting value of pavement deflection. Because the prime requirement in a modern pavement is a



Straight Asphalt Control　　Powdered Reclaim Treatment

Figure 6. Test for bleeding.

TABLE 1
BEARING STRENGTHS OF MIXES

Mix	Binder Content (percent)	Density	Voids	Bearing Strength		
				Ultimate	1.75 Percent Strain	3.50 Percent Strain
Straight asphalt	6.5	134.1	6.50	533	210	510
	7.0	134.1	5.63	628	182	330
	7.5	134.0	4.32	873	20	71
	8.0	133.8	3.32	878	5	38
Powdered reclaimed	6.5	130.7	9.31	324	215	640
	7.0	131.3	7.62	550	160	390
	7.5	131.6	5.76	533	140	300
	8.0	131.8	4.98	745	160	375
Ground vulcanized	6.5	130.9	9.31	380	105	283
	7.0	131.6	7.62	425	160	250
	7.5	130.8	6.79	383	150	200
	8.0	132.1	4.57	410	125	240

smooth ride for high-speed vehicles making almost astronomical numbers of passes, it then becomes necessary to set these limiting strains at low values in order to avoid creep and fatigue phenomena that may eventually manifest themselves in ruts and cracks. The authors recommend that the limiting GTM shear strain be set in the range of 1.75 to 3.5 percent. The application of these suggested limiting criteria will be discussed presently.

It was found that there is no significant difference in stress-strain properties among the various mixes at binder contents equal to or less than the optimum for the regular asphalt mix; however, there was a marked difference between treated and untreated mixes where the binder content exceeds the standard optimum. Mixes containing the powdered reclaimed rubber show higher gyratory shear values than those of the straight asphalt mix below about 4 percent strain, while the straight asphalt mix shows higher gyratory shear for strain greater than about 4 percent. As already stated, the maximum working range of deflection for pavements is considered to place the shear strain below about 3.5 percent.

PRANDTL BEARING RESISTANCE

It is evident that the ultimate bearing resistance is generally highest for the untreated mix; however, the ultimate bearing for all mixes at all binder contents is more than the requirements for any normal pavement loading (Table 1). In other words, once a pavement has experienced the 5 to 6 percent strain required to develop its shear strength, it has failed as a normal pavement. On the basis of the recommended limiting strains (1.75 to 3.50 percent), the straight asphalt mix (control) and the mix treated with powdered reclaimed rubber are about equal at 6.5 and 7.0 percent bitumen content, while the mix treated with ground vulcanized rubber is equal to or lower than the other two. On the other hand, if sufficient binder is incorporated into the mix to cause the rubber treatment to become fully effective, then the treated mixes are enhanced by the properties as discussed earlier (greater recovery and elimination of bleeding) while they still retain essentially full bearing resistance. Should a ½ to 1 percent increase in binder occur on an untreated mix (because of faulty design or poor control, as the case might be), then the Prandtl bearing resistance at this limited deformation becomes extremely small, and failure of the surface due to shoving would be imminent.

SUMMARY

The rubber-treated mixes were consistently found to show greater resistance to densification than the untreated mixes. Probably the most significant finding was that the addition of these rubber additives tends to desensitize the mix with regard to flushing and bleeding. It was found that in order for the rubber to be effective in altering physical properties, other than resistance to densification, the binder level (asphalt +

rubber additive) must be somewhat greater than the optimum for the straight asphalt mix. Another significant finding was that rubber-treated samples show improved dynamic recovery properties. Data presented suggest that the utilization of a small amount of either powdered reclaimed or ground vulcanized rubber in the mix will allow the design engineer to desensitize the mix against bleeding or shoving or both. In addition, one can apparently improve the strength of the pavement at low strain levels as well as retain the original "life" (dynamic recovery) properties of the pavement. The amount of reclaimed rubber additive required to be effective appears to be very small: in the order of one half of one percent.

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