Neoprene Bearing Pads Under Repeated Compression and Shear

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This study of neoprene bearing pads at three temperatures (primarily 0 F) and under three loading conditions was sponsored by the Pennsylvania Department of Highways and the Bureau of Public Roads. Most of the pads were of 60 durometer hardness, plain cut, and some were laminated, containing two steel shims. The loading conditions were repeated compression over a range corresponding to dead and maximum load, with some tests to 2 million load cycles; repeated alternating shear under constant vertical compression, usually to 1500 load cycles, and to ±50 percent shearing deflection; and nonrepetitive, unidirectional shear with constant vertical compression to a maximum shearing deflection of 90 percent. Surface abrasion occurred in all repeated shear tests, and raveling occurred in those at 0 F. Repeated loading in all tests at 0 F resulted in deformation of pads and marked increase in pad stiffness. The deformation rapidly vanished after thawing of the pads. Some separation of neoprene and steel shims and bending of the shims were observed in the 0 F tests. Increased vertical loads resulted in increase in shearing resistance at 0 F but appeared to have no effect at 120 F.

•THIS study (1) of neoprene bridge bearing pads was undertaken to furnish information on the behavior of the pads at several temperatures, primarily 0 F, under repeated compression, under constant compression combined with repeated alternating shear, and under constant compression combined with nonrepetitive, unidirectional shear. Fourteen pads were tested in repeated compression; 14 pairs of pads were tested under constant compression with repeated alternating shear; and 7 pairs were tested in nonrepetitive, unidirectional shear.

The pads tested in repeated compression were plain cut specimens, 5 by 30 in., mainly ⅞ in. thick, and of 60 durometer hardness. Most of the tests had a repeated load range of 600 psi to 1200 psi, at a rate of 100 cpm, and were continued to 1 million load cycles. The pads tested in repeated shear, mainly 5 by ½ by 15 in. and of 60 durometer hardness, were plain cut specimens except for a few which contained two steel shims. The constant vertical compression was usually 800 psi. The shearing loads were alternating and repetitive for deflections up to ±50 percent of the uncompressed thickness of the neoprene. The pads subjected to the nonrepetitive, unidirectional shear, termed "shear-slip," were deflected up to 95 percent of the neoprene thickness.

EQUIPMENT

All test loads were applied by hydraulic general purpose load cylinders for the compression test (Fig. 1a) and for the shear test (Fig. 2a) and actuated by a Riehle-Los fatigue testing machine. The cylinders had a static capacity of 40 to 160 kips and an

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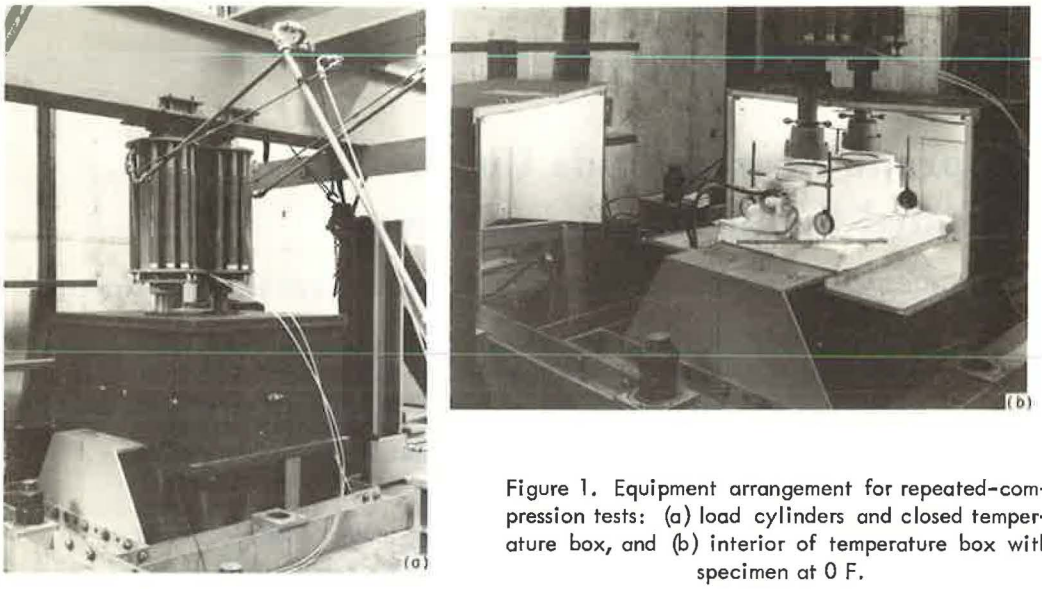

Figure 1. Equipment arrangement for repeated-compression tests: (a) load cylinders and closed temperature box, and (b) interior of temperature box with specimen at 0 F.

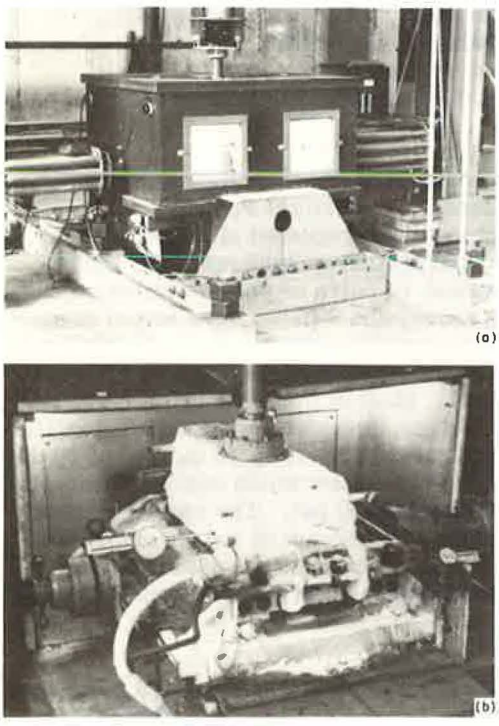

Figure 2. Equipment arrangement for repeated-shear and shear-slip tests: (a) load cylinders and closed temperature box, and (b) interior of temperature box with specimens at 0 F.

automatic load cycling rate of 100 to 1000 cpm. The magnitude of the applied loads was measured by pressure transducers in the console of the testing machine.

For the compression tests the specimen was placed between a lower loading plate and an upper loading block (Fig. 1b). In the shear tests a pair of specimens separated by a steel shear plate was placed between the lower plate and the upper block (Fig. 2b). A vertical cylinder supplied a constant compression, while two opposing horizontal cylinders applied the shear force. In all the tests, the steel surfaces in contact with the specimens were provided with an abrasive covering of medium grit emery cloth to prevent excessive slippage.

The specimens were tested in an insulated temperature box for tests at 0 F and at 120 F. Cooling of the specimens for the 0 F tests was effected by the circulation of freon coolant through channels in the lower loading plate and the upper loading block. The temperature for the 120 F tests was maintained by means of four 200-watt bulbs. The tests at room temperature were performed without the temperature box or temperature control other than that provided by the laboratory heating system.

Vertical and horizontal deflections under static loading were measured with dial

gages (visible in Figs. 1b and 2b). Deflections during repeated loading were obtained by two steel cantilever deflectometers equipped with strain gages whose strains were observed on the oscilloscope and measured with a bridge amplifier.

SPECIMENS

The specimens were of two types: plain cut neoprene pads and laminated pads, both obtained from a manufacturer approved by the Pennsylvania Department of Highways (2). The plain pads were used for all of the tests except that laminated pads were used for three repeated shear tests and three shear-slip tests. The laminated pads consisted of three ½-in. layers of neoprene, separated by and bonded to two 11-gage steel shims. The pad edges were buffed smooth to expose the edges of the shims. Information on the specimens and on test conditions is given in Table 1.

TEST PROCEDURE

Compression Tests

The specimen was placed on the test stand, and after it had attained the desired temperature, it was subjected to incremental vertical loading and the vertical deflections were observed and recorded. The repeated loading was then begun, and at various intervals the cycling was interrupted to take more static load-deflection readings. Such readings were also taken at the conclusion of the test. The specimen was then removed from the test stand, measured, and photographed. The measurements were repeated several times in order to determine the rate and extent of recovery from possible deformations.

TABLE 1

REPRESENTATIVE TEST SPECIMENS

Specimen Number	Nominal			Load			Total Cycles	Constant Vertical Compression (psi)	Maximum Shearing Deflecting (%)
	Hardness (durom.)	Thickness (in.)	Temperature (°F)	Range (psi)	Rate (cpm)	Defl. Range (%)			
(a) Repeated-Compression Tests[a]									
461002	60	½	0	450-900	200		1,000,000		
761008	60	⅞	120	600-1200	200		2,000,000		
761009	60	⅞	120	600-1200	100		1,000,000		
761007	60	⅞	72	600-1200	100-300		2,000,000		
761015	60	⅞	0	600-1200	100		700,000		
(b) Repeated-Shear Tests[b]									
461002	60	½	0		0.5	± 50	1,500		
464006	60	½	0		0.5	± 50	1,500		
L64011	60	1¾	0		0.3	± 50	1,500		
L64018	60	1¾	120		0.4	± 50	10		
464019	60	½	120		0.7	± 50	10		
(c) Shear-Slip Tests[b]									
464015	60	½	0					250	90
								500	90
								750	85
L64014	60	1¾	0					250	50
								500	85
								750	85
464019	60	½	120					250	85
								500	85
								750	85
L64018	60	1¾	120					250	90
								500	85
								750	90

[a]Compression specimens are 5 x 30 in.
[b]Shear specimens are 5 x 15 in., prefix "L" indicates laminated specimen.

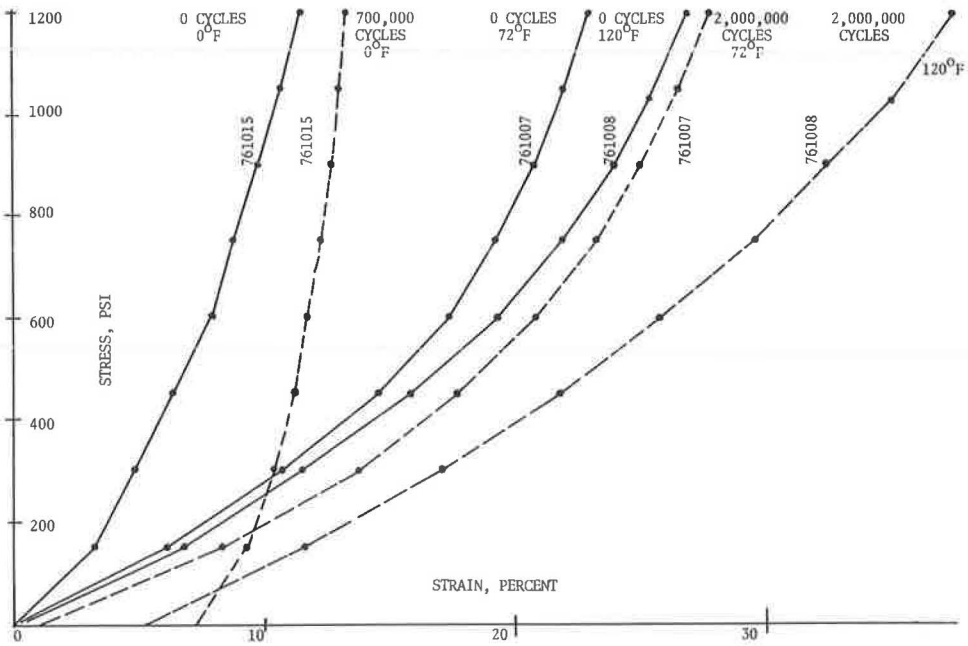

Figure 3. Stress-strain curves in repeated compression (Specimens Nos. 761007, 761008 and 761015).

Repeated Shear Tests

The pair of specimens was placed in the test position and brought to the desired temperature, and the constant compressive load applied, prior to the application of the shear loads. In the first shear tests, the automatic cycling rate of 100 cpm was used to a total

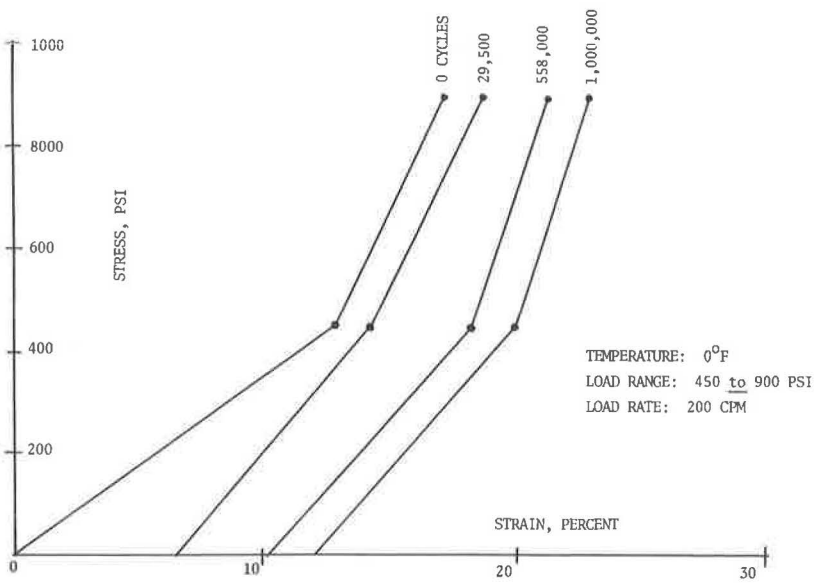

Figure 4. Stress-strain curves in repeated compression (Specimen No. 461002).

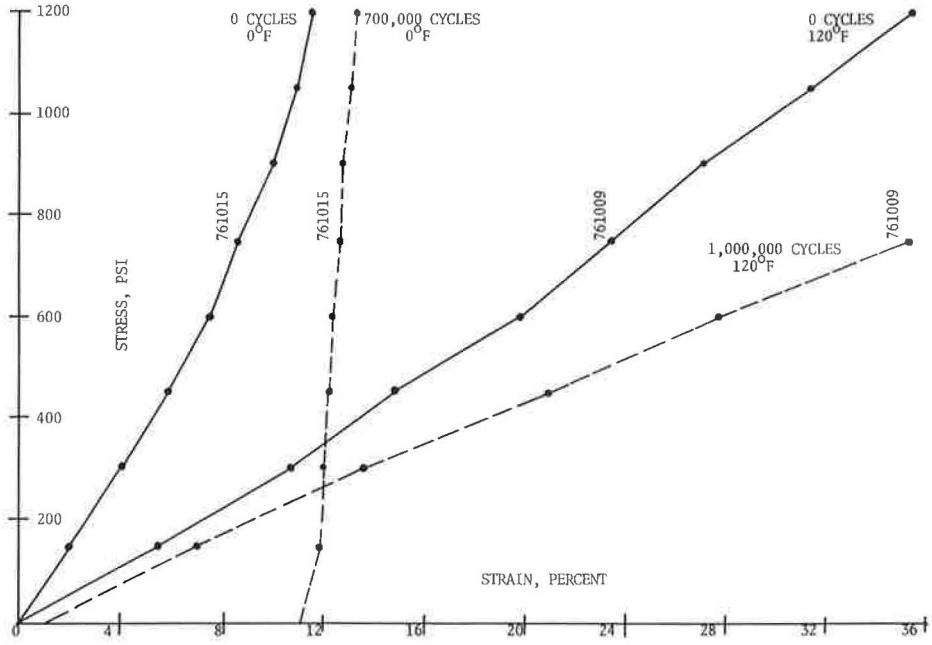

Figure 5. Lateral strains before and after repeated compression (Specimens Nos. 761009 and 761015).

of about 100,000 cycles. The heat generated at this rate, however, was so great that the rate had to be reduced. Further testing was done by manual cycling at about ½ cpm to a maximum total of 1500 cycles. It was also necessary to reduce the specimen size from the original 7 by 21 in. to 5 by 15 in. because of the large force required to deflect the larger pads at 0 F. In all shear tests, the cycling was stopped at various intervals and at the end of the test to permit static load-deflection readings.

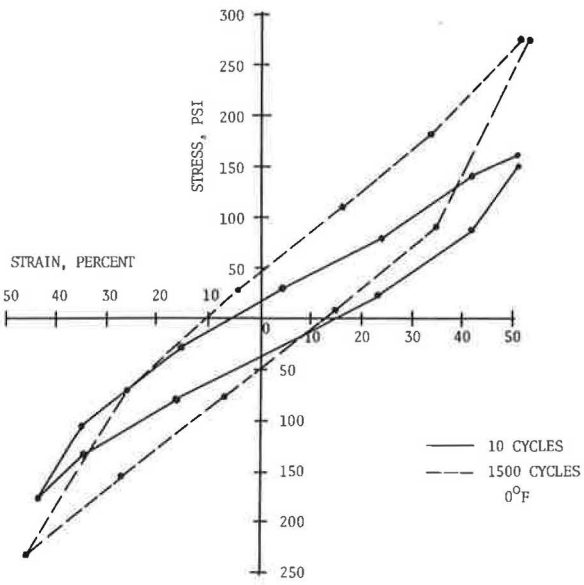

Figure 6. Stress-strain curves in repeated shear (Specimen No. 461002).

Shear-Slip Tests

The pair of specimens was placed in the same test position as for the repeated shear tests, and the constant vertical compressive load applied after the desired test temperature was reached. The shear load was then applied in increments in one direction only, and the shearing deflections and the loads were recorded at each increment. Each pair of specimens was tested for three different values of vertical compression. Specimens tested at 0 F were removed from the test apparatus and brought to room temperature for deformation recovery and recentering between changes in the vertical compression.

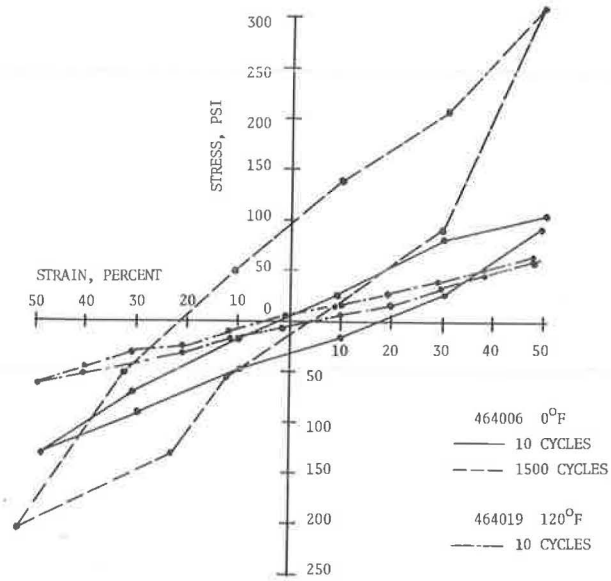

Figure 7. Stress-strain curves in repeated shear (Specimen Nos. 464006 and 464019).

DISCUSSION

Eleven specimens whose behavior is typical for all the specimens in the test program are presented in Table 1 and in the graphs. The latter represent the static stress-strain characteristics observed in the three types of tests.

Figures 3, 4, and 5 are stress-strain curves of specimens tested in repeated compression at 0, 72, and 120 F. Figures 3 and 4 show curves for vertical stresses and vertical strains. Figure 5 shows curves of vertical stresses and lateral strains, the lateral strain being the increase in pad width divided by the original pad width. In tests at the two higher temperatures, the specimens show some resiliency even after large numbers of cycles with a maximum compressive stress of 1200 psi. After repeated loading at 0 F for a much smaller number of load cycles, however, the ability of the material to deform either vertically or horizontally is almost eliminated. Specimen No. 461002 was tested to 1 million cycles in compression (Fig. 4) and then in repeated shear (Fig. 6) to a total of 1500 cycles. Specimen No. 464006, which was identical with No. 461002 except that it was not subjected to repeated compression, developed the stress-strain curve in shear shown in Figure 7. It is apparent that the 1 million compression cycles had not appreciably altered the shear stress-strain characteristics, if the general slope of the four loops after 1500 cycles is considered. The plain cut specimens did exhibit a characteristic not found in the laminated specimens. This is an apparent increase in the stiffness with the repetition of shear loading. In Figures 6 and 7, the general slope of the loops from 10 to 1500 cycles has increased, whereas in Figure 8 for a laminated specimen, 164001, the slope is about the same for 10 and 1500 cycles. The shear-slip stress-strain curves for plain cut, and laminated specimens are shown in Figures 9 and 10, respectively. An increase in vertical pressure resulted in an increase in the horizontal stress at 0 F, but in neither type of specimen did this occur at 120 F. When the specimens were deflected at 0 F, an initial force was required to attain the fixed deflection, and a "final" and lesser force was required

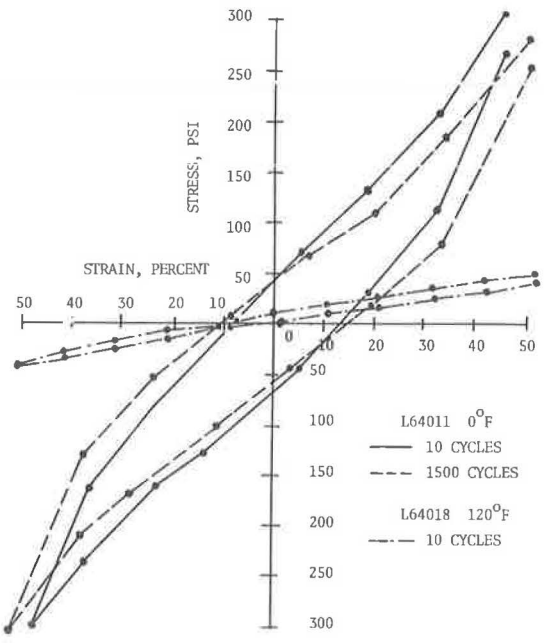

Figure 8. Stress-strain curves in repeated shear (Specimens Nos. L64011 and L64018).

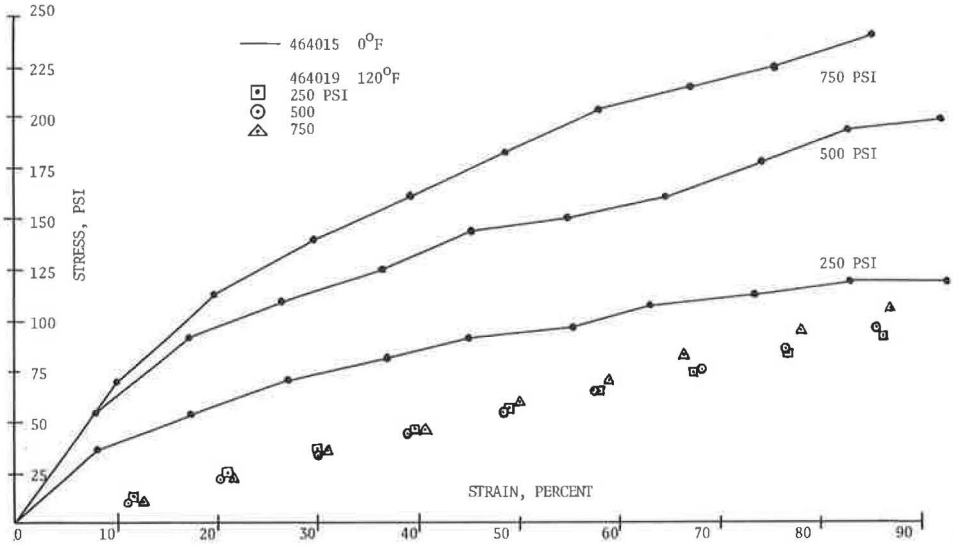

Figure 9. Stress-strain curves in shear-slip (Specimens Nos. 464015 and 464019).

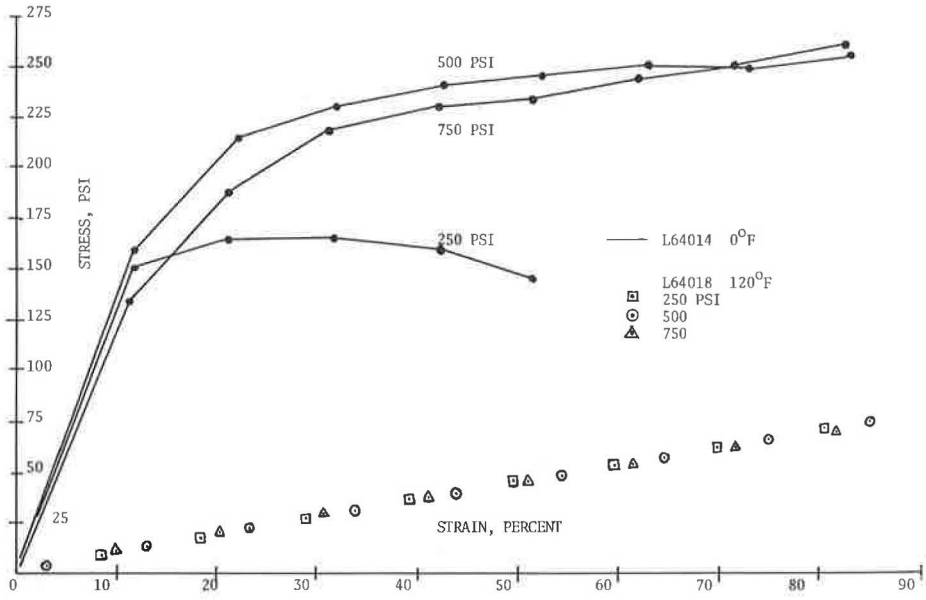

Figure 10. Stress-strain curves in shear-slip (Specimens Nos. L64014 and L64018).

to maintain that deflection. The curves in shear-slip at 0 F are the final set of curves. This behavior was also observed in the repeated-shear tests at 0 F, and curves for those tests also represent the final loads and the corresponding stresses. This behavior was not observed in the tests at 120 F.

The extent to which the load-deformation behavior of the pads is influenced by the roughness of the contact surfaces between pads and loading plates is not known. In the repeated-shear and shear-slip tests, it has been assumed that the deflection of the shear plate was the deflection of the pads.

CONCLUSIONS

If fatigue life were defined as the minimum number of load cycles after which a material no longer performs its intended task satisfactorily, then the neoprene pads tested in repeated compression at 0 F showed a fatigue effect after 100,000 load cycles since further deformations were small. Live load on a bridge acting over a long period of low temperature would therefore tend to reduce the effectiveness of the neoprene bearing pads.

In the repeated shear tests with constant vertical compressive load, the occurrence of tearing, chafing, raveling, of the neoprene, or separation (in one test) of the neoprene from the metal laminations caused no appreciable changes in the stress-strain curves. Large shearing deflections should be avoided in order to minimize the likelihood of such damage as well as possible bending of the metal laminations.

The laminated pads showed higher shearing moduli than did the plain pads at 0 F. The effect of the horizontal forces resulting from the shearing deflections of both types of pads might be significant in the design of bridge substructures.

Although variations in the vertical pressure have no appreciable influence on the shearing stiffness at 120 F, this is not the case at 0 F. At the lower temperature there is a considerable increase in shearing resistance with increase in vertical pressure. At 0 F, slippage is more likely to occur with lower vertical pressures.

ACKNOWLEDGMENTS

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