Report on Tests of Neoprene Pads Under Repeated Shear Loads

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The use of neoprene pads as bearing elements for bridge members poses the question of their behavior under repeated loads. Of special interest is the shear deformation of the pads caused by horizontal motion of the girders resting on them resulting from application of live load and also due to thermal effects on the girders.

The tests described in this report were devised to study the effects on neoprene pads of repeated shear loads with simultaneous compressive loads, simulating the actual load conditions in a bridge. The test program was limited in scope, and variables such as shape factor, thickness, hardness and magnitude of shear deformation have not been included in these studies. Furthermore, tests were run at room temperature and hence effects of temperature, humidity and presence of deleterious substances in contact with the neoprene or in the atmosphere were not studied.

DESCRIPTION OF TESTS

●THE TEST arrangement (Fig. 1) consisted of two stationary concrete side blocks and a center block which moved up and down applying the shearing force to the neoprene pads. The pads were placed between the center block and each side block. The surfaces of the blocks in contact with the pads were trowel-finished.

The compressive load was applied to the pads with four steel bolts bearing on the outside of the blocks. The bearing load was obtained by tightening these bolts and the magnitude of tension in each bolt was measured with SR-4 strain gages. Gage readings were taken frequently during the entire test period to determine the variation in normal load resulting from changes in the elastic properties of the neoprene pads and the creep of the material. Preliminary tests indicated that almost continuous tightening of the bolts would be required in order to compensate for the changes in the properties of the pads; hence maintaining a constant normal load was prohibitively time-consuming and impractical. For this reason no such adjustments were made.

The vertical travel of the center block and consequent shear load on the pads was produced by a fatigue machine. This machine is of the constant-deflection type, rated capacity 50,000 lb, with the motion of its loading beam obtained through a variable-throw eccentric. It is possible to measure the load being applied by the machine through a dynamometer which connects the eccentric to the loading beam.

Before and after being subjected to repetitive loading, each pad was tested statically to determine its load-deformation characteristics under direct loading. The elastic property of the pads thus determined was used as the basis of comparison and in the determination of the extent of damage caused by repeated loading. The pads were loaded in compression between two steel plates 1¼ in. x 6 in. x 12 in. The initial deflection reading was taken at a load of 50 psi and the maximum load was 1,000 psi. The rate of loading and unloading was kept constant, 3,000 lb per min, to assure consistency in the results.

TEST RESULTS

The neoprene pads furnished by the manufacturer were of two types herein called type A and type B. The physical properties of the two types of pads are as follows:

	Pads A	Pads B
Tensile Strength, psi	3,000	2,500
Elongation at break, %	310	230
Hardness, Shore A	72	76
Resilience, %	58	45
Compression set "B" 22 hr at 70 C, %	21	20
Brittle point	-43 C	-39 C

Pads A-1 and A-2 were 1 in. x 4 in. x 8 in., with a shape factor[1] of 1.33, and were tested under an initial bearing pressure of 815 psi. After 1,090,000 cycles of loading, the pads had not failed but the test was discontinued at which time the bearing pressure had been reduced to 645 psi. It is assumed that 1,000,000 repetitions of design load corresponds to the useful life of a structure. The repeated shearing deformation was 0.180 in. and the initial and final shearing stresses were 130 and 70 psi, respectively, based on applied load divided by contact area. The shearing force was applied along the 8-in. dimension of the pads. The load-deformation relationship of the pads before and after the test is given in Figure 2.

Pads A-3, A-4, A-5 and A-6 were 1 in. x 4 in. x 6½ in. The initial bearing pressure was 530 psi. The test was discontinued at 1,074,000 cycles of loading, at which time the bearing pressure was 380 psi. No failure occurred in these pads which were loaded along the 4-in. dimension. The shearing deformation was 0.180 in. and the initial and final shearing stresses were 120 and 65 psi, respectively. The load-deformation curves before and after testing are presented in Figure 3.

Pads A-7, A-8, A-9 and A-10 were 1 in. x 4 in. x 6½ in. The initial bearing pressure was 580 psi and the shear deflection 0.425 in., with the pads loaded in shear along the 4-in. dimension. The test was discontinued at 236,000 cycles of loading. The bear-pressure was then 425 psi and the four pads had failed. Figure 4 shows specimens A-8 and A-10 which were damaged the most. The distortion of the pads was permanent and

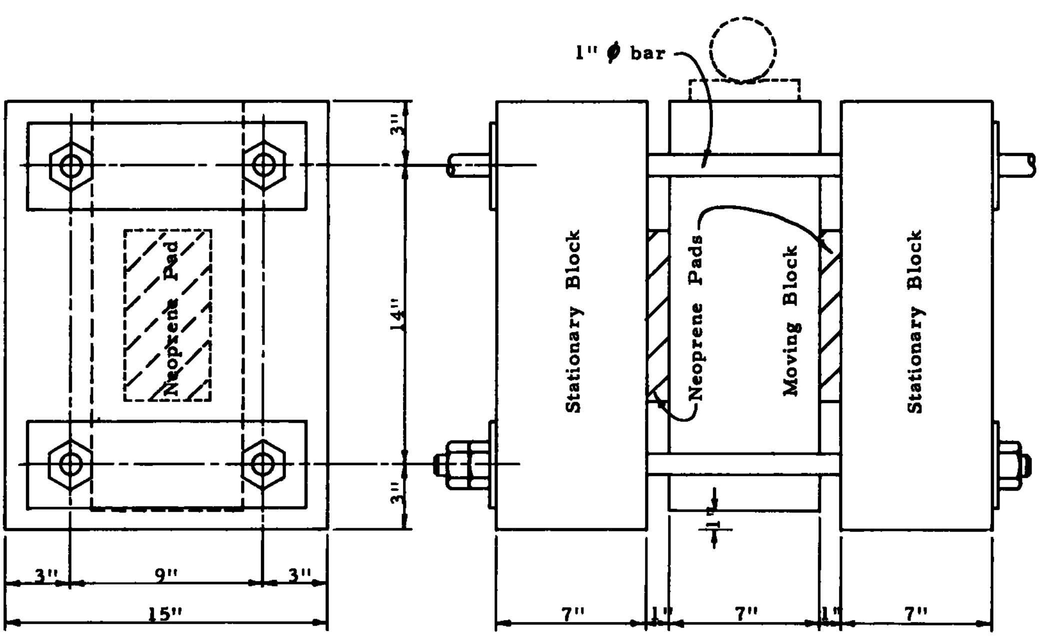

Figure 1. Test set-up.

[1] Shape factor is defined as the ratio of the bearing area to the perimeter surface area. Shape factor is significant because the perimeter surfaces bulge under bearing loads and the edge disturbance coupled with tendency to roll under shearing load renders the pads with relatively small bearing area but large perimeter area vulnerable to failure.

the cracks were similar in the four specimens although they were not quite as much developed in pads A-7 and A-9. Figure 5 shows the load-deformation curves before and after the test.

Pads A-11, B-1, B-2 and B-3 were 1 in. x 4 in. x 6 in. The initial bearing pressure was 310 psi and the final, 220 psi. The shear deformation was applied along the 4-in. dimension and was equal to 0.390 in. At 170,000 cycles, pad B-1 had failed while the others had been only distorted. The initial and final shearing stresses were

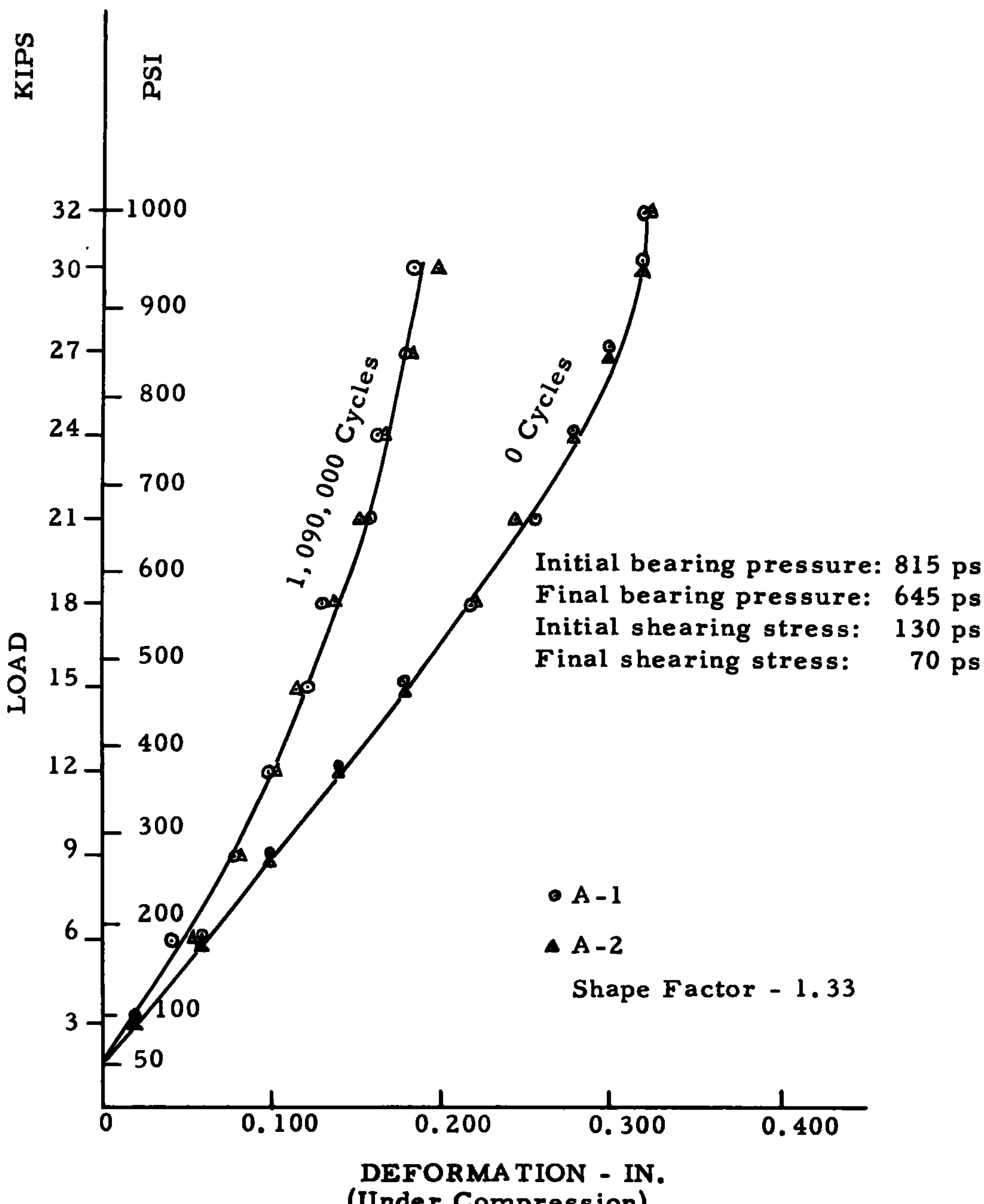

Figure 2. Load-deformation diagram for pads A-1 and A-2.

148 psi and 106 psi, respectively. The load-deformation curves before and after the fatigue test are presented in Figure 6.

Pads B-4, B-5, B-6 and B-7 were 1 in. x 4 in. x 6 in. They were loaded in shear along the 4-in. dimension and the corresponding deformation was 0.450 in. The bearing pressure was 500 psi at the start of the test and 200 psi at the end. At 120,000 cycles all pads showed extensive damage with large cracks present. Figure 7 shows the load-deformation curves before and after the test.

Pads B-8, B-9, B-10 and B-11 were 1 in. x 4 in. x 6 in. The initial bearing pressure was 540 psi and the final 375 psi. The shear load was applied along the 4-in. dimension. The initial shearing stress was 340 psi. These pads were subjected to an initial shear deformation of 0.100 in. and a subsequent additional repetitive deformation

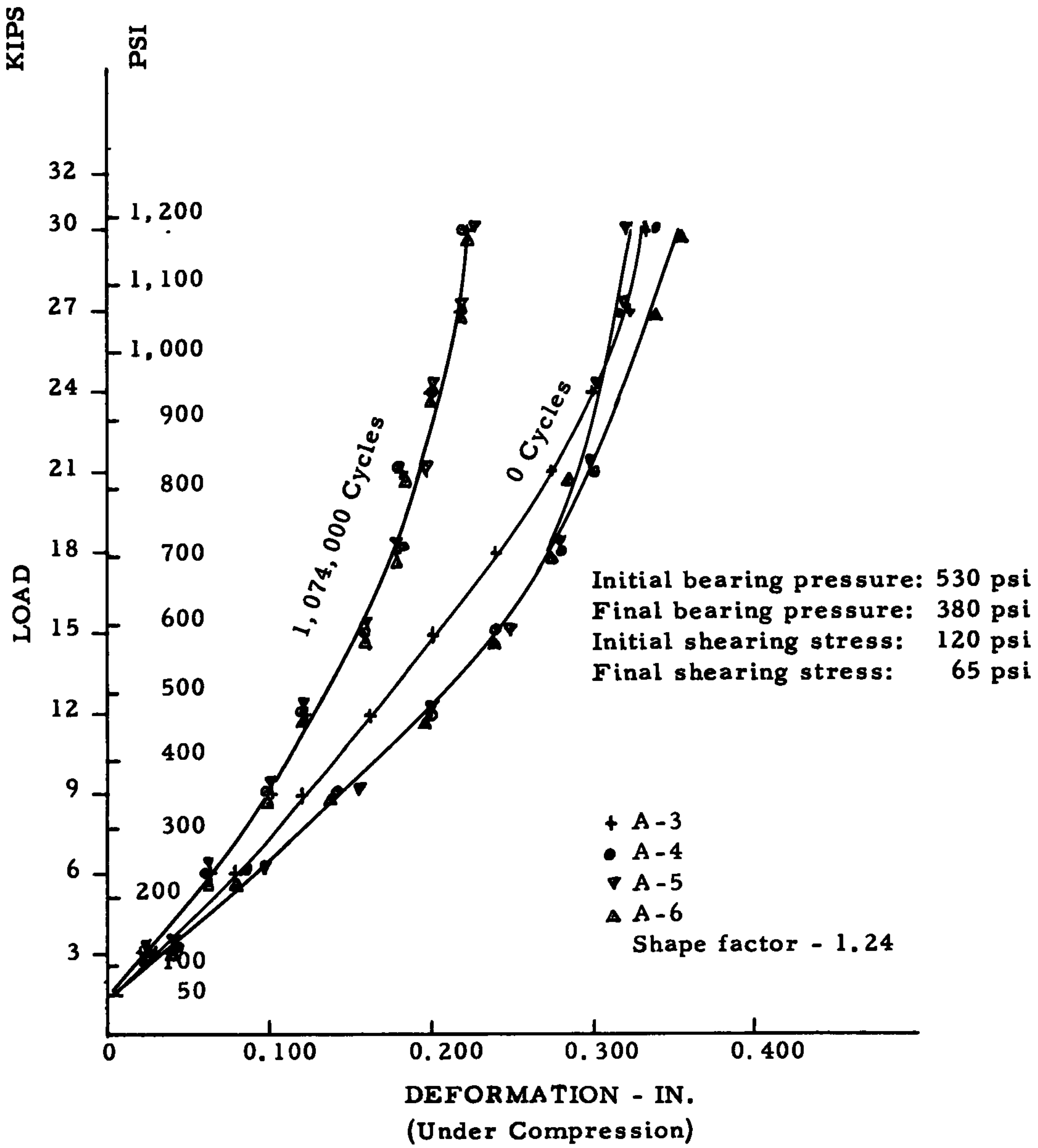

Figure 3. Load-deformation diagram for pads A-3, A-4, A-5, and A-6.

of 0.360 in. Cracks appeared at 20,000 cycles and the test was discontinued at 35,000 cycles. The load deformation curves for these specimens are shown in Figure 8.

Pads B-12 and B-13 were 1 in. x 4 in. x 8 in. (Previously, these pads had served as supports for prestressed concrete beams tested in fatigue and had been subjected to about 6,000,000 cycles of direct load at about 100 psi bearing stress.) The shear deformation was 0.450 in. applied along the 8-in. dimension. The initial shearing stress was 291 psi. After 17,000 cycles of loading, the specimens showed damage and the test was discontinued. Figure 9 shows the load-deformation relationship before and after the test.

DISCUSSION OF TEST RESULTS

Before examining the test results a word should be said about the compressive tests used to establish the load-deformation relationship of the pads.

The amount of deformation for a given compressive load is a function of the contact surface (smooth or rough, glued or unglued), the size of the lateral expansion area, the size and shape of the pads, the hardness (as measured by a durometer), and the speed of loading.

It is important that the exposed surfaces of the pads be free of cuts or imperfections which will cause the pads to tear when they bulge under the load.

These tests indicated that the pads hardened apparently as a consequence of fatigue action. This hardening took place before the pads were torn, as evidenced by the load-deformation curves of pads with or without cracks.

The compressive load on the pads at the end of the tests was considerably smaller than the initial load. This can be explained not only by the change in the elastic properties of the pads but also by the drift or creep of the neoprene. The reduction of the bearing pressure, as well as the shearing stress during the entire test period, was almost linear indicating a gradual change in the elastic properties of the neoprene and creep of the material.

In these tests the two studies on combination of variables were on the bearing pressure (compressive force) and the shear deformation. However, the bearing pressure in the average range of 265 psi minimum to 730 psi maximum did not seem to have much influence on the results. On the other hand, the amount of shear deformation was the most important single factor in the failure of the pads.

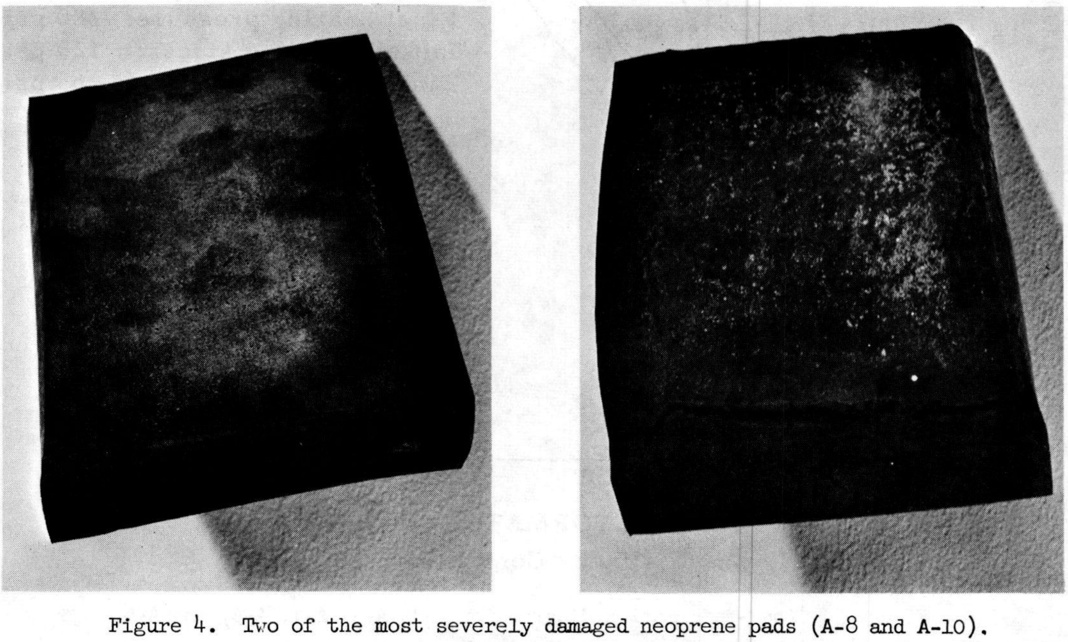

Figure 4. Two of the most severely damaged neoprene pads (A-8 and A-10).

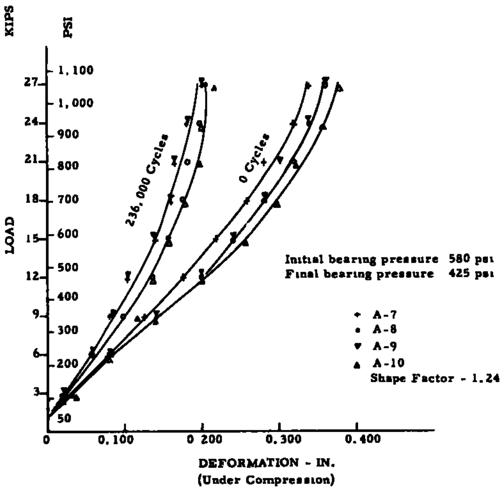

Figure 5. Load-deformation diagram for pads A-7, A-8, A-9, and A-10.

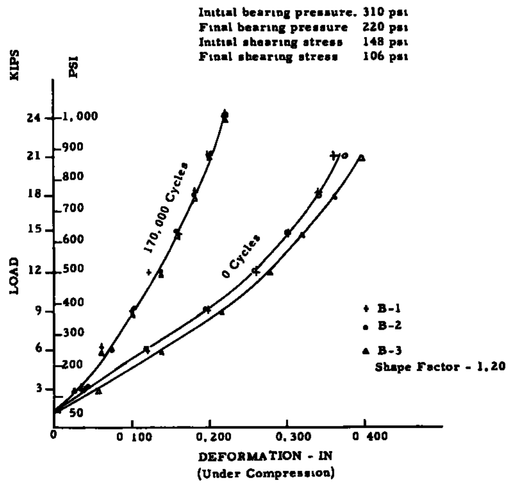

Figure 6. Load-deformation diagram for pads B-1, B-2, and B-3.

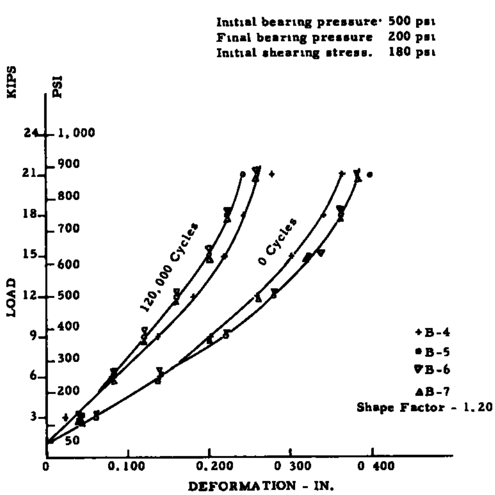

Figure 7. Load-deformation diagram for pads B-4, B-5, B-6, and B-7.

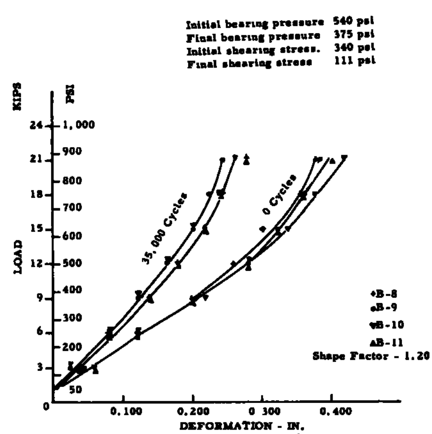

Figure 8. Load-deformation diagram for pads B-8, B-9, B-10, and B-11.

Pads A-1 and A-2 subjected to an average bearing pressure of 730 psi and a simultaneous shear deformation of 0.180 in. exhibited little visual damage (slight permanent distortion but no cracks) after 1,090-000 applications of shear deformation although some hardening of the neoprene had obviously taken place. Pad B-1 subjected to an average bearing pressure of 265 psi failed at 170,000 applications of 0.390 in. shear deformation. Pads B-8, B-9, B-10 and B-11, under an average bearing pressure of 458 psi, failed after 20,000 applications of shear deformation of 0.460 in.

From the above typical behavior and results it could be concluded that bearing pressures of about 700 psi with simultaneous shear deformation of about 0.25 in., one-fourth of pad thickness, could safely be assumed as the maximum limiting design criteria for the use of such pads.

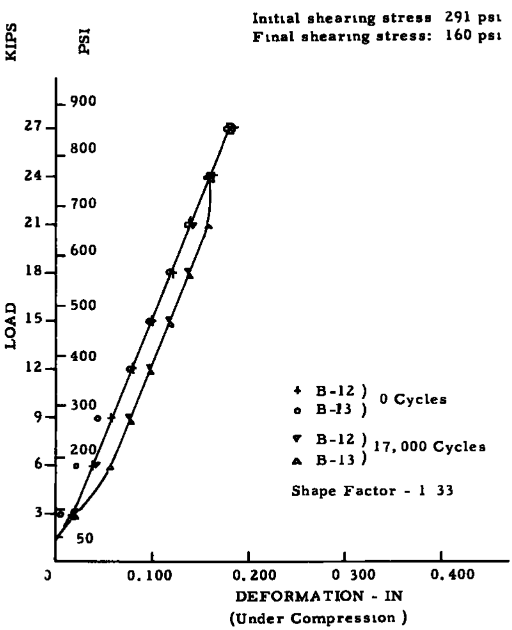

Figure 9. Load-deformation diagram for pads B-12 and B-13.

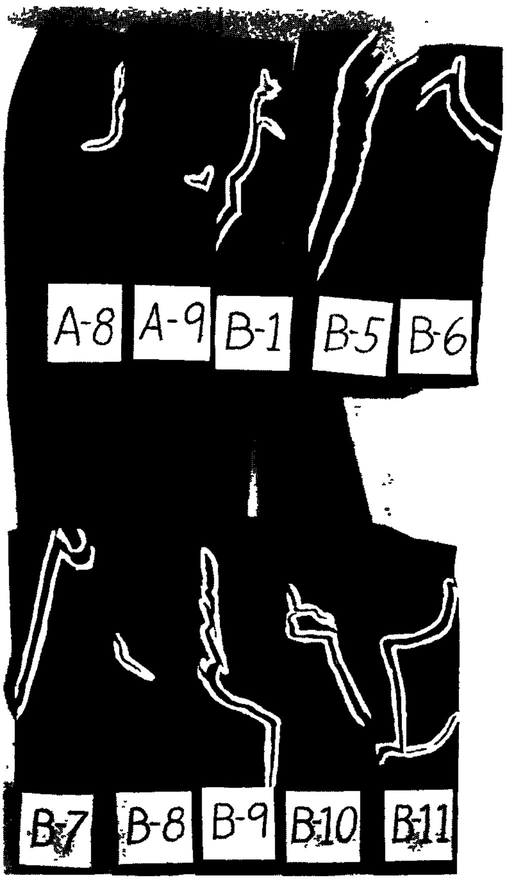

Figure 10. General view of pad failures.

Figure 10 shows photographs of some of the pads that failed, illustrating the type of cracks that occurred and the manner in which they were formed and developed.

CONCLUSIONS

The tests showed that repeated shear deformations of neoprene pads, under conditions similar to those of actual use, can cause failure at a relatively low number of repetitions of load when the shear deformations are comparatively large.

The critical factor, therefore, is the amount of shear deformation imposed to the pads, rather than the bearing stress.

For pads of the general shape and thickness of those tested, it appears that a limiting shear deformation of one-fourth the pad thickness is adequate for design purposes. Under such repetitive shear deformations an allowable bearing value of 700 psi is safe.

Repeated loads cause some hardening and creep of the pads although it was not definitely established that repetition alone was responsible for the change in these properties. Nevertheless, this hardening does not render the pads unsafe.

ACKNOWLEDGMENT

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Discussion

S.D. McCREADY, Product Engineer, Dupont Company, Wilmington, Delaware— Dr. Ozell has completed a thorough study of the dynamic characteristics of elastomer bearing pads, during which he developed a method for predicting their service life under laboratory conditions. The application of Ozell's data to actual service conditions will be discussed.

Under the most severe shear loads imposed in his testing, no failure was experienced in less than 17,000 cycles. Since expansion and contracting of bridge spans take place very slowly, 17,000 cycles represent many hundreds of years of good performance. This type translation of data is necessary in the rubber industry due to the difficulty in reproducing service conditions in the laboratory.

An illustration of this is the effect of rate of shear cycling to specimen life. Elastomers build up considerable frictional heat when flexed rapidly, which contributed to the breakdown of the vulcanizate. For example, the rubber industry employs tests, such as the St. Joe Flexometer, as described in ASTM Method D 623, to measure the rate of heat generation and fatigue characteristics of tire carcass and tread compounds. Ozell distorted his specimens in shear at the rate of 120 cycles per min. Because of this, it is safe to assume that considerable frictional heat developed which contributed to the failure of the neoprene pads. The rate of shear distortion of bearing pads in service would cause very little heat generation.

The conclusions drawn, therefore, by Ozell relative to shear deformation are somewhat conservative.

Ozell has confirmed the value of 700 psi maximum compressive stress on a 70 durometer pad which has been included in the tentative AASHO bridge pad specification. It should be pointed out that shape factor must be taken into account when computing compressive loads.

The maximum compressive deformation, not including drift, should not exceed 15 percent of initial bearing thickness for maximum long-term performance of the elastomer. For example, an 815 psi load on a 1 x 4 x 8 seventy durometer bearing, having a shape factor of 1.33, will compress it 24 percent. A 720 psi load on a 1 x 4 x 6½ seventy durometer bearing, having a shape factor of 1.24, will compress it 23 percent. Thus, the 700 psi value should apply only to a 70 durometer neoprene pad having a shape factor greater than 1.8. This is very important and should not be ignored in design calculations. By limiting the initial vertical deflection to 15 percent, the compressive stress in psi is automatically taken care of regardless of durometer of shape of the elastomer bearing pad.

A.M. OZELL, Closure — McCready's comment on the heating of the neoprene pads caused by friction resulting from excessive rate of load application is correct. However, although these pads were warm to the touch, they were never "hot." Such minor heating is believed not to have the drastic effect as McCready states.

As mentioned in the conclusions, the critical factor was found to be the shear deformation rather than the bearing stress which contributed to the fatigue failure of the pads. It should be emphasized that the severity of the shear deformation is related to the shape factor. In the tests reported the shape factors varied between 1.20 - 1.33 for which a limiting shear deformation of ¼ the pad thickness was suggested.

McCready's recommendation to limit, for design purposes, the bearing deformation to 15 percent of the pad thickness to account automatically for shape factor or durometer variation has merit.