Elastomeric Bridge Bearings

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Tests were made for the purpose of determining the adequacy of elastomeric bearings in bridge construction and to establish bearing design criteria. Samples of neoprene, 6 in. by 12 in. of varying thickness, molded or in bonded layers, were tested. Test equipment included a 500,000-lb Southwark-Emery tension compression machine, a 40,000-lb hydraulic jack and various recording gauges. The required compressive and shear loads were applied directly, alternately and in combination for varying periods. Test phases included vertical deflection under compression, horizontal and vertical deflection in combined compression and shear, shape effects, time-creep relationships and fatigue.

All bearing types tested bore close stress-strain relationships. Within the limits of the test procedures it is assumed that neoprene-based bearing products meeting current specifications have similar physical properties. It was found that vertical deflection increased inversely with durometer readings; with time and dynamic loading; and were proportionally greater with added thickness. Tests for additional vertical deflections similar to intermittent live bridge loads or dynamic creep, indicate that static deflections should be increased by 50 percent.

Bearings tested indicated, in each instance, similar horizontal deflections due to horizontal shear loads. Resistance to shear distortion increased with thickness and stiffness but was not affected by direct compressive loading or by shape or orientation of bearing. The absence of fatigue in the 3-hr alternating phase of the tests indicates the need for a longer testing period in this respect.

TEST OF ELASTOMERIC BRIDGE BEARINGS

●THE PURPOSE of the program leading to this report was twofold; first, to investigate the physical properties of elastomeric materials now available; and second, to establish a design procedure, based on experimental data, for the use of elastomeric bearings.

The use of elastomeric materials for bridge bearings has some precedent. The Texas and Florida Highway Departments, the British Railway System and the French National Railway have all used elastomeric bearings. The British Railways have conducted tests similar to those described herein; however, the materials tested were apparently of lower durometer hardness and may have differed in compounding.

The principal physical characteristics required of materials for elastomeric bearings include the following:

1. Resist compressive loading up to 1,200 psi without undue deflection and with definite limits of creep under sustained load.
2. Resist shear loads which produce deflections up to 50 percent of the thickness of the bearings without loss of elastic properties.
3. Resist repeated reversal of shear loads without undue loss of elastic properties.
4. Divergence from stress-strain ratio at 70 F not to exceed 25 percent for increase or decrease of temperature by 90 F.
5. Remain not brittle at minus 30 F.

The desirable chemical characteristics include:

1. Excellent resistance to weathering, ozone and natural aging.
2. Resistance to water absorption within acceptable limits.
3. Resistance to deterioration by oil to limit loss of strength characteristics to 20 percent after a standard immersion test.

Temperature and chemical tests of the elastomeric materials were beyond the scope of this program. These characteristics must be determined by tests conducted with equipment not normally available nor easily manufactured in laboratories maintained by public agencies. The importance of these tests is, however, not to be overlooked and the elastomeric materials must be found satisfactory in these tests before their use can be universally accepted.

The material selected for testing consisted of blocks of neoprene molded into the required shape or built up of layers of plies (each = 0.21 in. thick) to the required thicknesses and bonded with a cementing agent. The test specimens were of uniform width and length except in tests for shape factor. The width was 6 in., the length 12 in. and the thickness varied. This size was selected as an approximation of the average size anticipated for bridge bearings (Fig. 1).

The equipment was designed around a Southwark-Emery tension compression machine of 500,000-lb capacity. A 40,000-lb hydraulic jack was used to provide the shear force. The apparatus consisted of two concrete blocks set between the heads of the compression machine. A yoke was cast into the concrete blocks to hold the hydraulic jack and to provide a reaction for the base of the jack. The samples to be tested were placed above and below a steel or steel and concrete-shear plate and inserted between the concrete blocks in the compression machine. Loads were applied vertically by the compression

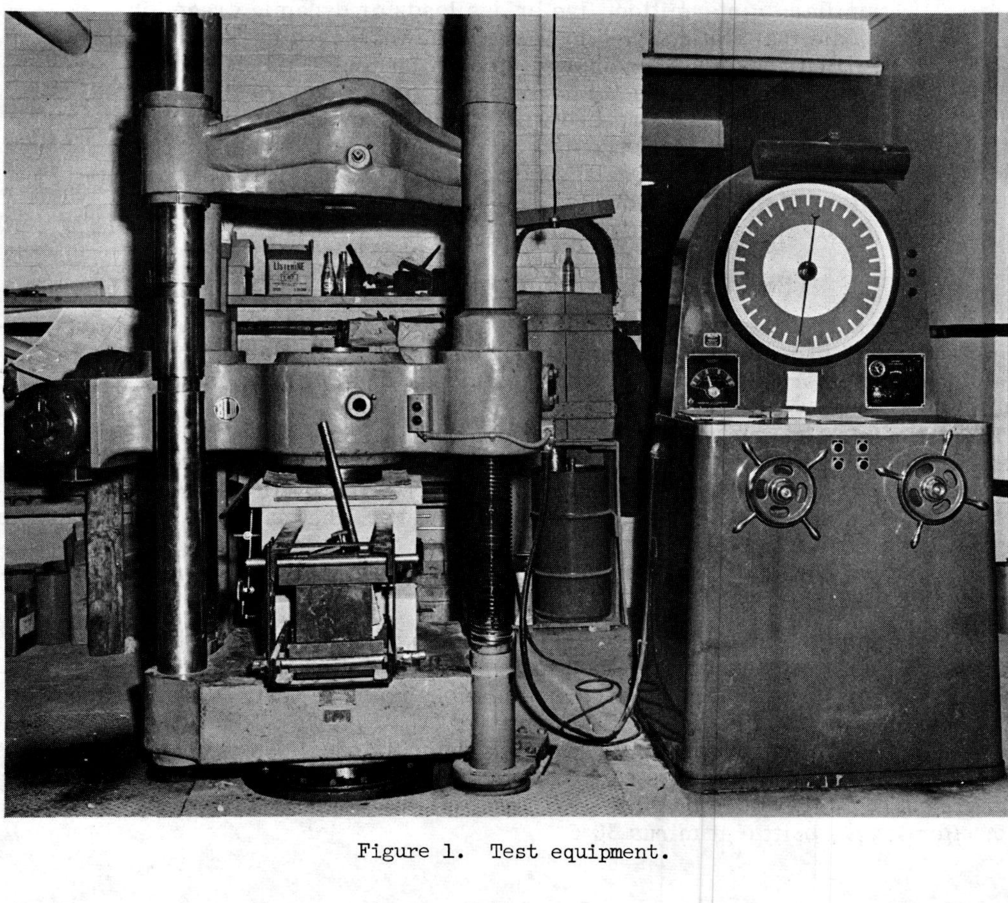

Figure 1. Test equipment.

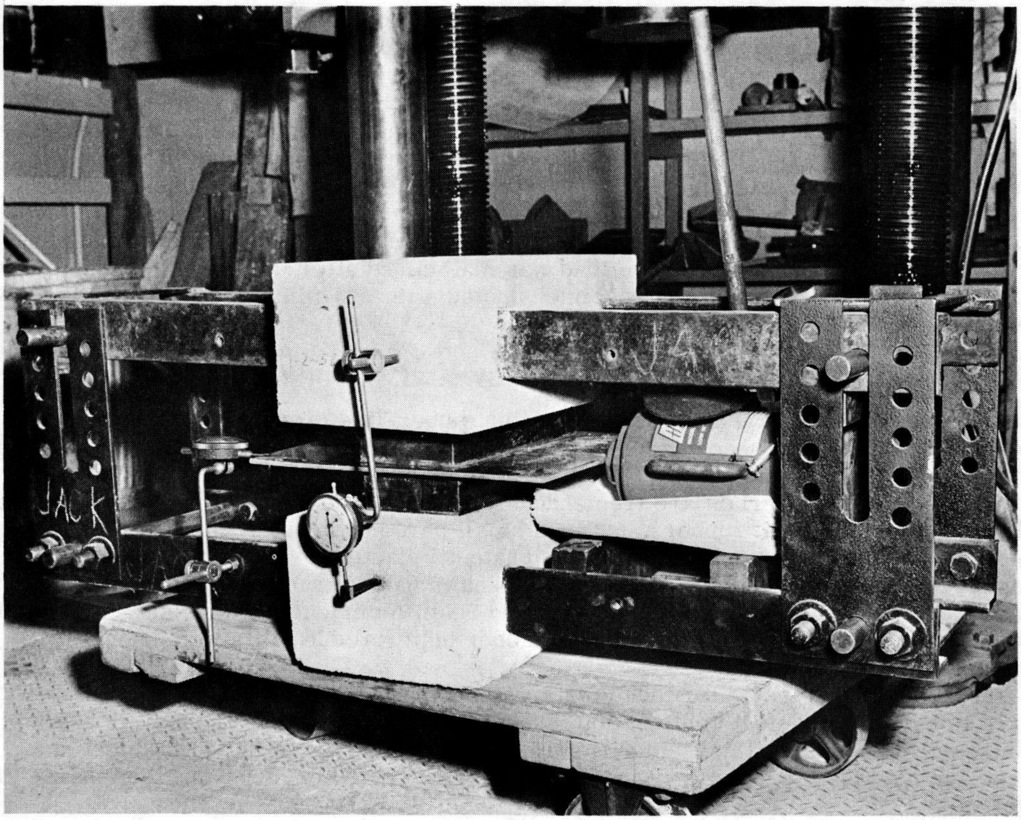

Figure 2. Shear stressing test equipment.

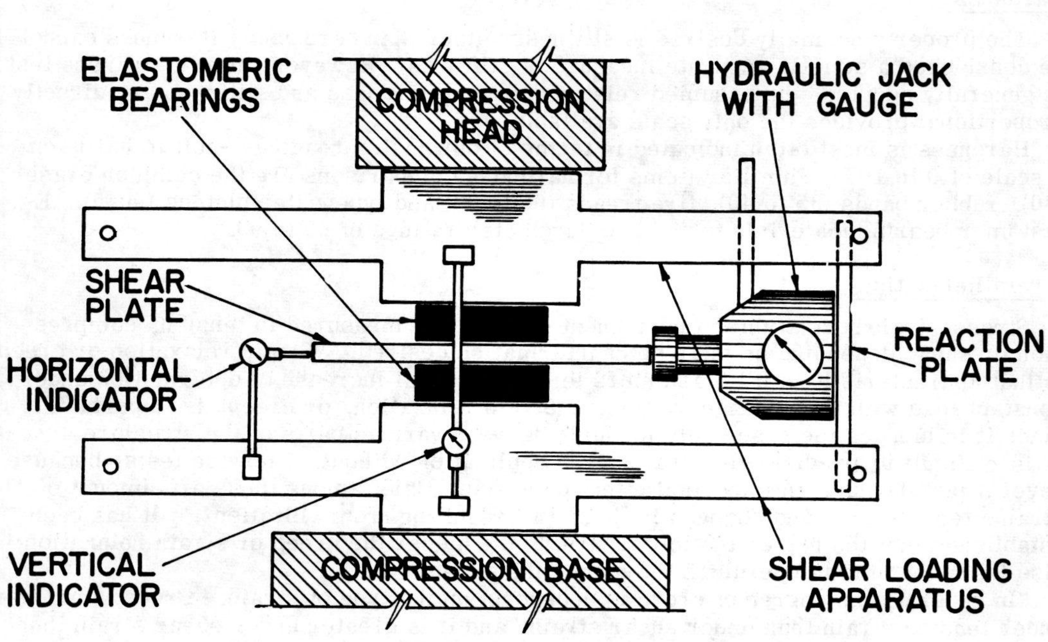

Figure 3. Diagram of testing apparatus.

machine and horizontally by the hydraulic jack (Figs. 2 and 3).

The instrumentation consisted of load gauges on the Southwark-Emery machine and hydraulic jack, and horizontal and vertical deflection dial indicators. Two dial indicators were used to measure vertical deflection and two for horizontal deflection. The resultant movements were the average of the dial readings.

The basic procedure was first to load the specimens in compression, recording load and deflection; hold the compressive load for 5 min and slowly unload. The specimen was then again loaded in compression and the compression load held constant while shear loads were applied up to 40 percent of the compressive load. The shear load to each of the two bearings of 20 percent (total 40 percent) was held for 5 min and then slowly unloaded. The compressive load was maintained after the shear load had been removed and the recovery of the specimens noted after a 5-min interval. All tests followed this general procedure.

ELASTOMER TERMINOLOGY AND PROPERTIES

Elastomer means all materials that exhibit rubber-like properties. The term elastomer, when generally recognized and accepted, will eliminate many of the prejudices associated with synthetic rubber. The physical and chemical properties of the man-made elastomeric materials are tremendously varied, exceeding in many cases the useful properties of natural rubbers, not by a small percentage but by many times.

Natural rubber is the term used to designate all elastomer materials manufactured from vegetable sap. Commercially the best known natural rubber is "Hevea," produced from rubber grown principally in Central and South America. Other elastomer materials are normally compared with natural rubber material due to its well-known characteristics.

The elastomer selected for these tests was neoprene. At this time, neoprene appears to have the greatest combination of required properties of the elastomers available. Future developments in this field will surely increase the desirable qualities of neoprene and may lead to an entirely new substance superior in every desirable characteristic.

ELASTOMER PROPERTIES AND STANDARD TESTS

Hardness

The property normally desired is stiffness rather than hardness. Hardness cannot be considered a strictly accurate measure of stiffness. However, until a stiffness test is generally adopted, the assumed relationship that hardness and stiffness are directly proportional provides the only scale available.

Hardness is most often indicated in terms of durometer readings—soft to hard—on a scale of 0 to 100. Familiar items for hardness comparisons are the common eraser (30), rubber bands (35 to 40), tire treads (60 to 70) and typewriter platens (90±5). Elastomer bearing materials tested had durometer ratings of 60 to 90.

Strain Relaxation

Stress-strain relaxation and permanent set must be measured in tension, compression or shear depending on the type of information desired. "Strain relaxation or creep is that characteristic of all elastomers to show gradual increase of deformation under constant load with the passage of time... Strain relaxation, or creep, is important... since it influences the space relationships between various parts of the structure.
It is difficult to predict creep for a given application without... service tests, because several factors have an important effect on creep. Chief among these are amount of strain, temperature and changes in these two resulting from vibration... It has been established that the higher the initial strain, the higher the creep or strain relaxation; also the higher the temperature the higher the creep.

"In general, the degree of creep is dependent on the type of strain. Creep is greater under tension strain than under shear strain, and it is greater under shear strain than under equal compression strain. Creep is also greater under dynamic loading than under static loading." (1).

Compression Load Deflection

In the region where compressive loads are 300 to 800 psi, the stress-strain curve is nearly straight, and design assumptions assuming proportional stress-strain can be made within reasonable error. Below this range, stress-strains are far from proportional and experimental curves must be developed for the range desired.

Shape

In addition to stiffness and range of deflection, another factor known as shape affects the stress-strain relationship. Elastomers subject to compressive loads lose little or no volume. To deflect vertically it is necessary for the elastomer to expand horizontally. If the contact surfaces restrain movement, the free surfaces bulge. Through much experimentation an empirical formula has been developed which relates this degree of restraint and is known as shape factor.

$$\text{Shape Factor} = \frac{\text{One Load Area}}{\text{Total Free Area}}$$

For a rectangular block of length A, width B, and thickness t, the formula for Shape Factor becomes

$$S = \frac{A \times B}{2t\ (a + B)}$$

The relation of Shape Factor (Fig. 4) to stiffness is well documented and it need only be noted that stiffness increases with Shape Factor. In bridge bearings the ratio of the area of loaded surface to the thickness of the bearing is so great the effect of Shape Factor error is small.

Shear Load Deflection

Shear deflection in elastomers is measured as the ratio of linear deformation d to the rubber thickness t. The angle of torsion is θ (Fig. 5).

When combined with compression, the thickness must be reduced by the deflection Δ t, due to compression, therefore

$$\frac{d}{t - \Delta t} = \tan \theta$$

Shape in shear has been found to have little effect except when the thickness to width ratio is greater than one to four. This ratio should probably be kept to one to five as a minimum to prevent edge disturbance and a tendency to roll.

SERVICE TESTS

The simulated service tests included the following categories:

1. Vertical deflection under varying compressive loads at room temperature;
2. Other variables: (a) thickness, (b) hardness, (c) compounding (manufacture), and (d) shape;
3. Horizontal deflection under varying horizontal shear and vertical compressive loads at room temperature; and
4. Other variables as previously indicated.

Analysis of the results of the above tests, together with special tests, combined to yield information on the effect of (a) shape, (b) creep, (c) compounding, and (d) fatigue on neoprene bearings.

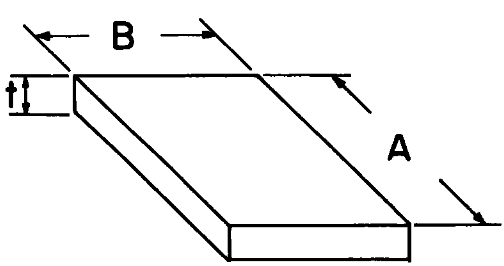

Figure 4. Shape factor.

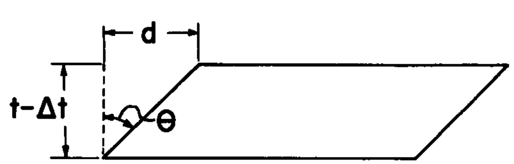

Figure 5. Shear deflection angle.

Compression Tests

During the compression tests, loads on the thicker bearings were observed to produce deflections well over 20 percent of the original thickness of the bearings. No sign of distress appeared in the molded bearings. The bearings built of plies tended to separate slightly at the edges under high loads, but on release of load the separations closed and were not discernible. One molded bearing consisting of two layers, each $^{3}/_{4}$-in. thick, bonded through a layer of metal mesh, tended to separate along the mesh layer.

Typical curves of deflection under compressive loading are shown in Figure 6. A study of these curves indicates a remarkable uniformity of compressive deformations. The ultimate bearing capacity of the neoprenes tested was beyond the range of these tests. The maximum load applied was 2, 000 psi to the samples and in no case did the curves of stress-strain change shape at or near this point.

Sources of Error

Vertical deflection results were inconsistent in the various tests due to:

1. Durometer ratings are inconsistent and not an accurate gauge of stiffness.
2. The rate of application of load was apt to vary due to factors beyond control of the test.
3. The temperature fluctuated day by day.

Tests for Combined Shear and Compression

The shear loads on the bearings produced horizontal deflections exceeding in some cases the thickness of the bearings. In three cases, the thicker bearings made up of several plies tended to separate under high shear loads, but as with the vertical loads the separations closed as the loads were removed and were not discernible in the free samples. In no case was the ultimate load capacity in shear found in the process of these tests. The bearings appeared to be as serviceable at the conclusion of the tests as at the start.

Typical curves of deflection under combined loading of compression and shear are shown in Figure 7. A study of all the curves for combined loading revealed that the shear distortions are very similar for all of the bearings tested. In contour they are almost identical. The difference in deflection for similar bearings is due to the variation in durometers (stiffness) far more than for any other reason.

The inconsistencies for the combined load testing were the same as listed for the compression tests with one notable addition. Steel and concrete plates were used interchangeably to transmit the shear loads. As the concrete surfaces were rougher than the steel surfaces, the degree of restraint of the rubber in contact with the concrete was probably greater. The horizontal deflections under low compressive loads may have been affected due to this interchange of shear plates but this was not apparent in the test results.

SPECIAL TESTS

Shape Effect on Vertical Deflections

To study the effect of shape, the formula:

$$\text{Shape Factor} = \frac{\text{width x length}}{\text{2 x thickness (width + length)}} \quad \text{was adopted.}$$

The vertical tests on neoprene bearings of varying thickness substantiate the shape curves for values of shape below three established by the Goodyear Tire and Rubber Company in their Handbook of Molded and Extruded Rubber (4). For high values of shape however, the deflections recorded were increasing below the computed deflections as the shape factor increased.

Shape Effect on Horizontal Deformations

Horizontal shear tests were run on a number of bearings of various size. The results indicate that the shape or orientation of the material has no visible effect on the horizontal stress-strain relationship. One exception was noted. Where the width (dimension parallel to the shearing force) becomes less than four times the thickness, the bearing tends to roll and slip noticeably when the horizontal force exceeds 5 percent of the vertical (Fig. 8).

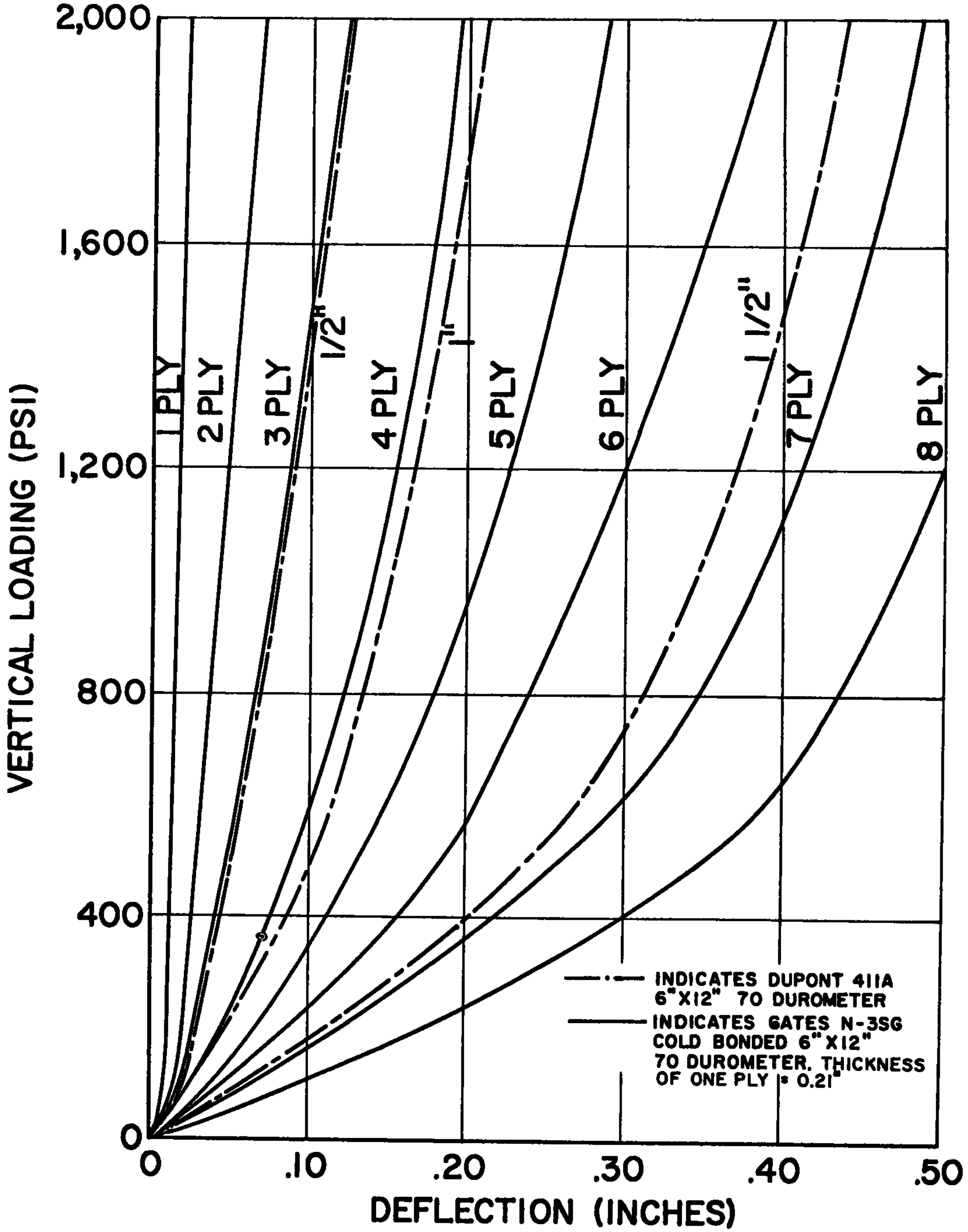

Figure 6. Vertical stress-strain test results.

Time

To study the effect of normal creep of elastomeric bearings under load, two static vertical deflection tests were performed. In the first test the 3-ply compound was subjected to a sustained vertical load of 2,000 psi for 2¾ hr. The creep deflections related to the deflection when full load was reached were 2.7 percent in 5 min and 6.1 percent in 2¾ hr. From the time curve it appears 50 percent of the creep occurs in the first 5 min.

The second test was run on a 6- by 12- by 1½-in. 70 durometer bearing. Test conditions were identical to those employed with the 3-ply unit. Resulting creep deflections related to the deflection when full load was reached were 3.8 percent in 5 min and 7.4 percent in 2 hr.

Keeping in mind the accuracy required in the computations of vertical deflections for bearings of this type it is evident that sufficient figures may be obtained if the vertical deflections obtained under full load are increased 15 percent for static creep. However, it will be shown in succeeding paragraphs that creep from dynamic loading will yield higher (governing) values.

Fatigue

An important question in the use of this material is the effect of fatigue under operating conditions. An attempt to simulate this condition was performed on two 6- by 9-in. by 1-in. 70 durometer units. The bearings were subjected to a sustained vertical load of 800 psi. A horizontal force of 17,200 lb was alternately applied against the opposite 6-in. faces. Eighteen force cycles were accomplished in three hours. The tabulation of horizontal deflections indicated no sign of fatigue.

Vertical deflections, however, show dynamic creep. This creep has the same proportions as static creep but with greater value. In three hours the percentage of creep to the initial deflection when full load was reached came to 47.8 percent.

To account for dynamic loading to which bridge structures are subject, the vertical deflections for full vertical load should be increased 50 percent. It is thought that the final deflections thus computed will closely approximate working values.

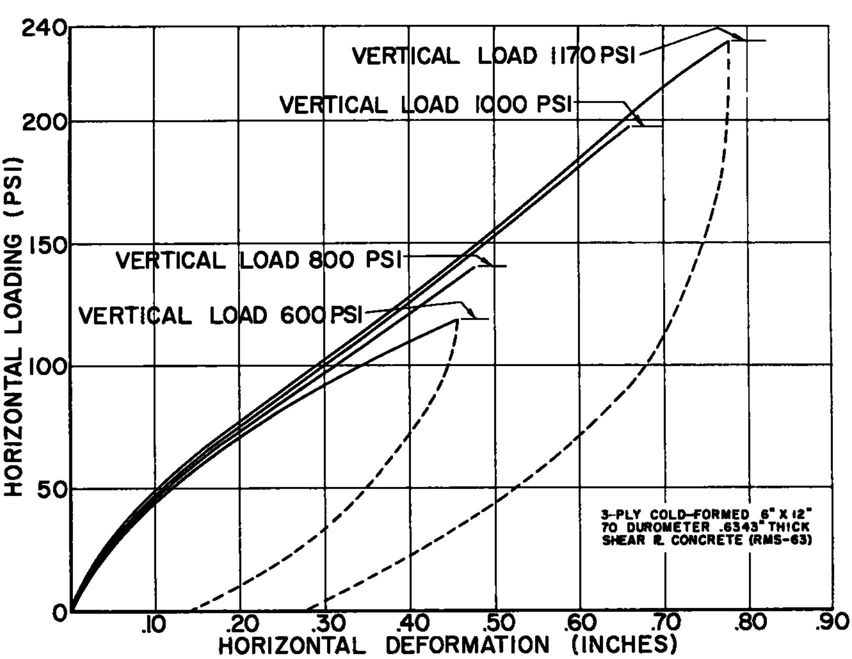

Figure 7. Typical horizontal deflections.

COMPOUND (MANUFACTURE)

From the data collected in tests on bearings provided by four manufacturers, the deflection curves for 70 durometer materials were compared. The results as shown by the curves indicate that all the materials used have approximately the same stress-strain relationship in compression and shear-compression in combination. The only control over the manufacture of the bearings other than size and hardness was the specification proposed by N. L. Catton of Dupont (5). It is encouraging to see the selection of bearings perform similarly. This result should not be construed to mean that every 6- by 12-in. unit of 70 durometer hardness will yield equally under the same stresses. Other properties such as durability and fatigue may vary in these samples as well as deviations from the stated 70 durometer hardness. However, it is felt that the methods of manufacture may be controlled by a specification to provide required engineering properties.

CONCLUSIONS

Hardness

Hardness of elastomeric bearings is an important consideration. The selection of various hardnesses may vary from those tested in this program due to varying requirements. To tabulate the varying stress-strain relationships due to hardness, four pairs of bearings were tested. The effect of varying vertical load may be considered to contribute little to horizontal deformations. In Figure 22, these hardness curves are plotted with the deformation reading as the ratio of horizontal movement to the vertical thickness under load. In this case the curves plot as a single contour for the hardness involved.

Vertical Deflections

The vertical deflections measured due to static vertical compressive loads were in general found to be less than anticipated. The deflection curves indicated the following:

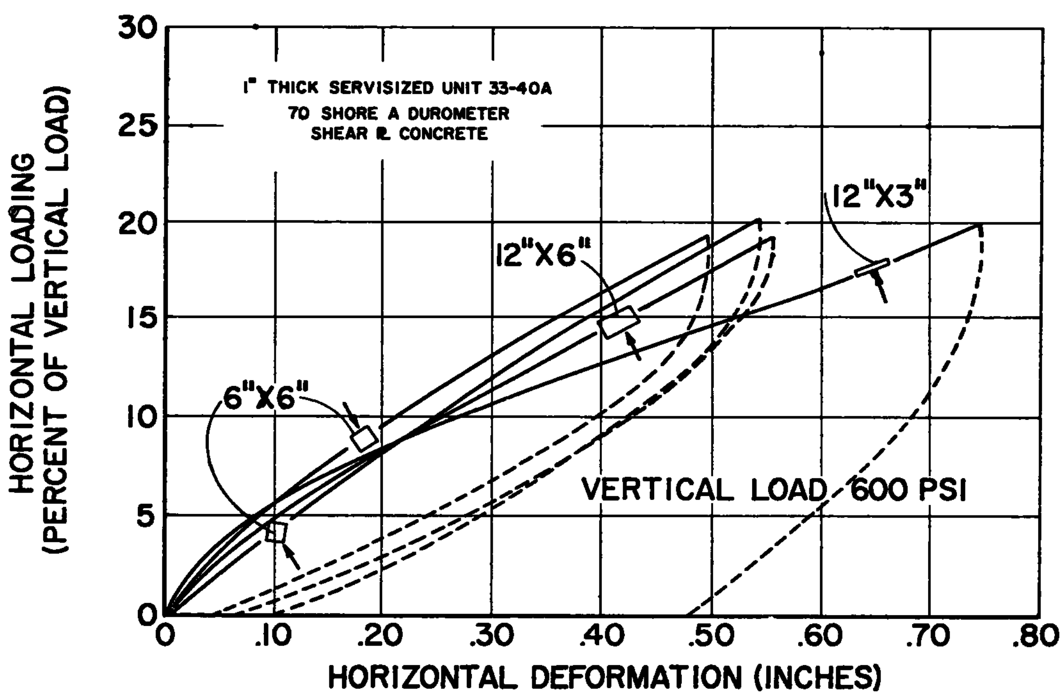

Figure 8. Effect of shape on horizontal deformations.

1. Deflection increased inversely with durometer ratings.
2. Deflection is proportionately greater (deflection divided by thickness) as the thickness of the bearing increases.
3. Shape deviation has limited effect on compressive resistance of elastomeric bearings.
4. Deflection increases with time and dynamic loading.

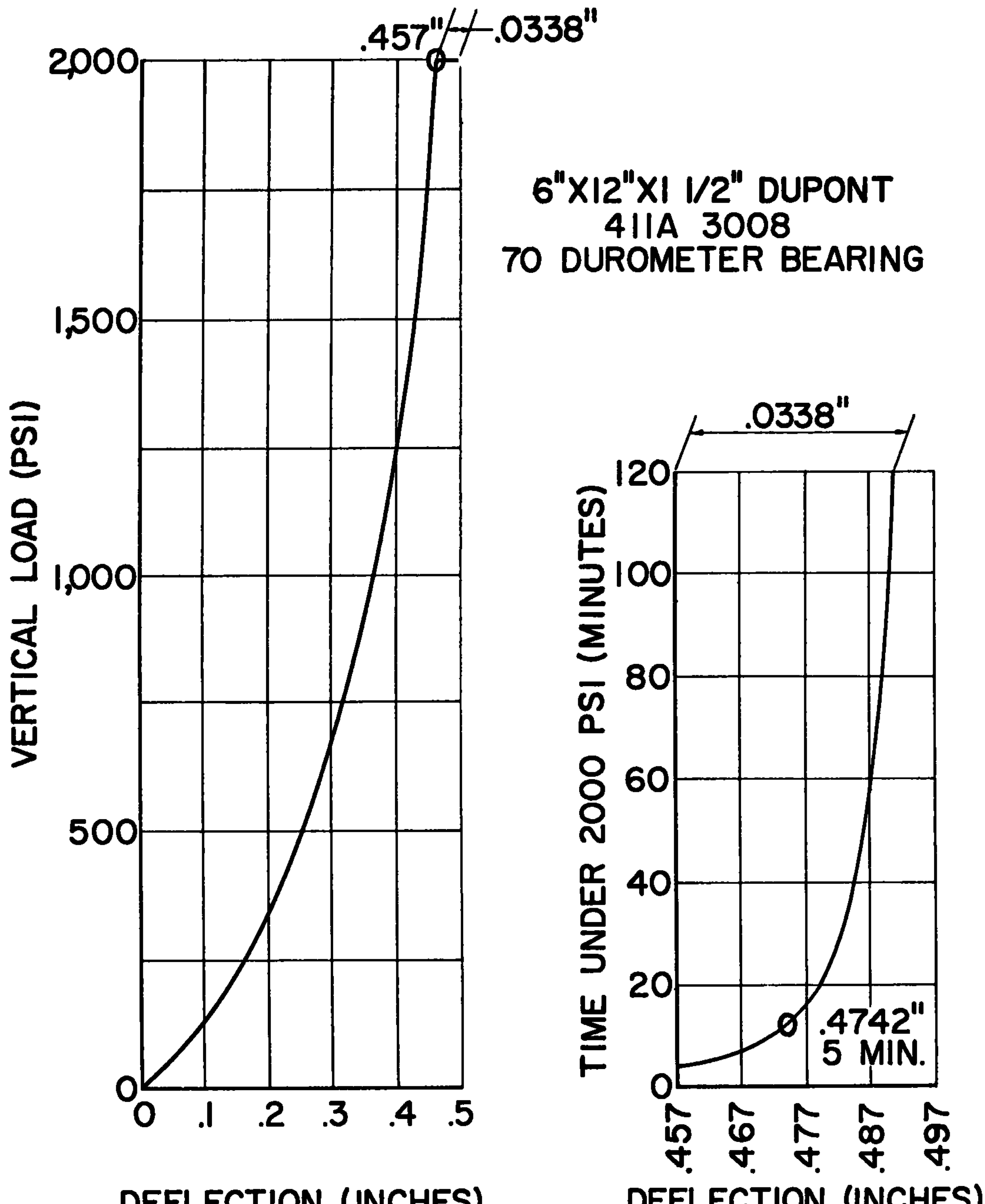

Figure 9. Vertical static loading.

The small vertical deflections and the limited effect of shape factor error is thought to be due to the large size of the samples tested. The curves indicate that shape factor determination with factors from 1 to 3 are consistent for use in predicting deformation

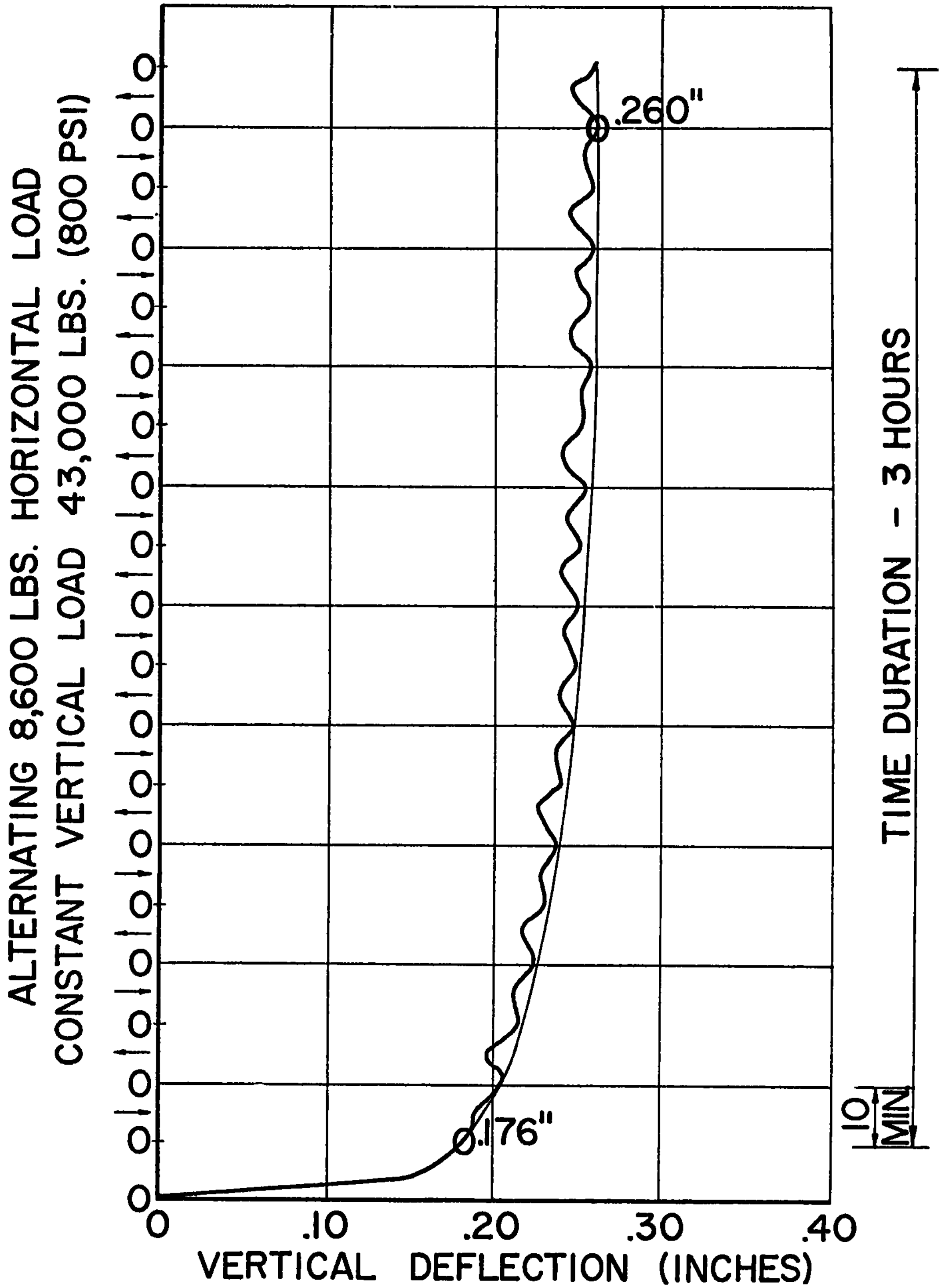

Figure 10. Horizontal fatigue loading.

under compression. As the shape factor increases above 3, the percent of error of the computed from the measured increases (Fig. 11).

Horizontal Deflections

The horizontal deflections measured due to horizontal shear loads were similar for all the bearings tested. Four important factors were determined for this condition of loading:

1. Direct compressive load has little appreciable effect on shear resistance.
2. Shear modulus of the elastomer increases with thickness.
3. Resistance to shear distortion increases as the stiffness of the elastomer increases.

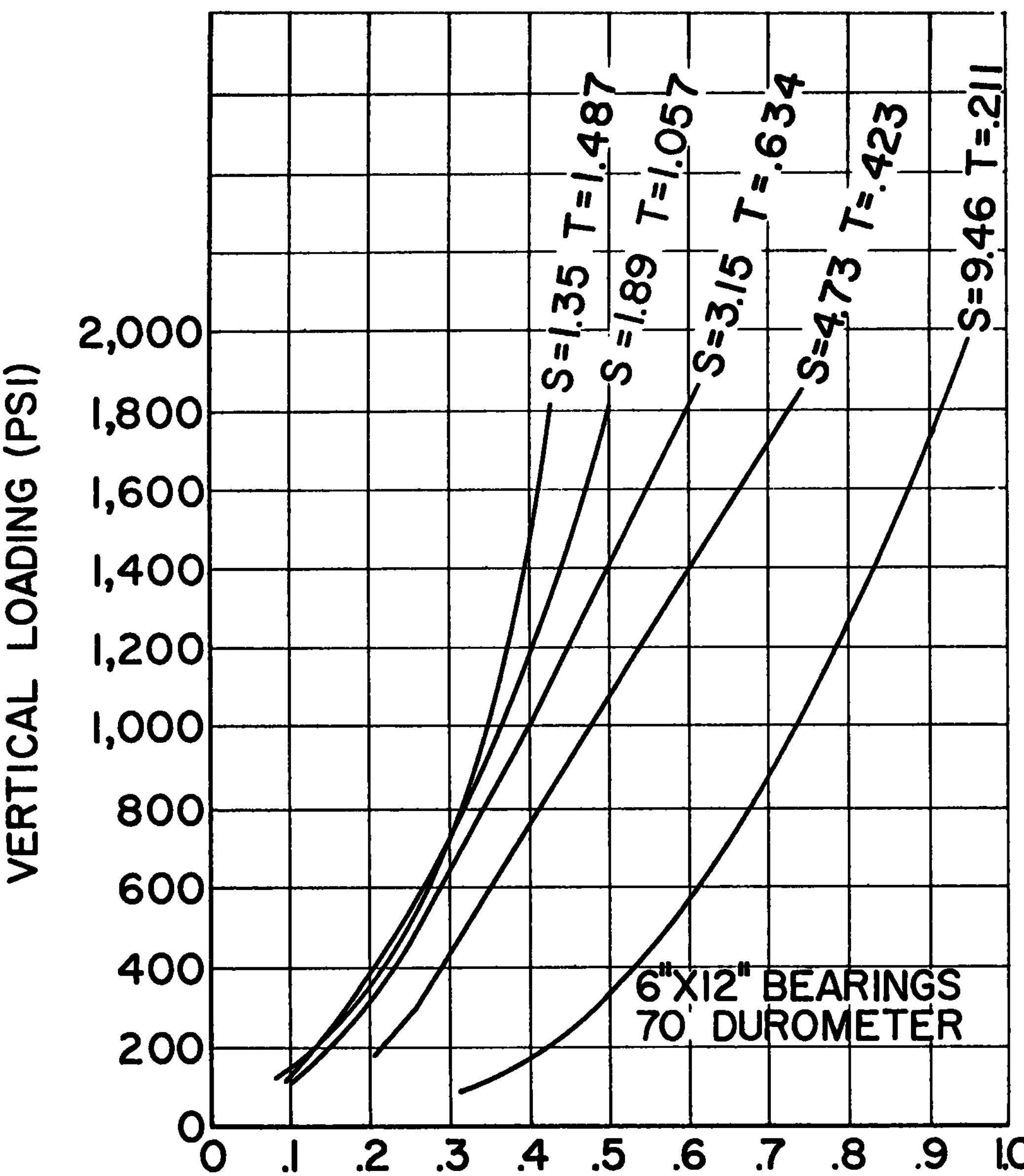

Figure 11. Effect of shape on vertical deflections.

4. The shape or orientation of the bearing has little or no effect on its shear resistance, unless the ratio of thickness to the minimum plan dimension is one-quarter or more.

A designer who knows what horizontal movement to anticipate can design an elastomeric bearing for almost any degree of restraint.

Dynamic Creep

An elastomeric bridge bearing under working conditions is subject to dynamic loading. The continual expansion-contraction action of the bridge deck will repeatedly deform the unit with reversing horizontal strains. The intermittent live load with associated vibrations will deform the elastomeric units to greater vertical deflections. These types of loadings are referred to as dynamic and the additional deflections appearing as a result are called dynamic creep.

Dynamic creep of the vertical deflections resulting from an alternating horizontal loading indicates that all static vertical deflection values arrived at by the use of charts in this report should be increased by 50 percent. A test to study dynamic vertical creep under intermittent vertical live load was not conducted.

The curve that resulted from the test of dynamic vertical creep under alternating horizontal load indicates that an additional 50 percent deflection is maximum for an indefinite period. This prognostication is based on one test. Many engineers believe that if the compression set of bridge bearing pads is kept below 20 percent, no significant amount of creep will occur. Compression set in the tests conducted for this report could not be measured accurately. The hysteresis curves indicate that compression sets would generally be less than 20 percent. It is obvious that additional tests are necessary for horizontal and vertical creep.

A fatigue test was attempted in 3 hours of alternating horizontal loading. The lack of fatigue may indicate that the duration of testing was insufficient. Additional tests particularly for fatigue in conjunction with extreme temperatures are recommended.

Negligible Factors

From this test program, three factors appear to be negligible for the design of bridge bearings.

1. The plan shape (not to be confused with shape factor) has little relationship to the vertical or horizontal stress-strain properties. The bearing unit may be round, rectangular or multi-sided. This provides the designer considerable freedom in selecting the plan shape to best fit the particular location.
2. Static creep is of negligible importance as dynamic creep yields much greater strain values.
3. There appears to be only slight variation of measured physical properties between bearings compounded to the same specification.

Design Factors

An important design and construction factor in the use of elastomeric bearings is the relation of the two bearing surfaces. When these surfaces are not parallel, one edge of the neoprene is subjected to high unit compression while the other side may be free of contact. Such a non-parallel condition may arise from (a) excessive camber or deflection in the beam; (b) roadway grade not parallel to the bearing seat; and (c) an uneven bearing seat.

To consider in detail the effect of these three factors is presently inadvisable as too little is known of the plastic action of elastomers. Until more precise information becomes available, the authors suggest the following procedure. Select a thickness of bearing for which the computed vertical deflection under dead load will be at least equal to the difference in thickness due to the greatest of the aforementioned three factors. This procedure is based on the assumption that a further increase in vertical deflection of 50 percent due to dynamic creep will adjust the bearing surfaces to a reasonably uniform bearing pressure.

Future Developments

The program of testing, completed by the Rhode Island Department of Public Works, together with the engineering firm of Charles A. Maguire and Associates, establishes within reasonable limits the physical properties at room temperature of the best neoprene now available for bridge bearings. Much more needs to be done.

The tests of elastomer properties proposed for current consideration by the American Association of State Highway Officials Bridge Committee are a starting point but are not considered sufficient for determining the adequacy of elastomers to be used in bridge construction.

The present tests are those that have been developed basically for the automobile industry. It is recommended that the American Society for Testing Materials develop additional tests more directly applicable to elastomeric bridge bearings.

Among the factors which should be considered in compiling new test requirements are tests for: a more stringent ozone resistance; freezing and thawing in a saturated condition; resistance to brine solutions; shear and compression at temperatures from -20 F to +160 F; dynamic creep; and simulated aging under service exposures.

Elastomer bearings should have a minimum useful life of 50 years, with a probable service life of 100 years.

The initial cost of the bearings is insignificant by comparison with the cost of replacement. For elastomeric bearings to be feasible they should outlast the estimated economic life of the structure they support.

DESIGN OF ELASTOMERIC BRIDGE BEARINGS

Utilizing the data collected from tests and other references the following is a suggested method for design of (neoprene) elastomeric bridge bearings.

Criteria

The brief specification below outlines general rules followed by Charles A. Maguire and Associates for the design of neoprene elastomeric bearings.

1. The maximum occasional vertical compressive load = 800 psi (live and dead loads).
2. The maximum continuous vertical compressive load = 500 psi (dead load).
3. The maximum horizontal shear deformation shall be equal or less than one-half the nominal thickness.
4. The maximum horizontal force from a deformed bearing shall equal or be less than 20 percent of the minimum vertical compressive load.
5. The minimum plan dimension shall equal or be greater than 5 times the thickness.
6. The estimated maximum vertical deflection shall be the vertical deflection derived from the charts or computed by formula increased 50 percent for dynamic creep.
7. The vertical deflection derived from the charts or computed by formula shall be greater than the tangent of the surface slope angle times the length of the bearing.

Formulas

The following equations are derived from the graphs on neoprene elastomeric bearings.

$$\text{Vertical deflection under vertical load (in.)} = \left(\begin{array}{c}\text{nominal}\\ \text{thickness}\\ \text{(in.)}\end{array}\right) \frac{(C_1 \times \text{Vertical load (psi)} + C_2)}{(100 \times \text{Shape Factor})}$$

$$\begin{array}{c}\text{Horizontal Force from}\\ \text{deformed bearing}\\ \text{(psi of plan area)}\end{array} = \frac{\begin{array}{c}\text{Modulus of}\\ \text{Shear-G (psi)}\end{array} \times \begin{array}{c}\text{Horizontal}\\ \text{deformation (in.)}\end{array}}{\begin{array}{c}\text{Nominal}\\ \text{thickness (in.)}\end{array} - \begin{array}{c}\text{Vertical deflection}\\ \text{under vertical load (in.)}\end{array}}$$

Values for G, C_1 and C_2 by durometer hardness:

Shore A Durometer	G	C_1	C_2
60	90 psi	0.030 sq in. per lb	12.0
70	160 psi	0.025 sq in. per lb	10.5
80	310 psi	0.020 sq in. per lb	6.0
90	580 psi	0.015 sq in. per lb	1.5

Procedure

There are a number of methods for locating elastomeric bearings under the stringers or girders. The standard arrangement shown in Figure 13 would have one end of the superstructure stringer pinned to the substructure with an elastomeric bearing at the other end to permit horizontal movement. A second method or equalized arrangement (Fig. 14) involves an equal capacity elastomeric bearing under each end. This allows each bearing to absorb more or less one-half the horizontal movement. The longitudinal forces due to traction and wind are, however, resisted only by the bearings extended in the direction of the applied force.

A compromise procedure would require two elastomeric bearings of variable thickness and size which may be designed to provide any degree of restraint between standard and equalized arrangements.

The procedure for the construction of any one bearing will depend on basically the required thickness. When the thickness of one unit exceeds 1¼ in. it is suggested a multi-unit be used. With this construction method the vertical deflections and horizontal forces from shear movements are kept to a minimum.

Design Problem

A simple beam can be analyzed as follows. This typical beam spans 60 ft between supports and has a camber under dead loads of 1¼ in.—neoprene bearings to be designed in an equalized arrangement.

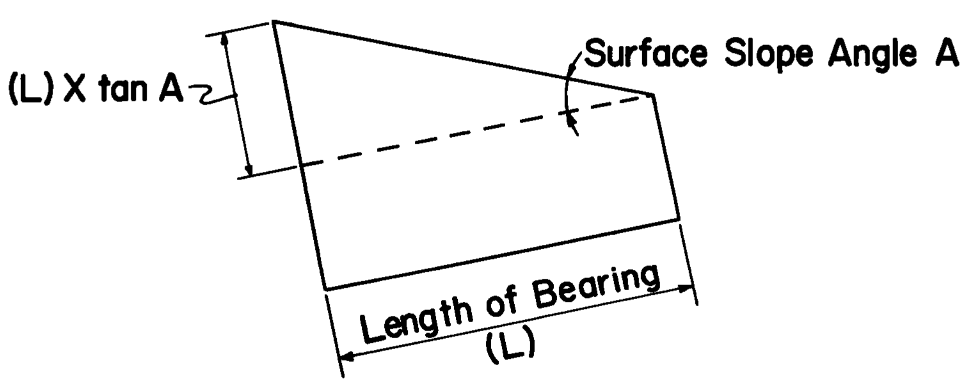

Figure 12. Diagram of the surface slope angle.

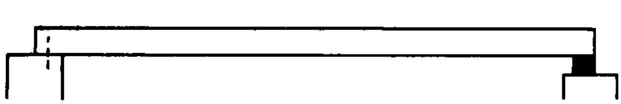

Figure 13. Standard arrangement.

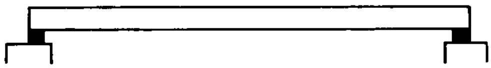

Figure 14. Equalized arrangement.

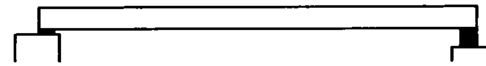

Figure 15. Varied arrangement.

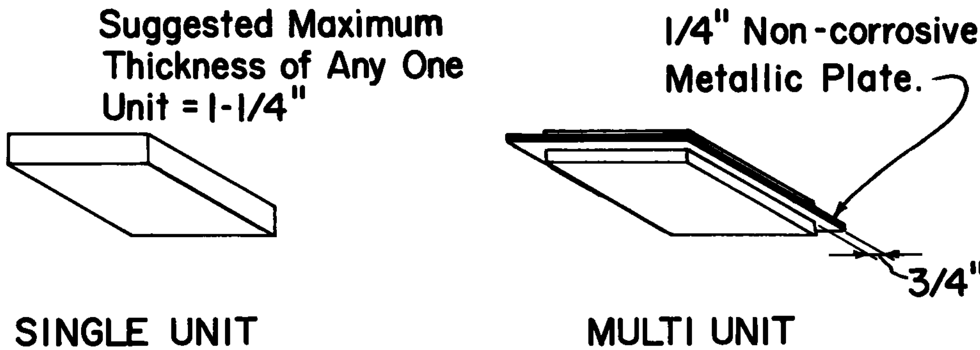

Figure 16. Bearing construction.

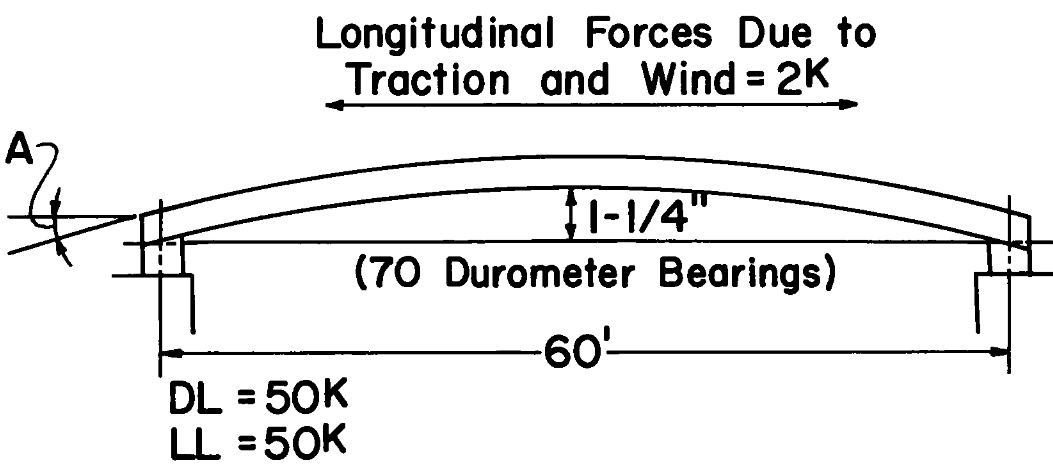

Figure 17. Simple beam example.

Change in length due to temperature $= \frac{60 \text{ ft} \times 12 \text{ in./ft} \times 40 \text{ F} \times 0.000008}{2} = 0.115$ in. each end.

$$\text{Area} = \frac{P_{max.}}{800} \text{ or } \frac{P_{D.L.}}{500} = \frac{100,000}{800} \text{ or } \frac{50,000}{500} = 125 \text{ sq in.}$$

assume width = 14 in., length = 9 in., thickness = ¾ in.

$$\text{Shape Factor} = \frac{14 \times 9}{2 \times 3/4 \times -14+9)} = 3.66$$

$$\text{Maximum vertical load} = \frac{100,000}{14 \times 9} = 795 \text{ psi}$$

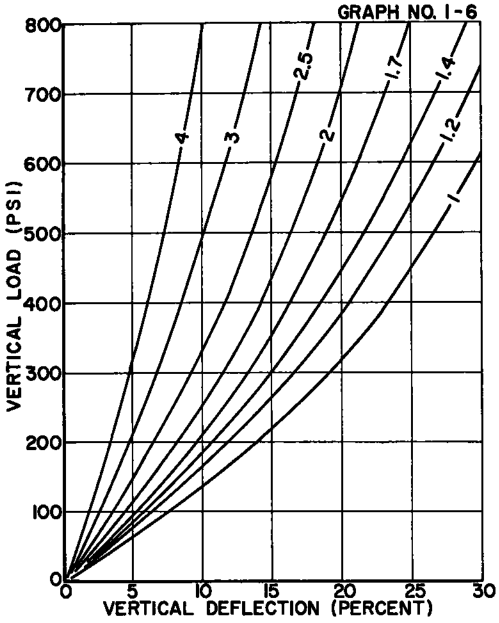

Figure 18. Vertical stress-strain by shape factor— 60 shore A durometer neoprene elastomers.

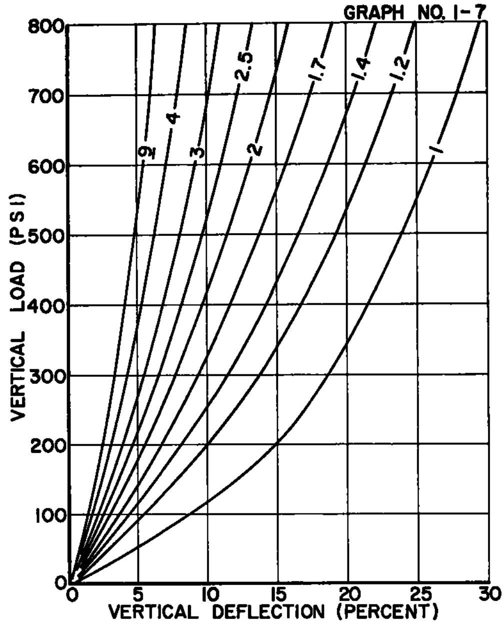

Figure 19. Vertical stress-strain by shape factor— 70 shore A durometer neoprene elastomers.

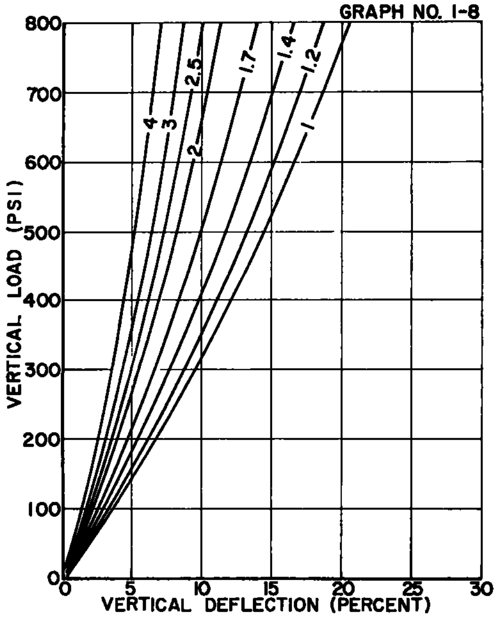

Figure 20. Vertical stress-strain by shape factor— 80 shore A durometer neoprene elastomers.

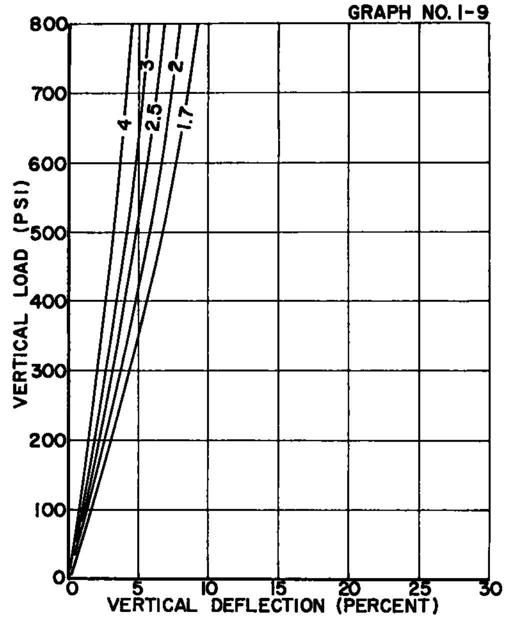

Figure 21. Vertical stress-strain by shape factor— 90 shore A durometer neoprene elastomers.

From graph 1-7: for a shape factor = 3.66 and a vertical load = 795 psi; the resulting vertical deflection = 9 percent or 0.067 in. The tangent of the surface slope angle A times the length L = 0.063 in. This value is less than the vertical deflection and therefore satisfactory.

From graph 2: for a 70 durometer bearing and a ratio of

$$\frac{0.115 \text{ in. (horizontal deformation)}}{0.75-0.06 \text{ in. (vertical thickness under load)}} = 0.17.$$

The resulting horizontal shearing force = 37 psi. Add to this the stress due to the longitudinal forces ($= \frac{2000 \text{ lb}}{126 \text{ sq in.}} = 15.8$ psi) and the total shearing force = 52.8 psi.

No sliding of the surfaces will occur if 20 percent of the minimum load on the bearing $\left(= \frac{0.2(50,000)}{126} = 79.5 \text{ psi}\right)$ is greater than the maximum shearing force. Which it is: 79.5 > 52.8.

From graph 2: for a 70 durometer bearing and a force of 52.8 psi, the resulting ratio = 0.28. The total horizontal movement at each end = 0.28 x 0.68 = 0.191 in.

The final vertical thickness after dynamic deflections = 0.75 in. - 1.5 (0.0675 in.) = 0.649 in.

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Discussion

S.D. McCREADY, Product Engineer, Dupont Company, Wilmington, Delaware—An elastomer bearing is primarily a flat rubber pad with lateral dimensions less than the pier or abutment it is seated on. It is placed between the support area with the girder resting on it. As the girder expands and contracts, the pad deflects horizontally in shear.

Under a compressive load the elastomer pad absorbs surface irregularities and distributes all forces uniformly. In shear, the neoprene bearing reacts as a spring, the resistance of which can be calculated at all times. There is no starting friction to overcome or no corrosion deposit to break loose. Another important advantage of a neoprene bearing is its freedom from costly maintenance. There is no need for lubrication or cleaning.

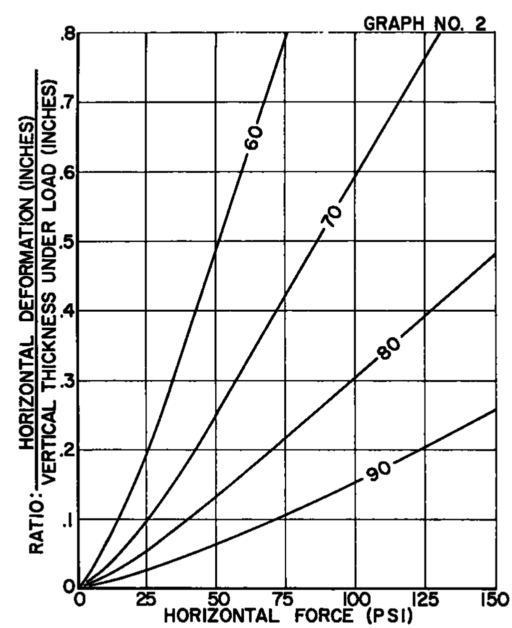

Figure 22. Horizontal stress-strain by shore A durometer.

The elastomer bearing pad was first used in France in rebuilding the bridges destroyed during World War II. The Freysinett Company, pioneers in prestressed concrete, did a lot of the original engineering on the subject. The English also are using elastomeric bridge pads and they too have developed engineering data on the subject.

About two years ago, according to records, the state of Texas became interested in elastomer bridge pads. At this time, the market was investigated and a high quality neoprene vulcanizate was recommended. The subject is actively being pursued, because it is believed that neoprene is the best all-around elastomer presently available for the application.

The Dupont Company manufactures neoprene—a synthetic rubber that is employed in elastomeric bearing pads. Because of this they are interested in assisting in the development of the bearing pad market and insuring that proper design considerations be applied to neoprene for maximum efficiency in service. They have, therefore, offered their assistance to the American Association of State Highway Officials, engineers, architects, and contractors on the subject.

A brief comment on the serviceability of neoprene pads at low temperatures follows. All elastomers tend to stiffen at successively lower temperatures. The rate and extent of stiffening is dependent upon the type of elastomer, the compounding ingredients used, and the state of vulcanization attained.

The rate and extent of stiffening of neoprene pads can readily be determined by laboratory tests. From these tests, it is believed that at temperatures normally experienced in this country, neoprene bridge bearings will be serviceable. As Pare has said however, further field work should be carried out on the subject. Under service conditions, the rate of shear movement in an elastomer bearing is extremely slow. Since stiffness is related not only to temperature but to rate of movement, a greater factor of safety is insured than would be predicted from laboratory tests.

A number of bridges in Ontario, Canada have successfully utilized neoprene pads and have performed satisfactorily over a winter period. A new span under construction in the White River area of Ontario, on the northeast side of Lake Superior, will employ neoprene pads over an expected temperature range of -65 to +120 F.

The amount of horizontal distortion to which a neoprene pad can safely be subjected has been discussed in many quarters lately. Rubber industry experience over the years has shown that neoprene vulcanizates, of a similar type and hardness to that specified in bridge bearing pads, can be distorted in shear 20 to 25 F in either direction from the neutral axis without difficulty. Therefore, it is believed that Pare's conclusions with regard to maximum attainable distortion are sound.