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HIGHWAY RESEARCH REPORT

LABORATORY AND FIELD PERFORMANCE OF ELASTOMERIC BRIDGE BEARING PADS

By

Eric F. Nordlin

J. Robert Stoker and R. R. Trimble

68-07

Presented at the 47th Annual Meeting
of the Highway Research Board
January, 1968

STATE OF CALIFORNIA

TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 646142-1

State of California
Department of Public Works
Division of Highways

LABORATORY AND FIELD PERFORMANCE OF ELASTOMERIC BRIDGE BEARING PADS

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Presented at the 47th Annual Meeting
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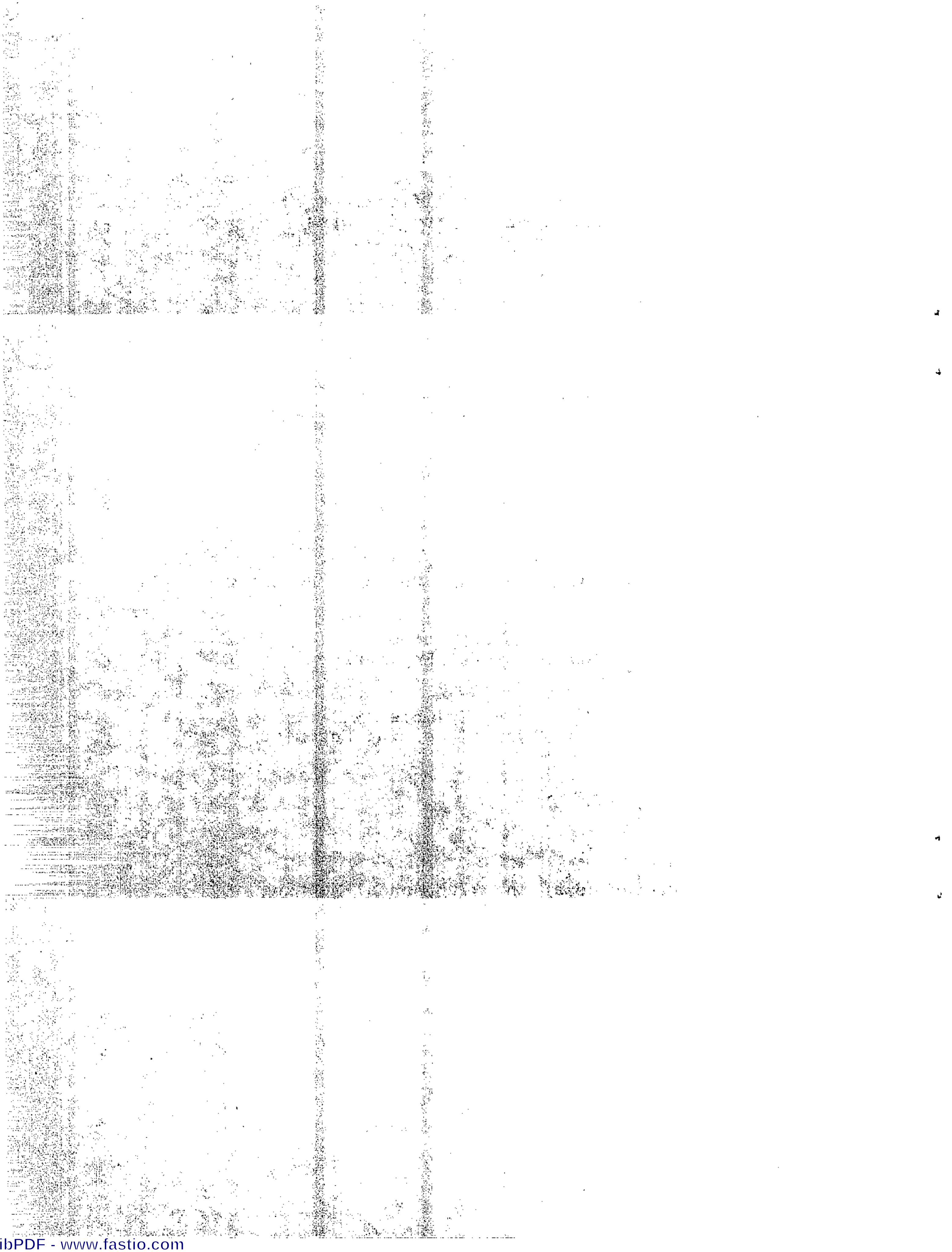
January 1968

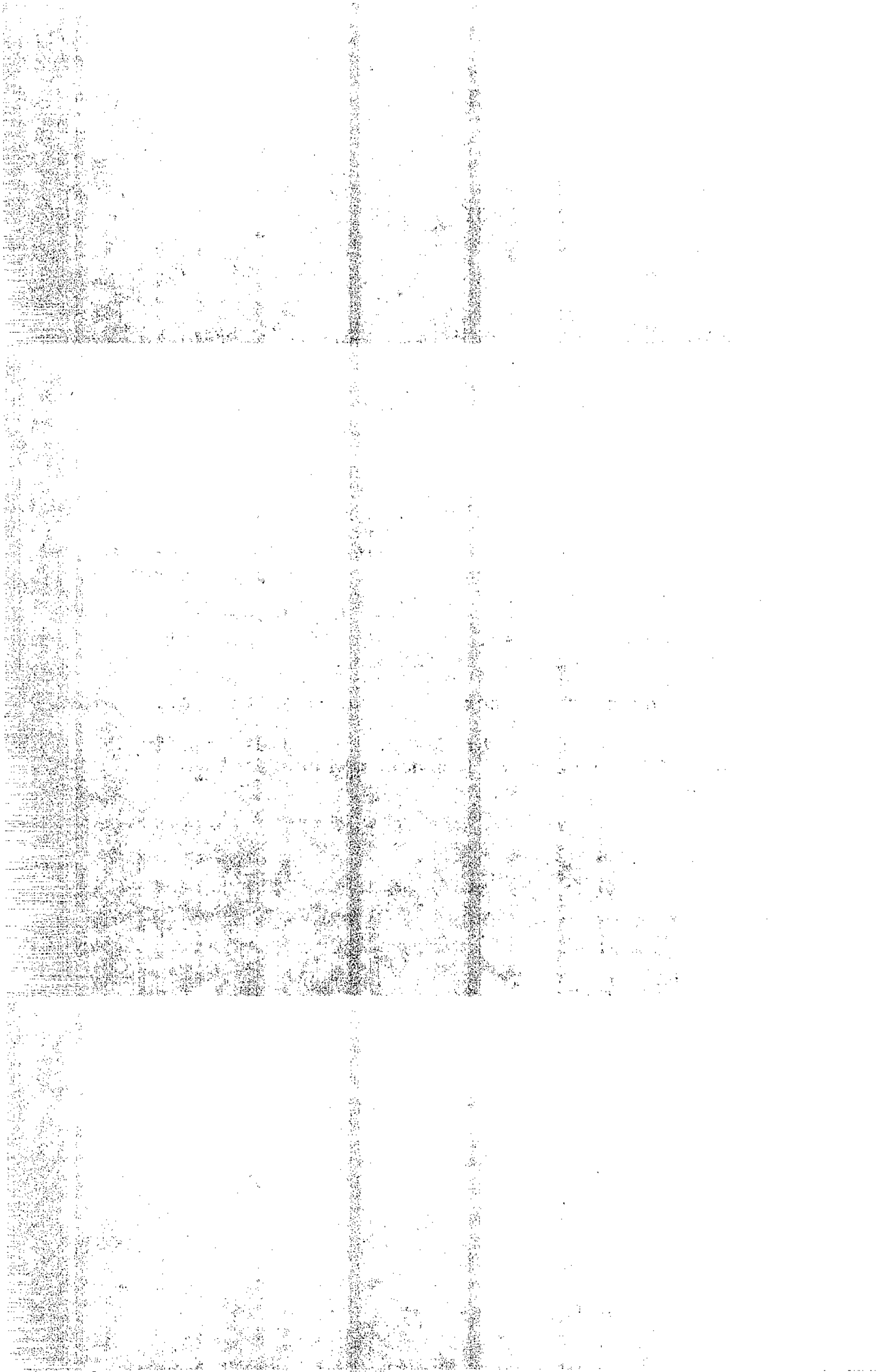


ABSTRACT

REFERENCE: Nordlin, E. F., J. R. Stoker, and R. R. Trimble, "Laboratory and Field Performance of Elastomeric Bridge Bearing Pads", State of California, Department of Public Works, Division of Highways, Materials and Research Department. Research Report 646142-1, January 1968.

ABSTRACT: A study to determine the best design for an elastomeric bridge bearing pad is reported. This included the development of a fatigue testing machine which can maintain a predetermined normal load and move the top surface of the pad with respect to the lower surface under this load. Solid elastomeric pads as well as pads laminated with various materials and bonded by various methods were evaluated. Findings indicate that for the best overall performance, each composite bearing pad should consist of neoprene layers not to exceed ½" in thickness with either steel, dacron, or nylon bonded to the interface between horizontal layers and to the exterior surfaces of the pad.

KEY WORDS: Bridges/structures, bridge bearing pads, testing, testing machines, fatigue tests, laminates, neoprene, composite materials.



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INTRODUCTION

A. Background

With the introduction of prestressed concrete I-beams to California highway structures in the mid 1950's, the need arose for a simplified and economical bearing to effectively carry the load and to accommodate the comparatively severe end rotations and translation that are typical of such structures. The design problems, high fabrication costs, and construction problems associated with conventional bearings in this application made their universal use impractical. Asphaltic fiberboard pads, graphite coated asbestos sheet packing and lubricated sliding plates exhibited inadequate performance.

The criteria used in judging the adequacy of a bearing include (1) uniform load transfer and distribution in both contacting elements, (2) the accommodation of bearing rotation due both to elastic and plastic changes within the structure, (3) provision for lateral and longitudinal movements due to thermal forces and other factors, (4) durability, (5) economy, and (6) a maintenance-free service life. In order to satisfy these criteria, particularly for application to prestressed bridge structures, the California Division of Highways initiated an investigation in 1955 to evaluate the use of elastomeric bearing pad assemblies.

The following is a report covering the development of an adequate elastomeric bridge bearing design and specification. The development of the present specification covering the properties of elastomeric bearings is the result of the correlation between field performance, laboratory fatigue tests, and physical property determinations.

B. Test Method Development

At the program's inception, it was felt that a testing machine that could simulate the vertical and horizontal loads to which an expansion bearing is subjected in a structure would be the best method to evaluate probable field performance. A fatigue testing machine was designed and constructed with the following capabilities: normal vertical load capacity up to 100 kips applied by a hydraulic ram, horizontal translation force capacity up to 10 kips applied by a hydraulic ram with a stroke of 3 inches, and variable cycling speeds of zero to approximately eight inches per minute. An SR-4 strain gage load cell connected to the translation ram provides for accurate monitoring of the dynamic forces and accurate computation of the internal shear or resistance to lateral translation within the pad.

Test Method No. Calif. 663-A (Appendix I) describes the testing procedures and machine operation for performing the fatigue test developed in this study.

DISCUSSION

A. Pad Development

The initial study was concerned with one inch solid elastomeric pads in the laboratory as well as two field installations. These solid pads were the first promoted by the industry and were of a 70 Shore "A" durometer hardness. Results of laboratory fatigue tests conducted in accordance with Test Method No. Calif. 663-A indicated that this type of pad, previously installed in the field, would fail by horizontal splitting approximately in the middle of the pad due to excessive bulging and creep of the elastomer (Figs. 1 and 2). Within two years after installation, the field applications showed the same distress as the laboratory test specimens. In an attempt to remedy this problem, several manufacturers fabricated test specimens of various configurations following basic design criteria used in Europe.

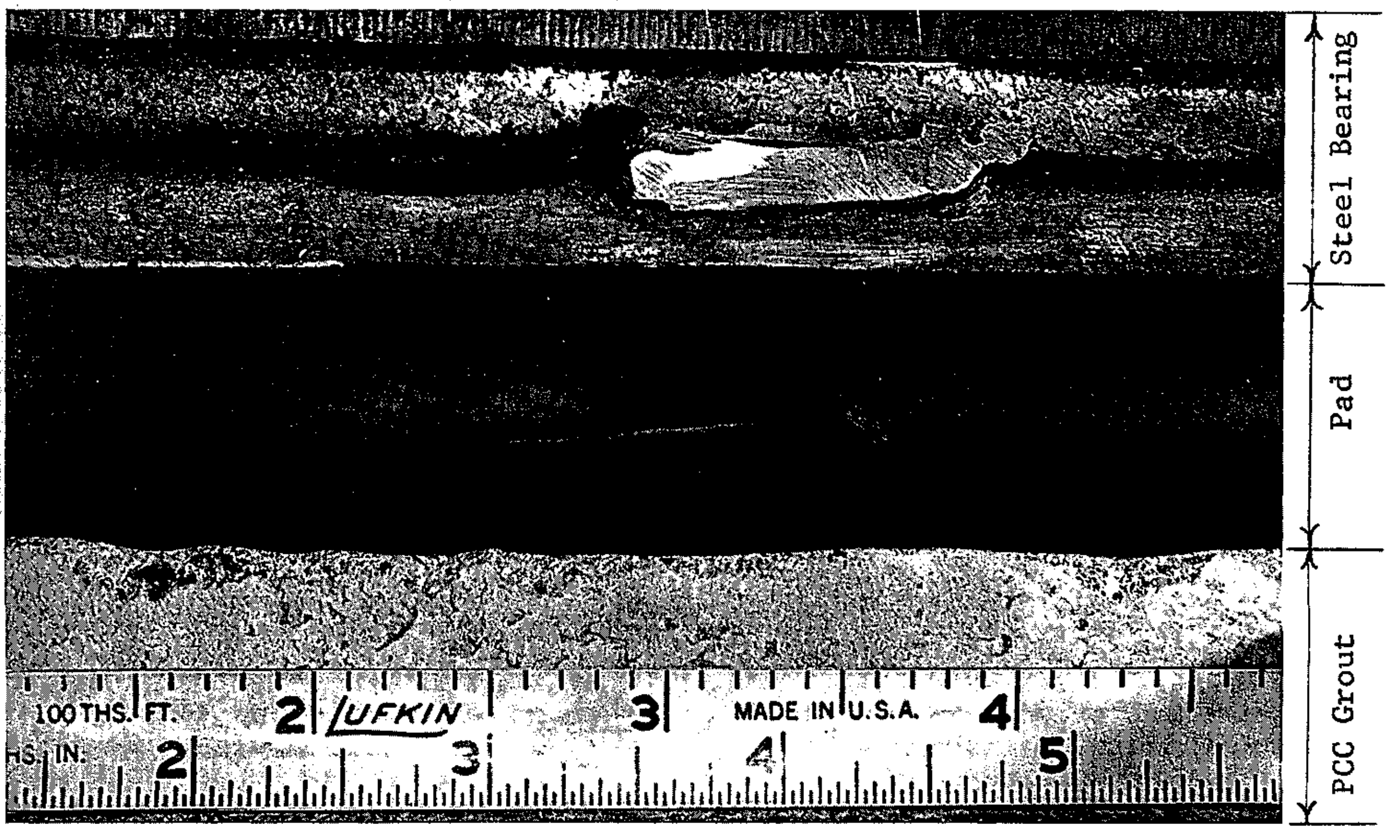


FIGURE 1

Typical Splitting Failure in Fatigue Testing Machine

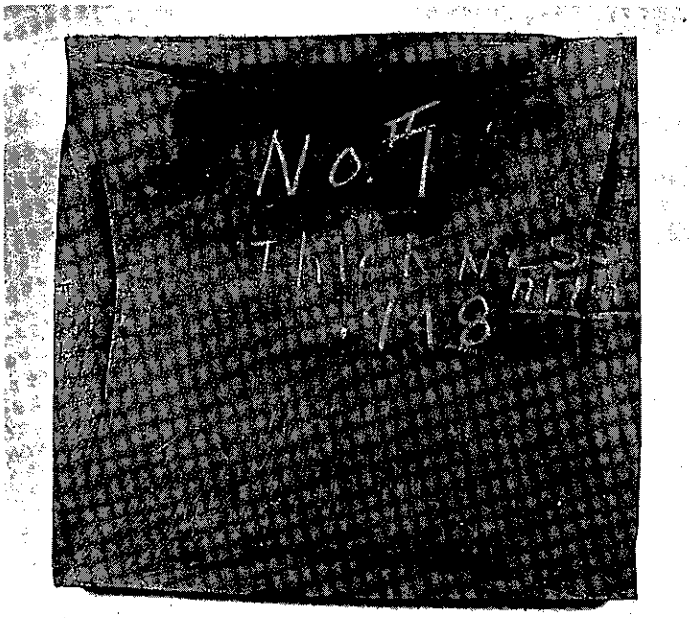


FIGURE 2

Permanent Distortion of 1" Solid Elastomer Pad
After Fatigue Testing.

Metal plates or inserts were bonded to layers of neoprene in an attempt to control the excessive internal stress that apparently was the cause of splitting or separation of the solid pads. Various inserts were tried, such as stainless steel mesh, aluminum sheet, and steel sheets bonded with various cementing agents. The only successful bonding of metal laminations to the elastomer was by the fully molded and heat vulcanized process. Industry recommended using 20 ga. carbon steel sheet since it appeared to be the most economical and easiest to mold into an elastomeric pad.

Early fatigue tests demonstrated that a better than average quality elastomer was required to withstand the severe tri-axial stresses and provide adequate service. Typical early test results are illustrated in Figs. 3 and 4. As a result, several manufacturers suggested physical specifications for a good quality neoprene designed to give at least a 50 year life in most exposures in California. These suggestions were used as a guide in developing our current material specifications (Appendix II) which include the requirement of high neoprene content (min. of 60%) to overcome the attack from high ozone concentrations present in metropolitan areas in California.

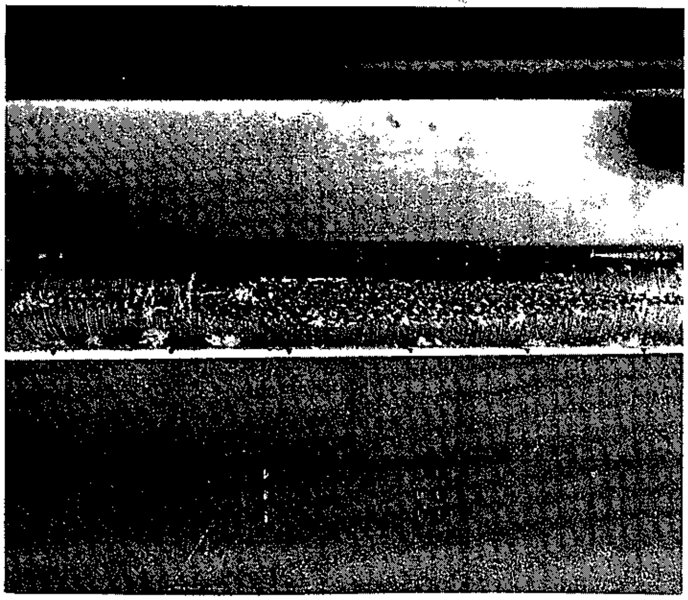


FIGURE 3

Typical splitting failure of fabric laminated pad due to inadequate bonding.

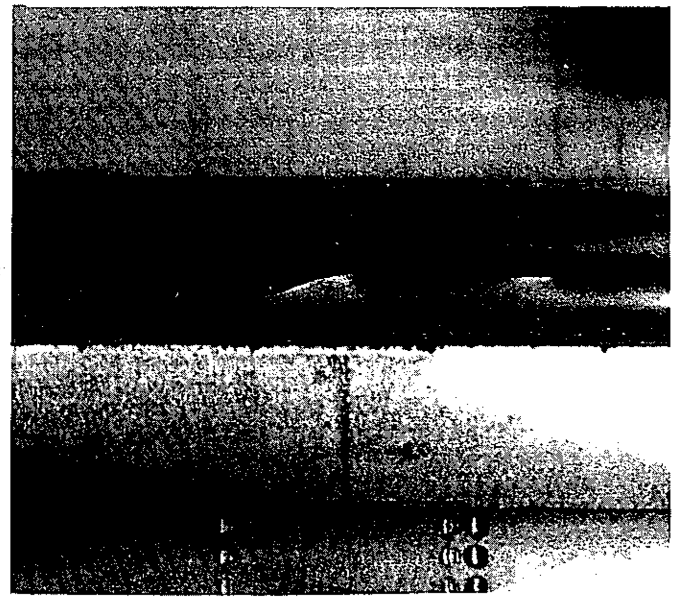


FIGURE 4

Typical splitting failure of steel sheet laminated pad due to inadequate bonding.

With one possible exception, we are in general agreement with industry in regard to the physical property requirements of the elastomer. Although we feel that the tear test is an indicator of the properties required of a good quality elastomer, we have found that correlation of test results are extremely difficult to obtain between different specimen cutting dies. Repeatability with any individual die, however, appears to be very good. Therefore, this test is of definite value as a manufacturing quality control tool. Correlation testing between the consumer's and manufacturer's laboratories should eliminate apparent disagreement in values obtained and questions over specification compliance.

Design criteria for laminated pads were established by laboratory fatigue testing. Variables in these tests included hardness of the neoprene elastomer and thickness of elastomer laminations. Design limitations established as the result of the testing were: (1) a hardness range of 50 to 60 Shore "A" durometer, (2) a maximum lamination or layer thickness of 1/2 inch, and (3) an unreinforced pad thickness of 1/2 inch maximum.

In an attempt to simplify the lamination process and reduce fabrication costs, one manufacturer fabricated pads reinforced with nylon or dacron fabric in lieu of steel sheet (Fig. 5). Fatigue tests on these pads showed them to be superior in performance to those reinforced with steel sheet, due to lower shear forces within the elastomer, as indicated by reduced lateral force required for a given displacement. Furthermore, these pads can be manufactured economically in large slabs of any desired thickness and readily cut to size to satisfy job requirements. Our specifications were then changed to permit the use of fabric reinforcement. Most California manufacturers subsequently changed to the use of fabric reinforcement, enabling them to manufacture pad stock in sizes as large as 4 x 6 feet.

A further advantage to the use of fabric laminated pads is the elmination of a corrosion problem created by the exposed edge of sheet steel laminations due to a sheared or damaged molded edge. This problem may be avoided by the use of stainless steel sheet; however, economy of this alternate is questionable.

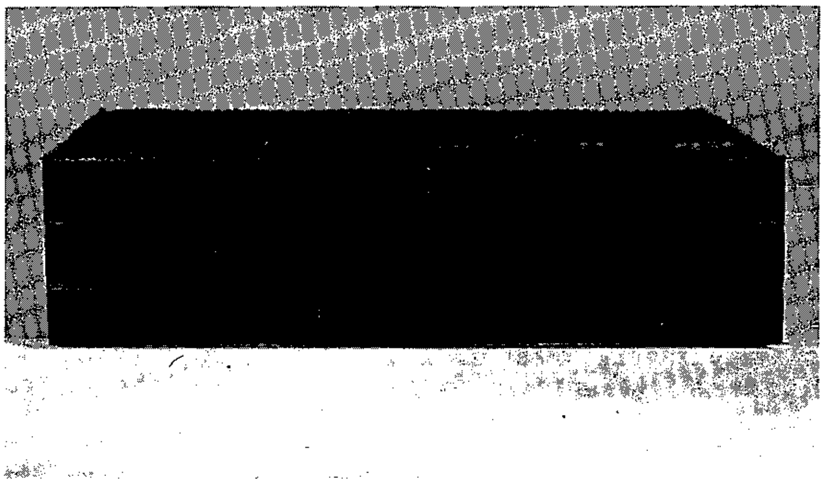


FIGURE 5

Dacron Fabric Laminated Elastomeric Pad with Double Fabric Layers at Interface of ½" Thick Neoprene Elastomer Layers and Single Fabric Layers on Both Bearing Faces.

B. California Practice

The fabric reinforced pad design was first used on bridge structures in 1958. Since that time most of the structures built in California calling for elastomeric expansion bearings have utilized this design. Subsequent inspections indicate no signs of distress in this type of bearing. The need for a good quality elastomer cannot be overemphasized. Conformance to high quality requirements is believed to be the main reason for the successful performance of elastomeric pads in California bridges.

Field investigations have shown that the pad should not be larger than the actual bearing area. When the pad is larger than the bearing area, bulging along the unloaded edges produces combined stresses that may cause the pads to split.

If the dead load bearing stress is less than 300 psi, a method of retaining the pad in position should be provided. Three 1" diameter drill point recesses in a steel sole plate provide adequate lateral keying action for a pad size of 10 x 18 inches with a bearing load of 300 psi. This is a standard detail for use on precast prestressed bridge girders.

Experience has shown that there is no need for making wedge shaped pads to accommodate out-of-parallel bearing surfaces. Where relatively large angles (over 5°) are involved, a beveled steel shim plate will readily serve the purpose more economically than custom-made beveled pads.

Elastomeric bearing pads have been used successfully on a variety of bridges in California including steel girders, precast concrete girders, precast prestressed concrete girders, and cast-in-place conventional and prestressed concrete structures (Figures 6 through 9). The greatest movement has been accommodated on multispan continuous prestressed bridges including five 3-span structures varying in over-all length from 360 to 465 feet. Pads as thick as 3½" and with bearing areas of up to six square feet have been used in California as bearings for structural members on some of these multispan bridges. On these structures bearing pad design thickness was based only on movement after initial shortening due to prestressing and initial concrete shrinkage had taken place. This criteria was based on the fact that when much of the initial movement is taking place the structure dead load is essentially being carried by the false work, permitting slippage of the concrete-pad interfaces until prestressing is nearly completed. This results in considerably less pad thickness than would be required by design criteria used in Europe and by some agencies in this country where the pad thickness is based on total movement.

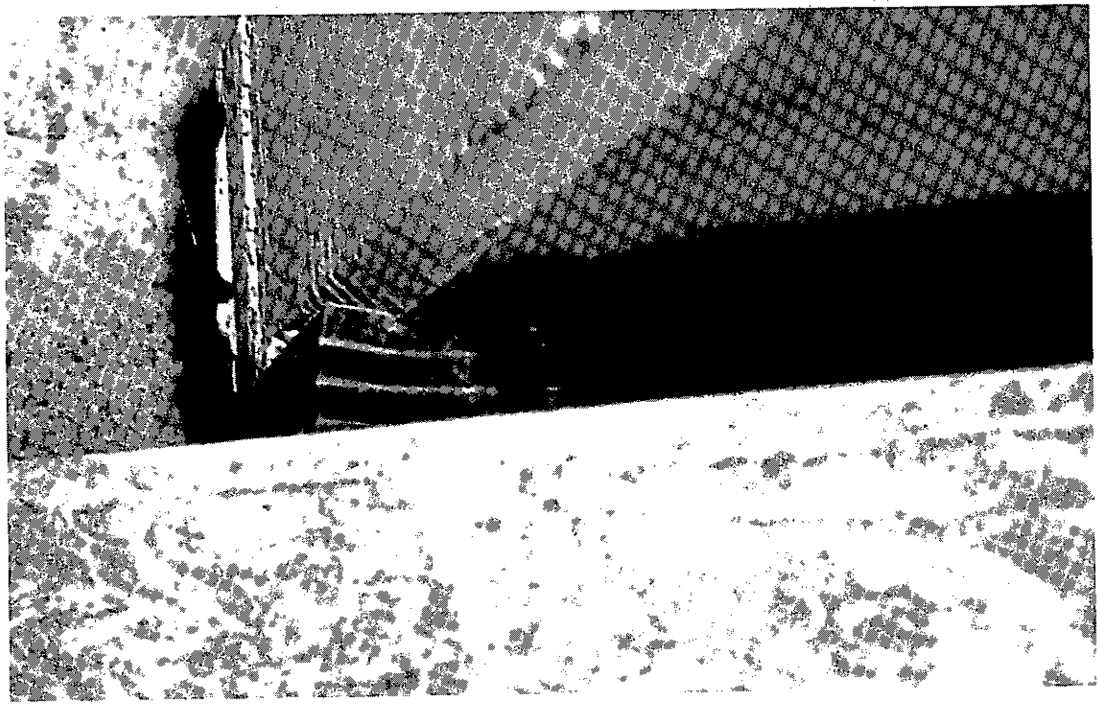


FIGURE 6

Fabric Laminated Pad Installation on a Precast Prestressed I-Girder Bridge. Note Bulging of Exposed Pad Illustrating the Desirability of Limiting the Pad Size to the Bearing Area.

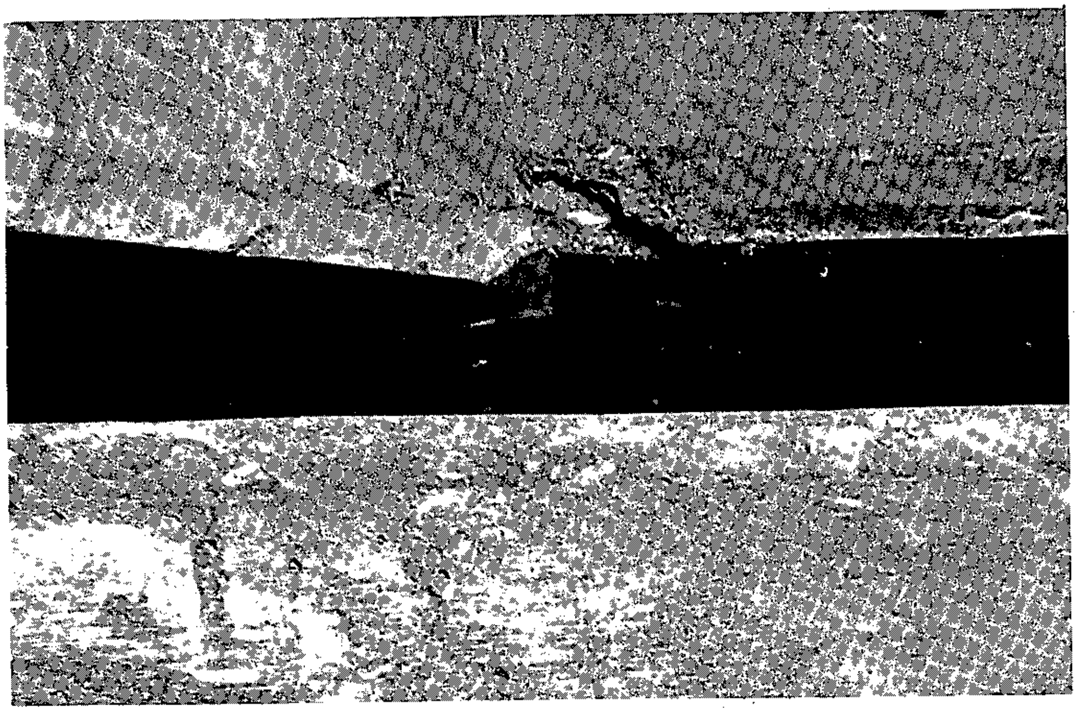


FIGURE 7

Fabric Laminated Pad Installation on a Precast Prestressed I-Girder Bridge.

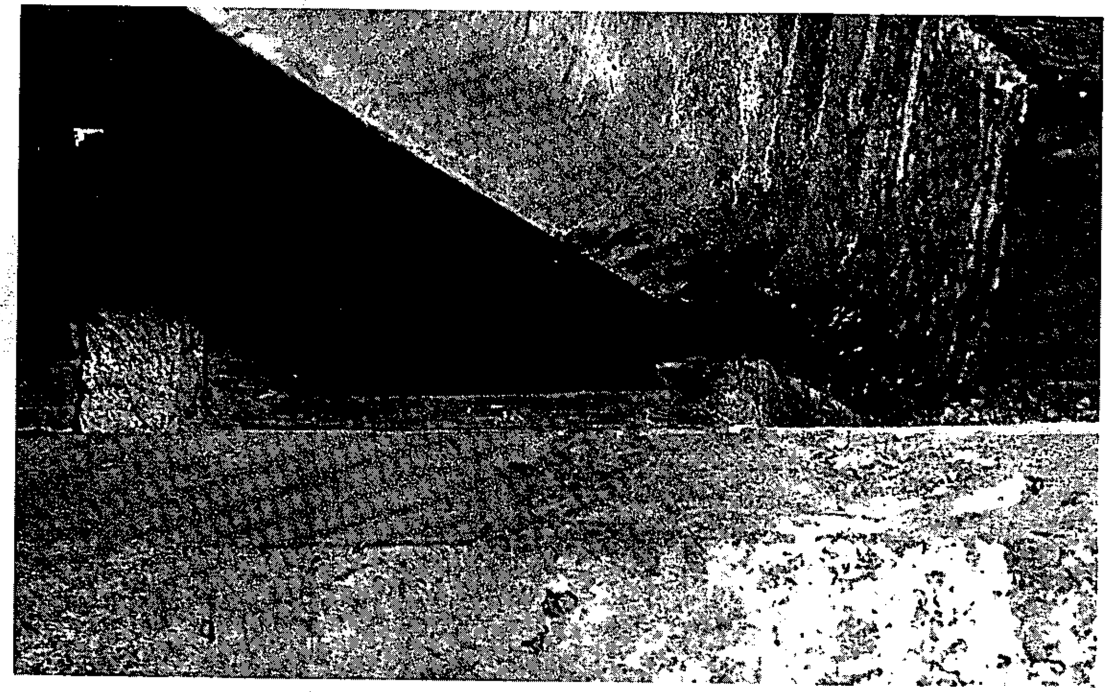


FIGURE 8

Steel Sheet Laminated Pad Installation on a Precast-Prestressed T-Girder Bridge.

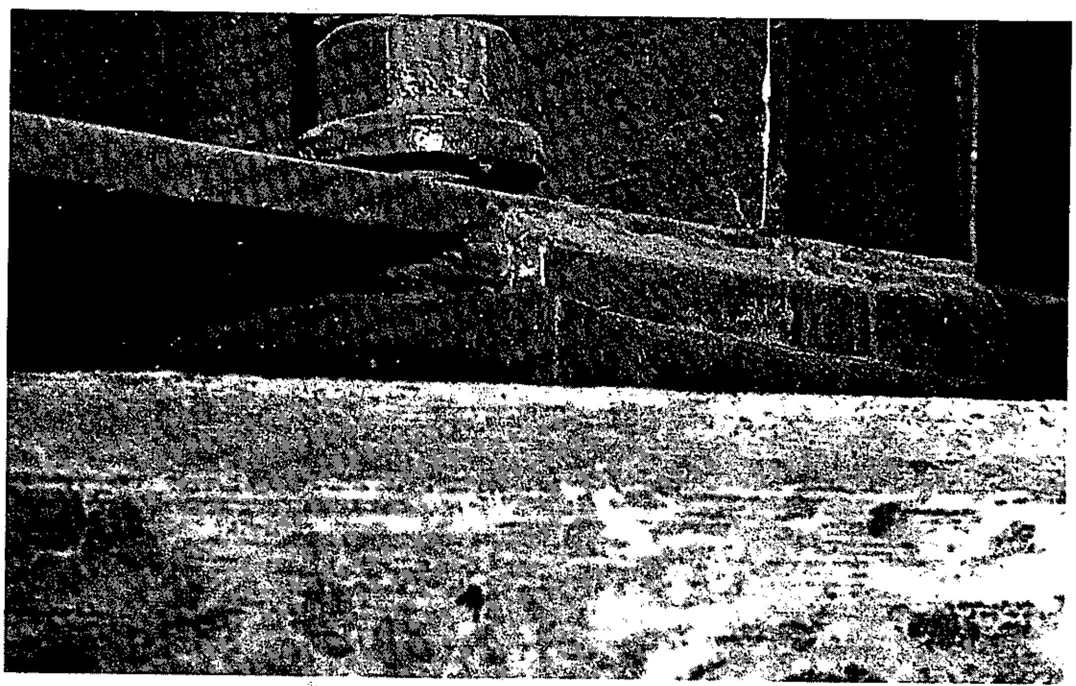


FIGURE 9

Solid Elastomeric Pad (1 in. thick) Installation on a Welded Steel Girder Bridge. Note Beveled Steel Sole Plate to Compensate for Slope.

Current design criteria used by our Bridge Department include the following limitations:

1. Thickness of pad shall not exceed on-fifth of the width (least dimension) or be less than twice the maximum horizontal movement. Minimum thickness is one inch (two ½" layers).

2. Initial vertical deformation (including rotation or non-parallel bearing surfaces) shall not exceed 15% of the uncompressed thickness of the pad. Maximum pressure on the pad shall not exceed 800 psi (includes dead load, live load, and impact).

3. $\text{Shear Force} = \frac{\text{Modulus x Area x Movement}}{\text{Pad Thickness}}$ shall not exceed one-fifth of the dead load.

Design temperature ranges provide for actual climatic conditions with an added factor to allow for shrinkage and creep after the bearing is loaded.

It should be noted that none of the California highway installations of elastomeric bearing pads are in areas that are considered to be cold temperature exposures. Installations in such exposures were avoided since most of our structures are in mild climate areas and little information was available until recently regarding cold temperature characteristics of neoprene working under anticipated stresses in elastomeric bearing pads. Recent reports[1,2] indicate that temperatures down to -40° F. will not adversely affect performance of a good quality neoprene elastomer bearing pad.

CONCLUSION

Elastomeric bearing pads laminated with sheet steel, dacron fabric or nylon fabric in layers not exceeding 1/2 inch thickness are a satisfactory alternate for most conventional fixed and expansion bearings on short to moderate span highway bridge structures, both from the design and economic viewpoint. Ease of fabrication and installation followed by maintenance-free performance all serve to make this a desirable alternate to more conventional bearings. This general conclusion is based on the following factors:

1. Laminated elastomeric bridge bearing pads have performed satisfactorily in both laboratory and field tests for the past 10 years in California.

2. Fabric laminated pads have performed as well as the steel laminated pads, with greater convenience and economy.

REFERENCES

1. Suter, G. T. and R. A. Collins, "Static and Dynamic Elastomeric Bridge Bearing Tests at Normal and Low Temperatures", Department of Civil Engineering, University of Toronto, Toronto, Ontario.

2. Du Pont, E. I. de Nemours & Company, "Design of Neoprene Bridge Bearing Pads", Elastomer Chemicals Department.

ACKNOWLEDGEMENTS

1. Kuhlman, H. F. (Retired), the original California Division of Highways investigator, contributed much to the development of elastomeric bearings and related test methods.

2. The Thermoid Division (formerly of Pioneer Rubber Company), H. K. Porter Company, Inc., the American Rubber Mfg. Co., and the Kirkhill Rubber Company all contributed much in materials development. Without their cooperation in furnishing samples and technical advice, it would have been much more difficult to establish meaningful design and inspection criteria.

APPENDIX I

MATERIALS AND RESEARCH DEPARTMENT

State of California
Department of Public Works
Division of Highways

Test Method No. Calif. 663-A
October 2, 1967

TESTING OF BRIDGE EXPANSION BEARING PADS FOR COEFFICIENT OF FRICTION AND FATIGUE LIFE

Scope

This test method describes the procedures to be used for the determination of the fatigue life and coefficient of friction or internal shear resistance of various bearing pad assemblies such as bronze, elastomeric, TFE (Teflon), etc.

Procedure

A. Testing Apparatus and Accessories

1. Expansion bearing pad fatigue testing machine. (See photograph and schematic drawing, Figures I and II).

2. Acetone

3. Stop watch

4. SR-4 strain indicator

5. 6-inch steel scale graduated in 1/100 of an inch.

B. Test Record Form

Use work card, Form HMR T-6028, for recording test data.

C. Specimen Preparation

1. Clean all test specimens and both platens so that they are free of any foreign substances such as dust, grit, moisture, etc., except for the lubricants used in conjunction with the bronze specimens such as oil, grease, etc. Cut the elastomeric specimens to size (standard size 6" x 6") and wipe clean. File smooth any rough edges on the bronze specimens and wipe clean. Use acetone to clean the bearing surfaces of TFE (Teflon) bonded specimens only.

D. Test Procedure

1. After the specimen has been centered on the lower platen of the fatigue machine, screw the eight platen leveling rollers far enough into the platen so that they do not contact the vertical guide plates.

2. Zero in the strain indicator.

D. Test Procedure (Continued)

3. Apply vertical load by operating valves #1 and #2.

4. Then adjust valve #6 to maintain the required pressure as read on gage #2.

5. At this time the loading platens should be parallel; check with steel scale. If loading heads are not parallel, unload and repeat the loading procedure.

6. Remove the "at rest" shims and screw the eight platen leveling rollers finger tight against the guide plates to maintain platen stability.

7. Operate the top loading platen using the following procedure:

   a. Start hydraulic pump (start button).

   b. Open valve #5 all the way and then adjust valve #4 to maintain the proper testing speed. Note: Valve #5 must be opened before speed can be adjusted by valve #4.

   c. Adjust the testing speed by the use of a stop watch.

   d. Measure the horizontal load by use of the SR-4 strain indicator.

   e. The pressure indicated on gage #3 is controlled by valve #7. The function of valve #7 is to control the pressure applied to the horizontal ram.

8. At the end of the test period, stop and unload the machine by reversing the loading steps.

E. Horizontal Force Measurements

During the course of the test, record the strain gage readings to determine the horizontal force.

1. Take static coefficient of friction readings at the instant of impending motion or slip between the surfaces in question. For flexible backed TFE (Teflon) bearings, measure strain at the point of maximum displacement.

2. Obtain kinetic coefficient of friction readings by taking the average reading while surfaces are sliding. Do this in both directions of movement.

F. Calculations

$$f = \frac{F}{N}$$

Where:

F = Horizontal force due to friction or internal shear resistance (lbs.).

N = Normal force (lbs.).

f = Coefficient of friction

f_s = static

f_k = kinetic

Determine "F" from the strain gage indicator readings by use of calibration plot I (Figure III). Determine N from gage #2 (Figure II) by use of calibration plot II (Figure IV).

REPORTING RESULTS

1. Report the following test results on test report Form HMR T-6028.

   a. Maximum static coefficient of friction.

   b. Average static coefficient of friction.

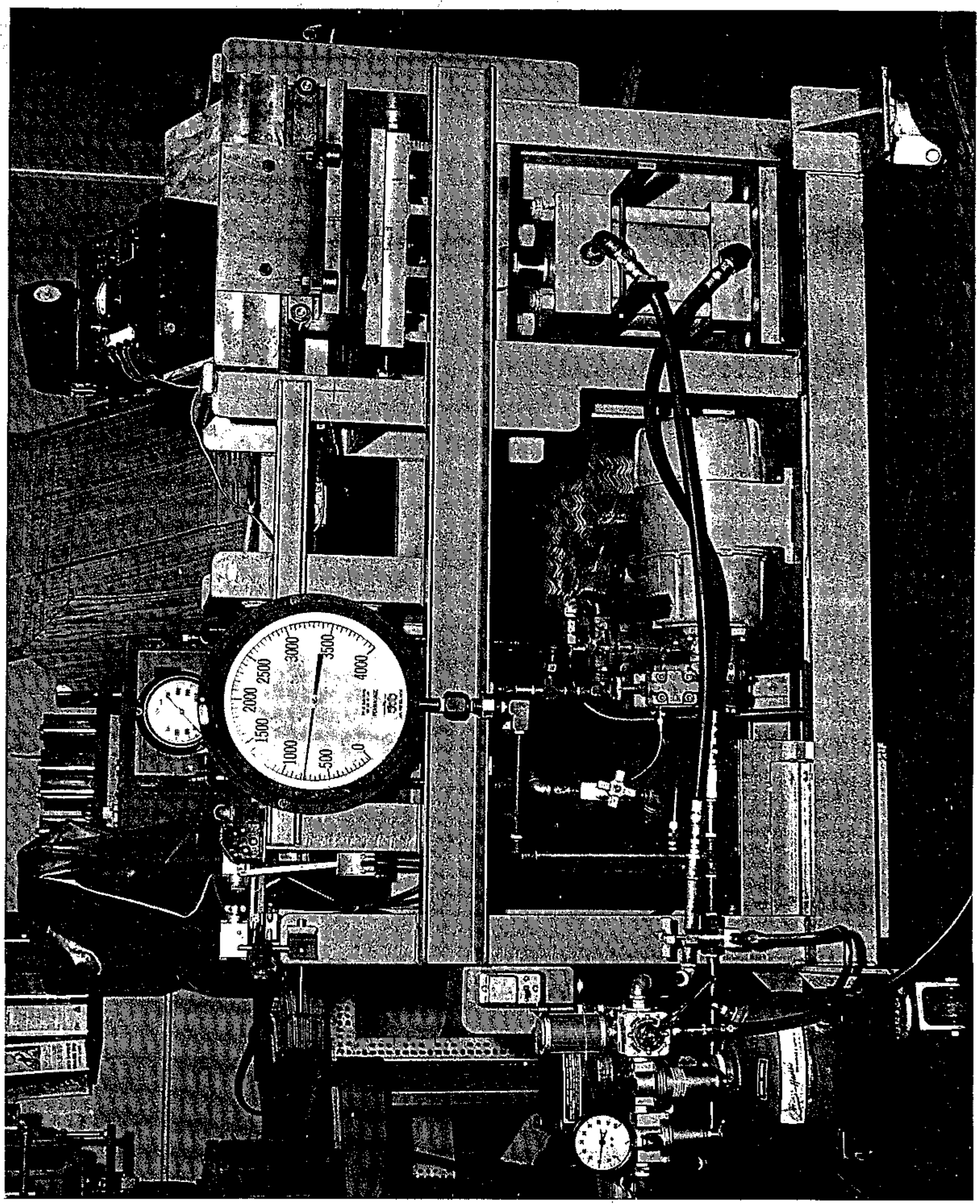
   c. Average kinetic coefficient of friction.

   d. Remarks concerning the specimen's appearance after completion of test, excessive wear, delamination, etc.

The "The maximum friction coefficient" as determined on Form HMR T-6028 is defined as the highest coefficient as averaged over any 50 cycles of the test.

The "Average friction coefficient" is defined as the average of at least 5 and not more than 10 readings taken between 2,000 and 8,000 cycles. These readings shall be taken at intervals of not less than 500 cycles apart.

REFERENCE
A California Method
End of Text on Calif. 663-A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500
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SCHEMATIC DIAGRAM OF FATIGUE TESTING MACHINE

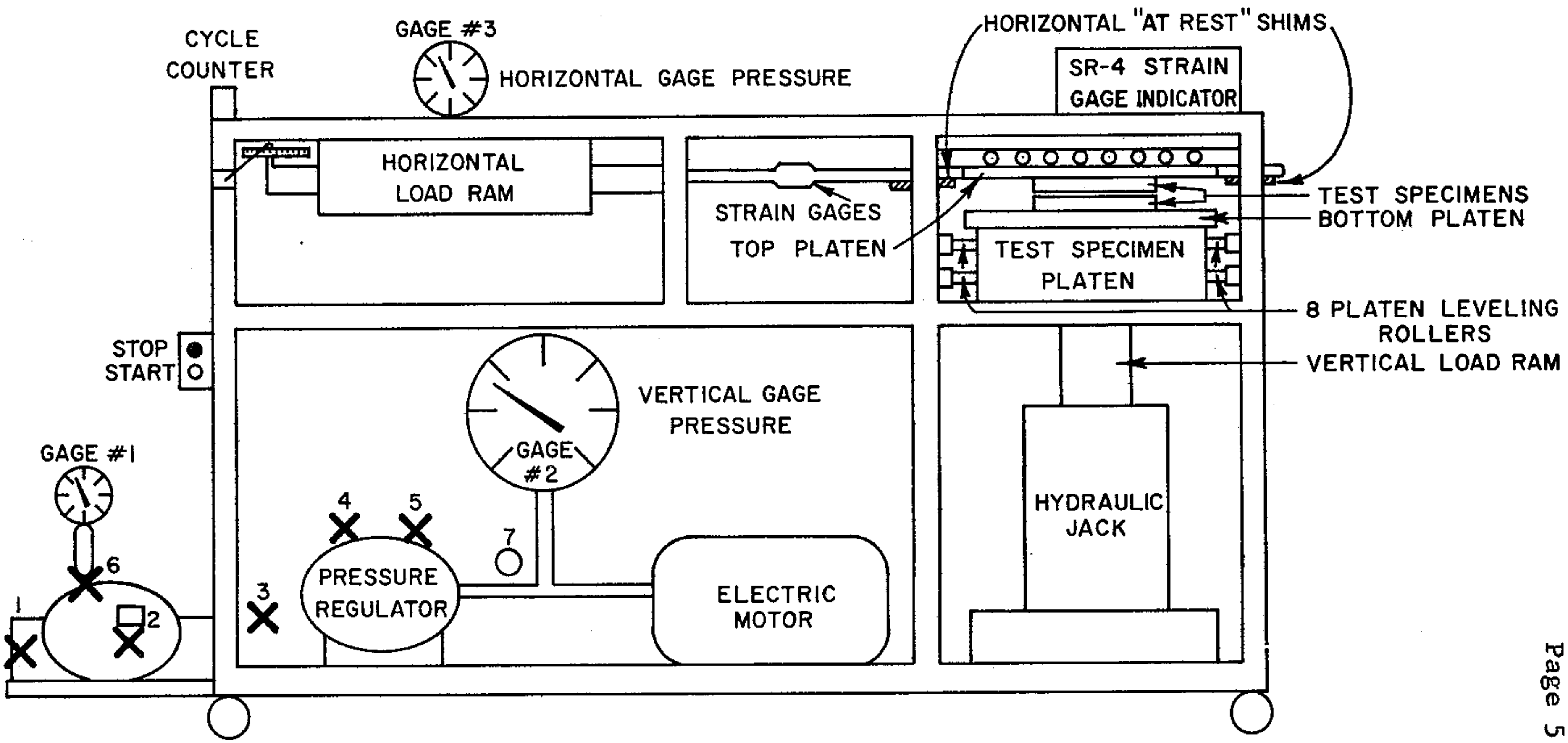

FIGURE II

BEARING PAD FATIGUE TESTING MACHINE

STRAIN GAGE CALIBRATION CURVE

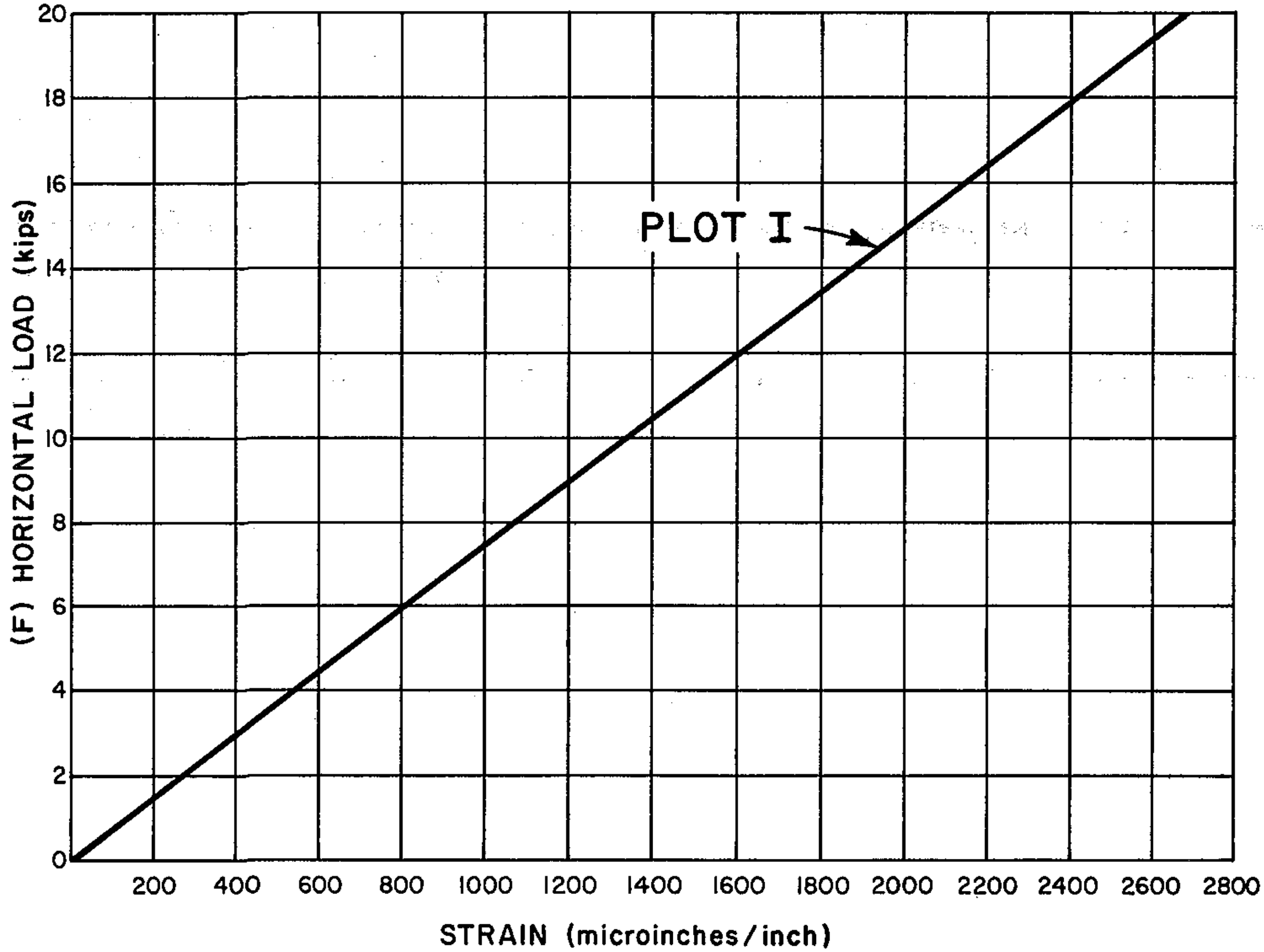

FIGURE III

BEARING PAD FATIGUE TESTING MACHINE

VERTICAL LOAD CALIBRATION CURVE

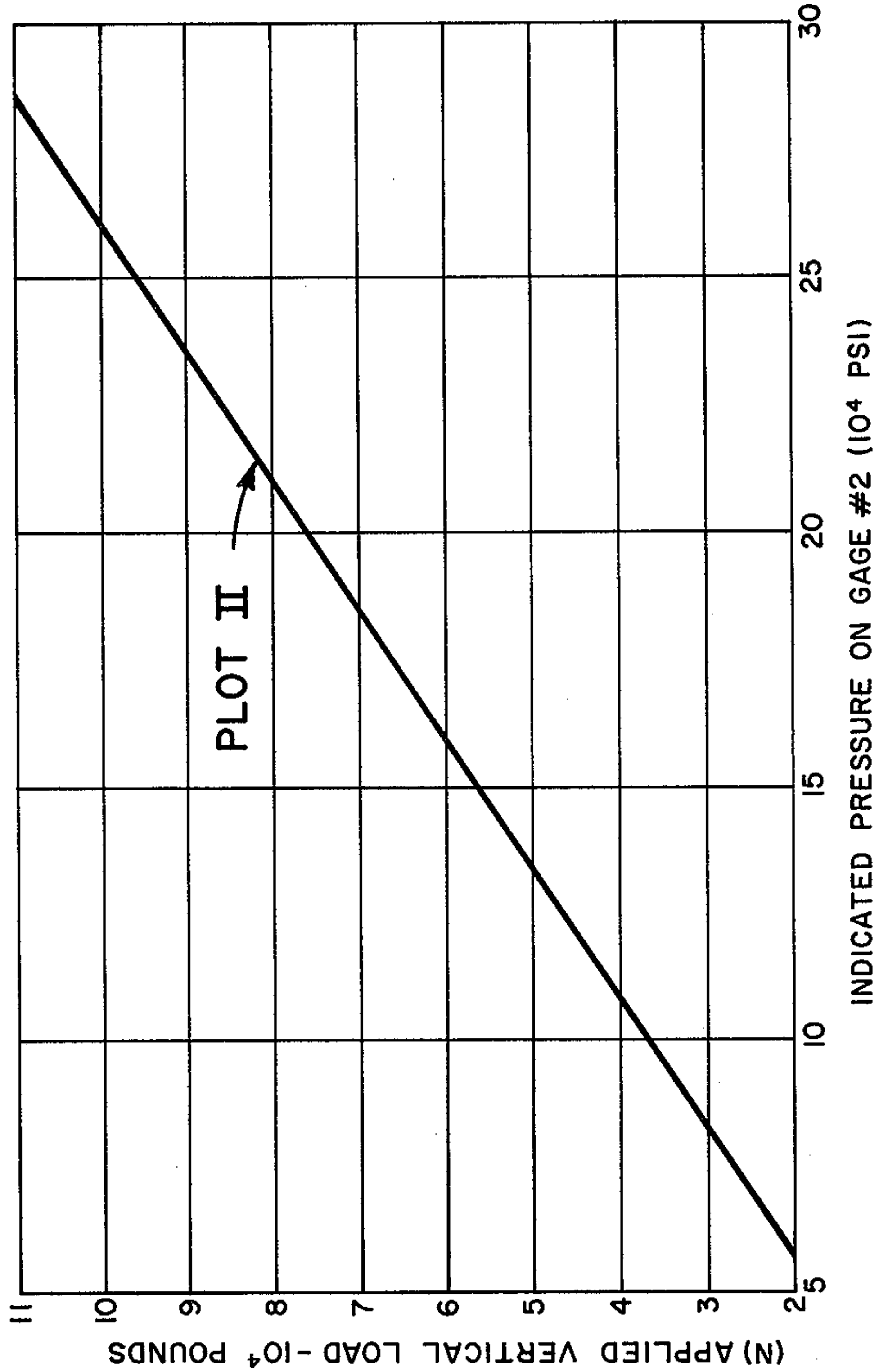

FIGURE IV

MATERIALS AND RESEARCH DEPARTMENT

FATIGUE AND COEFFICIENT OF FRICTION TEST DATA SHEET

TYPE: ____________________

SIZE: ____________________

DATE: ____________ LOAD: ____________

STROKE: SPEED:

DRAWING OF SPECIMEN

CYCLES	SPEED INCHES/ MINUTE	+ READING	− READING	MOVING AVERAGE	GAGE PRESSURE	N KIPS	+f KIPS	−f KIPS	MOVING f KIPS	+u	−u	THICKNESS INCHES	REMARKS

HMR T-6028 (Orig. 11/66)

APPENDIX II

Elastomeric Bearing Pads.--Elastomeric bearing pads shall conform to the requirements in these specifications and the special provisions.

Pads 1/2 inch and less in thickness may be either laminated or all elastomer.

Pads over 1/2 inch in thickness shall be laminated.

Laminated pads shall consist of alternate laminations of elastomer and metal or elastomer and fabric bonded together.

The outside laminations shall be metal or fabric. The outside and edges of metal laminations shall be coated over with elastomer not more than 1/8 inch in thickness.

Laminations of elastomer shall be 1/2 inch ± 1/8 inch in thickness. Variation in thickness of an individual elastomer lamination shall not exceed 1/8 inch within the width or length of a pad and the variation in thickness of all elastomer laminations within a pad shall be such that each metal or fabric lamination will not vary by more than 1/8 inch from a plane parallel to the top or bottom surface of the pad.

The total out to out thickness of a pad shall not be less than the thickness shown on the plans nor more than 1/4 inch greater than that thickness. Variation of total thickness within an individual pad shall not exceed 1/8 inch.

The length and width of a pad shall not vary more than 1/8 inch from the dimensions shown on the plans.

Pads containing metal laminations shall be full molded. Pads of all elastomer or with fabric laminations may be cut from large sheets. Cutting shall be performed in such a manner as to avoid heating of the material and to produce a smooth edge with no tears or other jagged areas and to cause as little damage to the material as possible.

Corners and edges of molded pads may be rounded at the option of the Contractor. Radius at corners shall not exceed 3/8 inch, and radius of edges shall not exceed 1/8 inch.

The bond between elastomer and metal or fabric shall be such that, when a sample is tested for separation, failure shall occur within the elastomer and not between the elastomer and metal or fabric.

Metal laminations shall be rolled mild steel sheets not less than 20-gage in thickness.

Fabric laminations shall be either (1) a long chain synthetic polymer containing at least 85 percent of polyester from ethylene glycol and teraphthalic acid or (2) a long chain synthetic polymeric amide from hexamethylene diamine and adipic acid. The fabric woven from alternative (2) shall have a hexagon weave. Each ply of fabric shall have a breaking strength of not less than 700 pounds per inch of width in both directions. Fabric laminations shall be single ply at top and bottom surfaces of the pad and either double ply or double strength within the pad.

The rubber constituent of the elastomer laminations shall be not less than 60 percent (by volume) neoprene.

The elastomer, as determined from test specimens conforming to ASTM Designation: D 15, shall conform to the following requirements:

Test	ASTM Designation	Requirement
Tensile strength, psi	D 412	2,500 Min.
Elongation at break, percent	D 412	350 Min.
Tensile Stress (Modulus)		
at 50% elongation, psi	D 412	250 Max.
at 100% elongation, psi	D 412	450 Max.
Compression set,		
22 hrs. at 158° F., percent	D 395 (Method B)	25 Max.
Tear strength, pounds per inch	D 624 (Die C)	275 Min.
Hardness (Shore A)	D 676	55 ± 3
Ozone resistance 20% strain		
100 hrs. at 100° ± 2° F.	D 1149 (except 100 ± 20 parts per 100,000,000)	No cracks
Low temperature stiffness, Young's Modulus at -30° F., psi	D 797	5,000 Max.
Low temperature brittleness,		
5 hrs. at -40° F.	D 736	Passed

After accelerated aging in accordance with ASTM Designation: D 573 for 70 hours at 212° F. the elastomer shall not show deterioration changes in excess of the following amounts:

Tensile strength, percent	± 15
Elongation at Break, percent	-40 (but not less than 300% total elongation of the material)
Hardness, points	± 10

The Contractor shall furnish to the Engineer a certification by the manufacturer that the elastomer, and fabric (if used), in the elastomeric bearing pads to be furnished conforms to all of the above requirements. The certification shall be supported by a certified copy of the results of tests, performed by the manufacturer upon samples of elastomer, and fabric (if used), to be used in the pads covering all of the above mentioned requirements.

The Engineer will take for testing a sample pad not less than 6 inches x 9 inches in size, from each lot of pads or batch of elastomer to be furnished, whichever results in the greater number of samples. The samples will be selected at random preferably at the point of manufacture or, at the option of the Contractor, at the job site. Samples taken at the job site shall consist of complete pads as detailed on the plans, and the Contractor shall furnish additional complete pads to replace those taken for testing. Pads shall be available for sampling 3 weeks in advance of intended use. All sample pads for testing shall be furnished by the Contractor at his expense.

Test specimens prepared by the Engineer from pads taken for testing will be obtained by cutting and grinding to the dimensions specified in ASTM Designation: D 15. The test results from such test specimens shall not be more than 10 percent below the values specified in this Section 51-1.12H.