# PRACTICAL METHOD OF CONDUCTING THE INDIRECT TENSILE TEST

by

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Thomas W. Kennedy

Research Report Number 98-10

Evaluation of Tensile Properties of Subbases
for Use in New Rigid Pavement Design

Research Project 3-8-66-98

conducted for

The Texas Highway Department

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR HIGHWAY RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

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# PREFACE

This is the tenth in a series of reports dealing with the findings of a research project concerned with the evaluation of the tensile properties of stabilized subbase materials. The equipment and test procedures involved in conducting the indirect tensile test are described in detail. In addition a method of analysis of the test results to determine tensile strength, Poisson's ratio, modulus of elasticity, and total tensile strain at failure is also described.

Special appreciation is due to Messrs. James L. Brown, Larry J. Buttler, and Dr. Robert E. Long of the Texas Highway Department, who provided technical liaison for the project.

Future reports will be concerned with

(1) tensile properties for use in the design of cement-treated materials,
(2) tensile behavior of stabilized materials under repetitive loads, and
(3) a comprehensive design for stabilized bases.

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# LIST OF REPORTS

Report No. 98-1, "An Indirect Tensile Test for Stabilized Materials," by W. Ronald Hudson and Thomas W. Kennedy, summarizes current knowledge of the indirect tensile test, reports findings of limited evaluation of the test, and describes the equipment and testing techniques developed.

Report No. 98-2, "An Evaluation of Factors Affecting the Tensile Properties of Asphalt-Treated Materials," by William O. Hadley, W. Ronald Hudson, and Thomas W. Kennedy, discusses factors important in determining the tensile strength of asphalt-treated materials and reports findings of an evaluation of eight of these factors.

Report No. 98-3, "Evaluation of Factors Affecting the Tensile Properties of Cement-Treated Materials," by Humberto J. Pendola, Thomas W. Kennedy, and W. Ronald Hudson, presents factors important in determining the strength of cement-treated materials and reports findings of an evaluation by indirect tensile test of nine factors thought to affect the tensile properties of cement-treated materials.

Report No. 98-4, "Evaluation of Factors Affecting the Tensile Properties of Lime-Treated Materials," by S. Paul Miller, Thomas W. Kennedy, and W. Ronald Hudson, presents factors important in determining the strength of cement-treated materials and reports findings of an evaluation by indirect tensile test of eight factors thought to affect the tensile properties of lime-treated materials.

Report No. 98-5, "Evaluation and Prediction of the Tensile Properties of Lime-Treated Materials," by Walter S. Tulloch, II, W. Ronald Hudson, and Thomas W. Kennedy, presents a detailed investigation by indirect tensile test of five factors thought to affect the tensile properties of lime-treated materials and reports findings of an investigation of the correlation between the indirect tensile test and standard Texas Highway Department tests for lime-treated materials.

Report No. 98-6, "Correlation of Tensile Properties with Stability and Cohesiometer Values for Asphalt-Treated Materials," by William O. Hadley, W. Ronald Hudson, and Thomas W. Kennedy, presents a detailed correlation of indirect tensile test parameters, i.e., strength, modulus of elasticity, Poisson's ratio, and failure strain, with stability and cohesiometer values for asphalt-treated materials.

Report No. 98-7, "A Method of Estimating Tensile Properties of Materials Tested in Indirect Tension," by William O. Hadley, W. Ronald Hudson, and Thomas W. Kennedy, presents the development of equations for estimating material properties such as modulus of elasticity, Poisson's ratio, and tensile strain based upon the theory of the indirect tensile test and reports verification of the equations for aluminum.

Report No. 98-8, "Evaluation and Prediction of Tensile Properties of Cement-Treated Materials," by James N. Anagnos, Thomas W. Kennedy, and W. Ronald Hudson, investigates, by indirect tensile test, six factors affecting the tensile properties of cement-treated materials, and reports the findings of an investigation of the correlation between indirect tensile strength and standard Texas Highway Department tests for cement-treated materials.

Report No. 98-9, "Evaluation and Prediction of the Tensile Properties of Asphalt-Treated Materials," by William O. Hadley, W. Ronald Hudson, and Thomas W. Kennedy, presents a detailed investigation by indirect tensile test of seven factors thought to affect the tensile properties of asphalt-treated materials and reports findings which indicate the important factors affecting each of the tensile properties and regression equations for estimation of the tensile properties.

Report No. 98-10, "Practical Method of Conducting the Indirect Tensile Test," by James N. Anagnos and Thomas W. Kennedy, describes equipment and test procedures involved in conducting the indirect tensile test along with a method of analyzing the test results.

# ABSTRACT

This report describes a practical method of conducting the indirect tensile test and a method of analyzing the test results to determine the tensile properties of all types of stabilized materials except cohesionless materials.

The test methods are reported in two parts. The first describes the relatively simple equipment and test procedures required to obtain tensile strength. The second part describes equipment, test procedures, and a method of analysis to determine Poisson's ratio, modulus of elasticity, and tensile strains.

KEY WORDS: test equipment, test procedures, method of analysis, tensile strength, Poisson's ratio, modulus of elasticity, tensile strains.

# SUMMARY

The purpose of this report is to describe in detail a practical method of conducting the indirect tensile test to determine the tensile properties of stabilized materials. A pair of half-inch-wide curved face loading strips and loading equipment capable of applying a compressive load at a controlled deformation rate, preferably 2 inches per minute, must be used to determine tensile strength. The large motorized gyratory press in use by the Texas Highway Department can provide this loading rate and can be easily modified to accept the loading strips. From the dimensions of the test specimen and failure load, the tensile strength can be calculated.

The determination of Poisson's ratio, modulus of elasticity, and tensile strains requires the measurement of vertical and horizontal deformations of the specimen at various applied loads. Simple mathematical equations have been developed to calculate these tensile properties.

## IMPLEMENTATION STATEMENT

The information contained in this report describes the indirect tensile test, the equipment and procedures required to conduct the test, and the method of calculating the tensile properties of the material tested. Emphasis has been placed on utilizing equipment readily available to the district laboratories of the Texas Highway Department.

The test can be used to evaluate all stabilized materials, and it is hoped that it can be used to evaluate all pavement materials except cohesionless materials. Thus, it will be possible to compare the behavioral characteristics of these materials on the same basis using the same test. The tensile properties obtained from this test are expressed in terms of standard engineering units, which are more meaningful than empirical numbers and which can be used in theoretical design procedures requiring the elastic constants of the materials involved. In addition, since the test is very simple to conduct and uses cylindrical specimens which are easily prepared, it can be used to control quality of construction materials.

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# INTRODUCTION

A need exists for a simple test method which can be used to evaluate the tensile properties of all types of pavement materials and to obtain information which can be used for pavement design. In addition to failing from cracking of the surface layers, rigid pavements may fail due to loss of support as the result of subbase cracking, and flexible pavements may also fail due to the formation of tensile cracks in the subbase and base layers with subsequent propogation of the crack upward through the surface layer.

In recognition of the need for information on the tensile characteristics of stabilized subbase materials, the Texas Highway Department and the Federal Highway Administration sponsored Project 3-8-66-98, "Evaluation of Tensile Properties of Subbases for Use in Rigid Pavement Design," which was conducted by the Center for Highway Research at The University of Texas at Austin. As a part of this project, the various tests which were currently available and which could be used to obtain information on the tensile characteristics of highway materials were evaluated (Ref 3). As a result, the indirect tensile test or splitting tensile test was adopted and further developed to provide a test method which could be used to obtain estimates of tensile strength, Poisson's ratio, modulus of elasticity, and tensile strains for all types of stabilized materials (Ref 1). In addition, it is felt that the test can be used to evaluate other pavement materials except cohesionless materials, such as sand, gravel, and crushed stone.

The purpose of this report is to provide a detailed description of the test, test procedures, equipment, and methods of calculating tensile strength, Poisson's ratio, modulus of elasticity, and tensile strains. The portion of the report concerned with procedures, equipment, and methods of calculating the various properties has been divided into two sections, since determination of tensile strength is relatively simple, requiring only a method of applying and measuring the total compressive load applied to the specimen, whereas the determination of Poisson's ratio, modulus of elasticity, and tensile strain is more difficult, requiring accurate measurements of specimen deformations.

# INDIRECT TENSILE TEST

The indirect tensile test involves loading a cylindrical specimen with compressive loads which act parallel to and along the vertical diametrical plane, as shown in Fig 1. To distribute the load and maintain a constant loading area, the compressive load is applied through a half-inch-wide stainless steel loading strip which is curved at the interface with the specimen and has a radius equal to that of the specimen.

This loading configuration develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametrical plane, which ultimately causes the specimen to fail by splitting or rupturing along the vertical diameter (Fig 2). The tensile stress in the center of the specimen can be calculated using the following equation:

$$\sigma_T = \frac{2P}{\pi a h} \left(\sin 2\alpha - \frac{a}{D}\right) \tag{1}$$

where

$\sigma_T$ = indirect tensile stress;

P = total vertical load applied to specimen, in pounds;

a = width of loading strip, in inches;

h = height of specimen at beginning of test, in inches;

D = diameter of specimen, in inches; and

$2\alpha$ = angle at the origin subtended by the width of loading strip (Fig 3).

When P is maximum, $\sigma_T$ equals the indirect tensile strength $S_T$ .

In addition, based upon developments by Project 3-8-66-98 at the Center for Highway Research, it is possible to estimate Poisson's ratio, modulus of elasticity, and total tensile strain at failure. The theoretical relationships required for calculating these parameters are contained in Center for Highway Research Report No. 98-9 (Ref 1). These relationships are rather complex and require integration of various mathematical functions. However, by assuming a specimen diameter the required integrations can be conducted and the relationships can be simplified. The simplified relationships for calculating

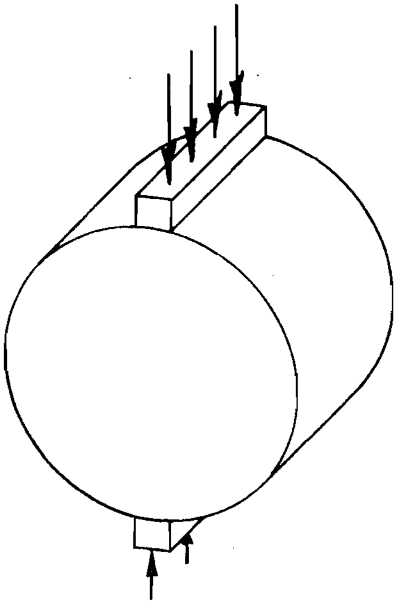

Fig 1. Cylindrical specimen with compressive load being applied.

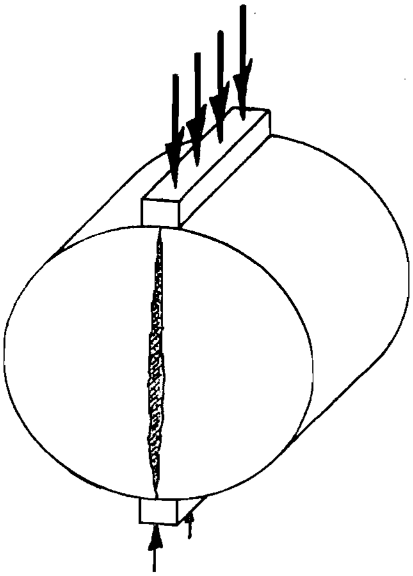

Fig 2. Specimen failing under compressive load.

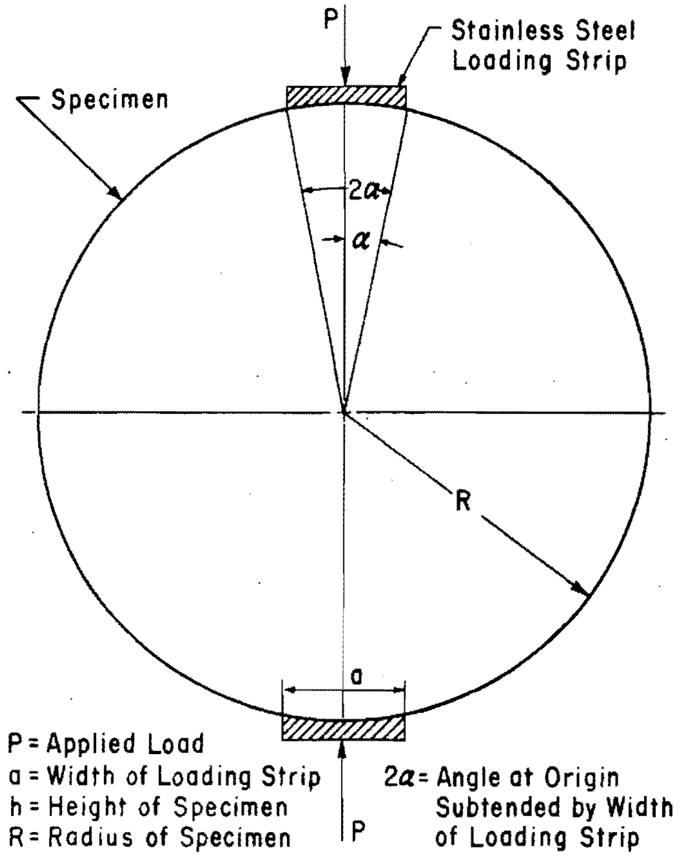

Fig 3. Indirect tensile test.

Poisson's ratio, modulus of elasticity, and failure strains for 4-inch and 6-inch diameter specimens with a half-inch-wide curved loading strip are summarized in Table 1.

It is recommended that the test be conducted at a controlled deformation rate of 2 inches per minute at 75° F utilizing half-inch-wide curved face loading strips. Other loading rates and testing temperatures can be utilized for studies of special interest, and in the case of relatively stiff materials it may be desirable to reduce the loading rate.

The remainder of this report describes the procedures and equipment required to conduct the test and to obtain estimates of tensile strength, Poisson's ratio, modulus of elasticity, and tensile strains.

## DETERMINATION OF INDIRECT TENSILE STRENGTH

### EQUIPMENT

The basic testing apparatus includes loading equipment capable of applying compressive loads at a controlled deformation rate, preferably 2 inches per minute, a means of measuring the applied load, and half-inch-wide curved face loading strips, which are used to apply and distribute the load uniformly along the entire length of the specimen.

#### General Use

Any loading equipment which is capable of applying compressive loads at a prescribed loading rate and can provide an accurate measure of the maximum load can be used, providing that the load capacity of the equipment is sufficient to fail the specimen. In addition, since it is necessary to apply the load to the specimen through steel loading strips which must remain essentially parallel, it is recommended that a guided loading head with loading strips attached to the upper and lower parallel platens be used. Such a device, which has been used at the Center for Highway Research, can be obtained by modifying a commercially available die set such as shown in Fig 5. The specifications and required modifications for this die set and the loading strips are presented in Appendix 1.

## TABLE 1. EQUATIONS FOR CALCULATION OF TENSILE PROPERTIES

| Tensile Property | Diameter of Specimen | |
|---|---|---|
| | 4-Inch | 6-Inch |
| Tensile strength $S_T$ , psi | $0.156 \frac{P_{Fail}}{h}$ | $0.105 \frac{P_{Fail}}{h}$ |
| Poisson's ratio $\nu$ | $\frac{0.0673DR - 0.8954}{-0.2494DR - 0.0156}$ | $\frac{0.04524DR - 0.6804}{-0.16648DR - 0.00694}$ |
| Modulus of elasticity E , psi | $\frac{S_H}{h} \left[0.9976\nu + 0.2692\right]$ | $\frac{S_H}{h} \left[0.9990\nu + 0.2712\right]$ |
| Total tensile strain at failure $\epsilon_T$ | $X_{TF} \left[\frac{0.1185\nu + 0.03896}{0.2494\nu + 0.0673}\right]$ | $X_{TF} \left[\frac{0.0793\nu + 0.0263}{0.1665\nu + 0.0452}\right]$ |

$P_{Fail}$ = total load at failure (maximum load $P_{max}$ or load at first break point), in pounds;

h = height of specimen, in inches;

$X_{TF}$ = total horizontal deformation at failure (deformation at the maximum load or at first break point), in inches (Fig 4);

DR = deformation ratio $\frac{Y_T}{X_T}$ (the slope of line of best fit* between vertical deformation $Y_T$ and the corresponding horizontal deformation $X_T$ up to failure load $P_{Fail}$ );

$S_H$ = horizontal tangent modulus $\frac{P}{X_T}$ (the slope of the line of best fit* between load P and total horizontal deformation $X_T$ for loads up to failure load $P_{Fail}$ ).

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* It is recommended that the line of best fit be determined by the method of least squares.

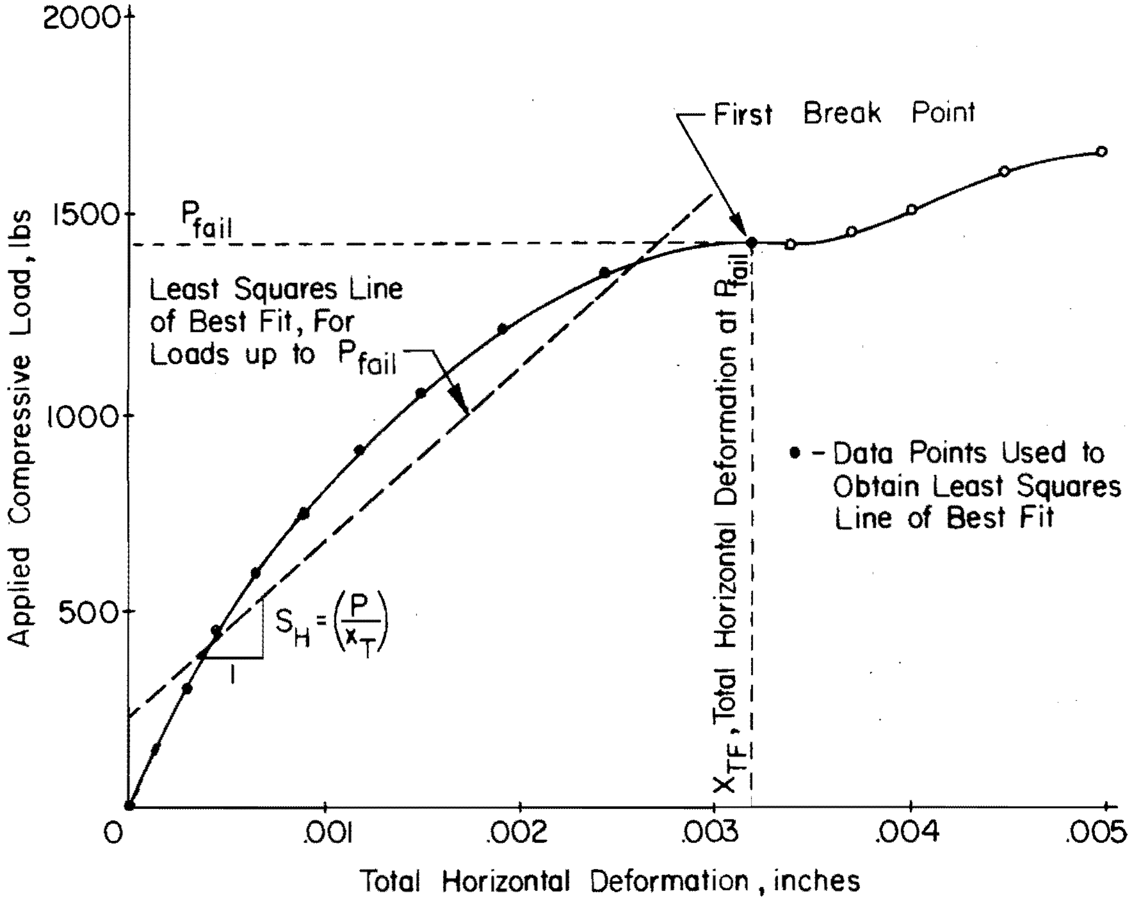

Fig 4. Generalized characterization of load-horizontal deformation data.

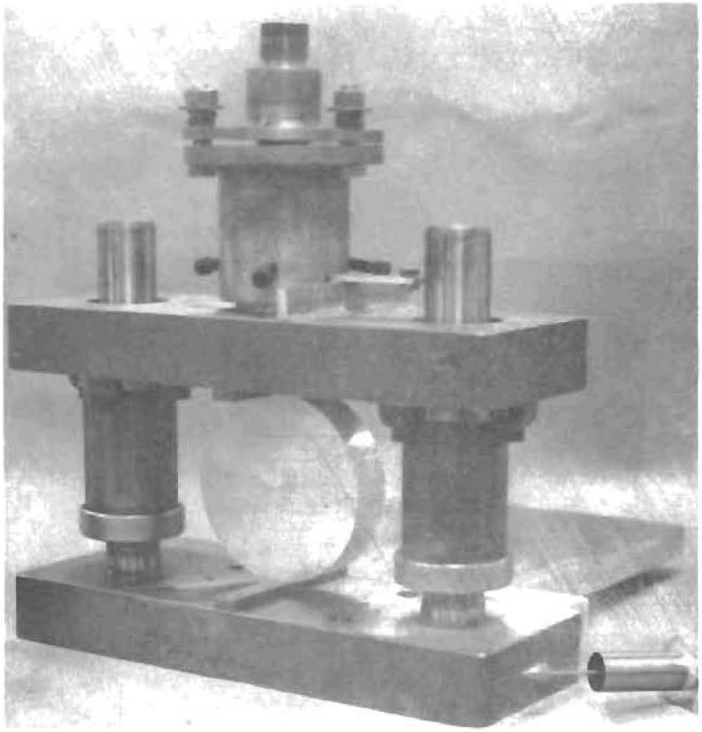

Fig 5. All steel precision die set with loading strips and specimen in place.

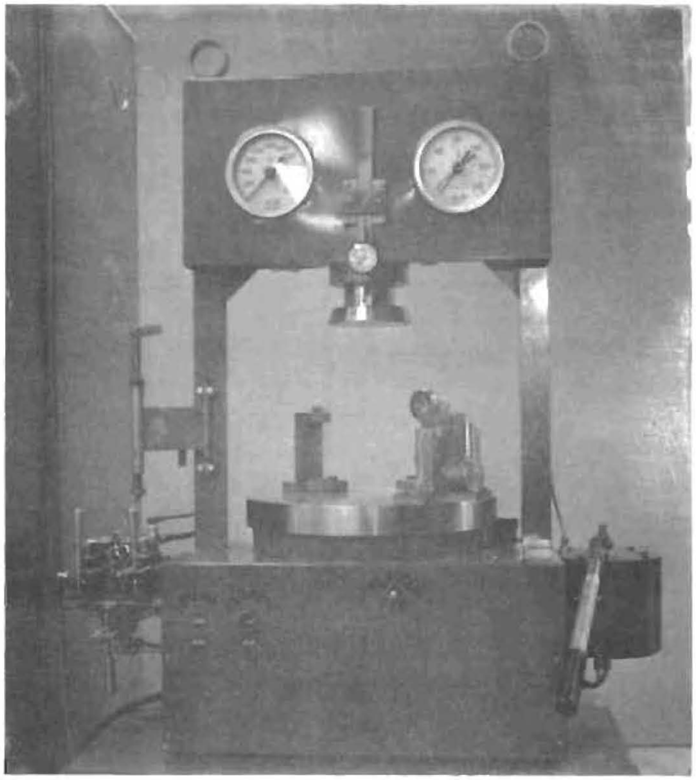

Fig 6. Motorized gyratory press.

### Texas Highway Department Use

Serious consideration should be given to using the motorized gyratory press (Fig 6) for loading specimens since this press is available in most of the district laboratories and in the Materials and Test Division of the Texas Highway Department (Ref 2) and would require only minor modifications (Appendix 2). The press is capable of applying compressive loads up to 25,000 pounds at controlled deformation rates ranging from 0.05 to 10 inches per minute. If the gyratory press is used, probably the guided loading head should not be used*; rather a different set of loading strips should be attached directly to the platens of the gyratory press, as shown in Fig 7. Machine drawings of the loading strips for use with the gyratory press are shown in Appendix 2. In addition, a list of equipment needed to perform the test and a description of the modifications of the press are contained in Appendix 2.

## TEST PROCEDURE

(1) Determine the height and diameter of the test specimen.

(2) Carefully center the test specimen on the lower loading strip.

(3) Slowly bring the head down until light contact is made with the test specimen.

(4) Apply the load at a controlled deformation rate of 2 inches per minute and determine the maximum pressure at failure of the specimen.

## CALCULATION OF INDIRECT TENSILE STRENGTH

Tensile strength for nominal 4-inch and 6-inch-diameter specimens can be calculated from the following equations (Table 1):

### 4-inch-specimens

$$S_T = 0.156 \frac{P_{Fail}}{h}$$

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*The guided loading head can be used (Fig 7), but space limitations restrict the specimen size to diameters and lengths of 6 inches or less.

Fig 7. Motorized gyratory press with upper and lower loading plates and strips.

6-inch-diameter specimens

$$S_T = 0.105 \frac{P_{Fail}}{h}$$

where

$S_T$ = indirect tensile strength, in psi;

$P_{Fail}$ = total applied vertical load at failure, in pounds; and

$h$ = height of specimen, in inches.

## DETERMINATION OF POISSON'S RATIO, MODULUS OF ELASTICITY, AND TENSILE STRAIN AT FAILURE

In order to estimate the Poisson's ratio, modulus of elasticity, and tensile strains, it is necessary to measure the vertical and horizontal deformations of the specimens and to relate these deformations to the applied load. Thus, deformation measuring equipment as well as continuous load-deformation recording equipment is required.

### EQUIPMENT

Loading equipment capable of applying a compressive load at a controlled deformation rate, preferably 2 inches per minute, is required as is a guided loading head with parallel platens such as the previously discussed die set with attached loading strips. The gyratory press probably should not be used to apply the load since accurate load-vertical deformations and load-horizontal deformations must be continuously measured and recorded. These measurements on specimens of stabilized materials have been satisfactorily obtained at the Center for Highway Research by using a linear variable differential transformer (Schaevitz Engineering Type 1000 DC-LVDT) to measure vertical deformation and a specially designed horizontal deflection device (Fig 8) to measure horizontal deformations. The specifications for this device are contained in Appendix 3. In addition, a load cell was used to measure the applied load. Figure 9 illustrates this equipment in a testing mode.

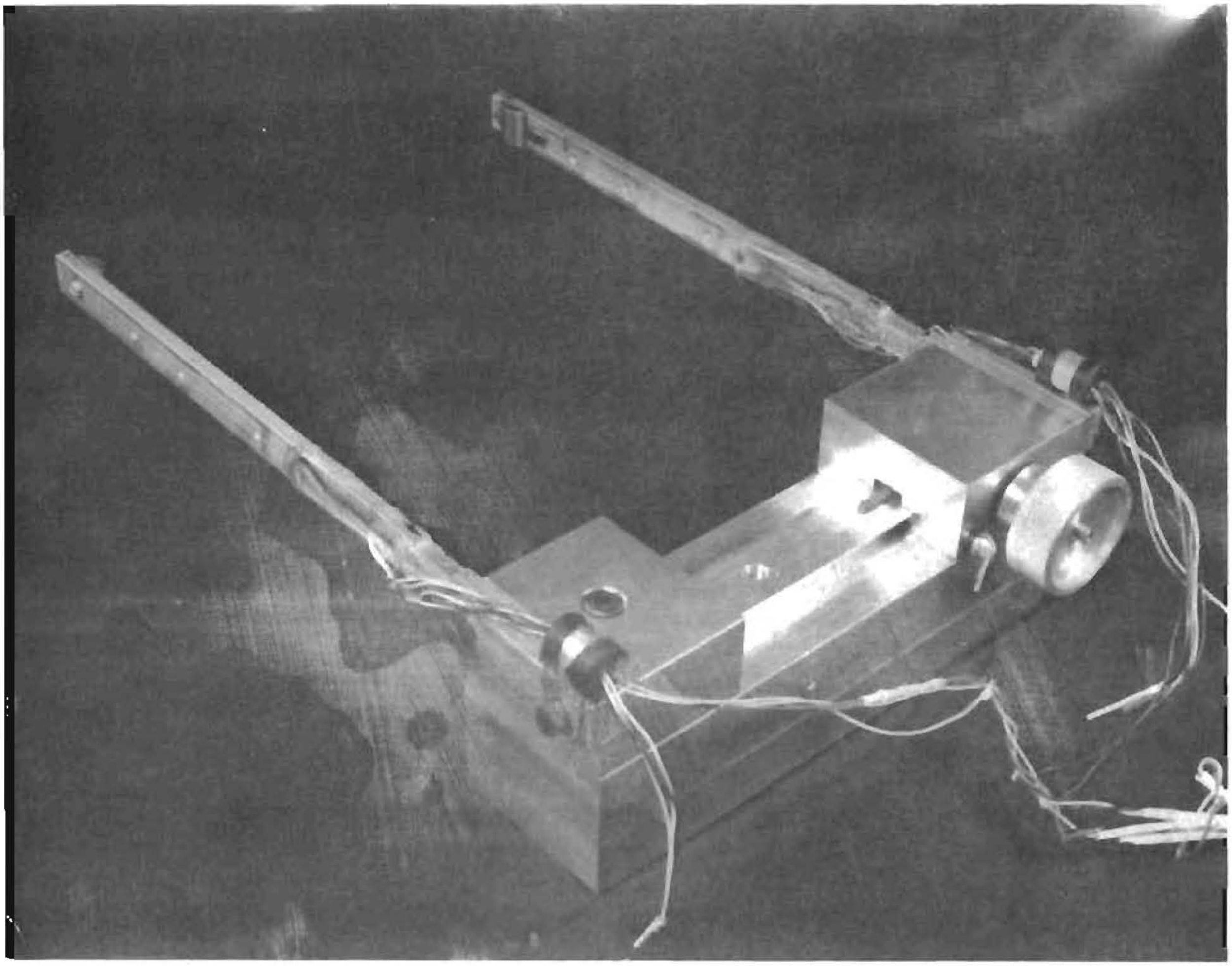

Fig 8. Horizontal deflection device.

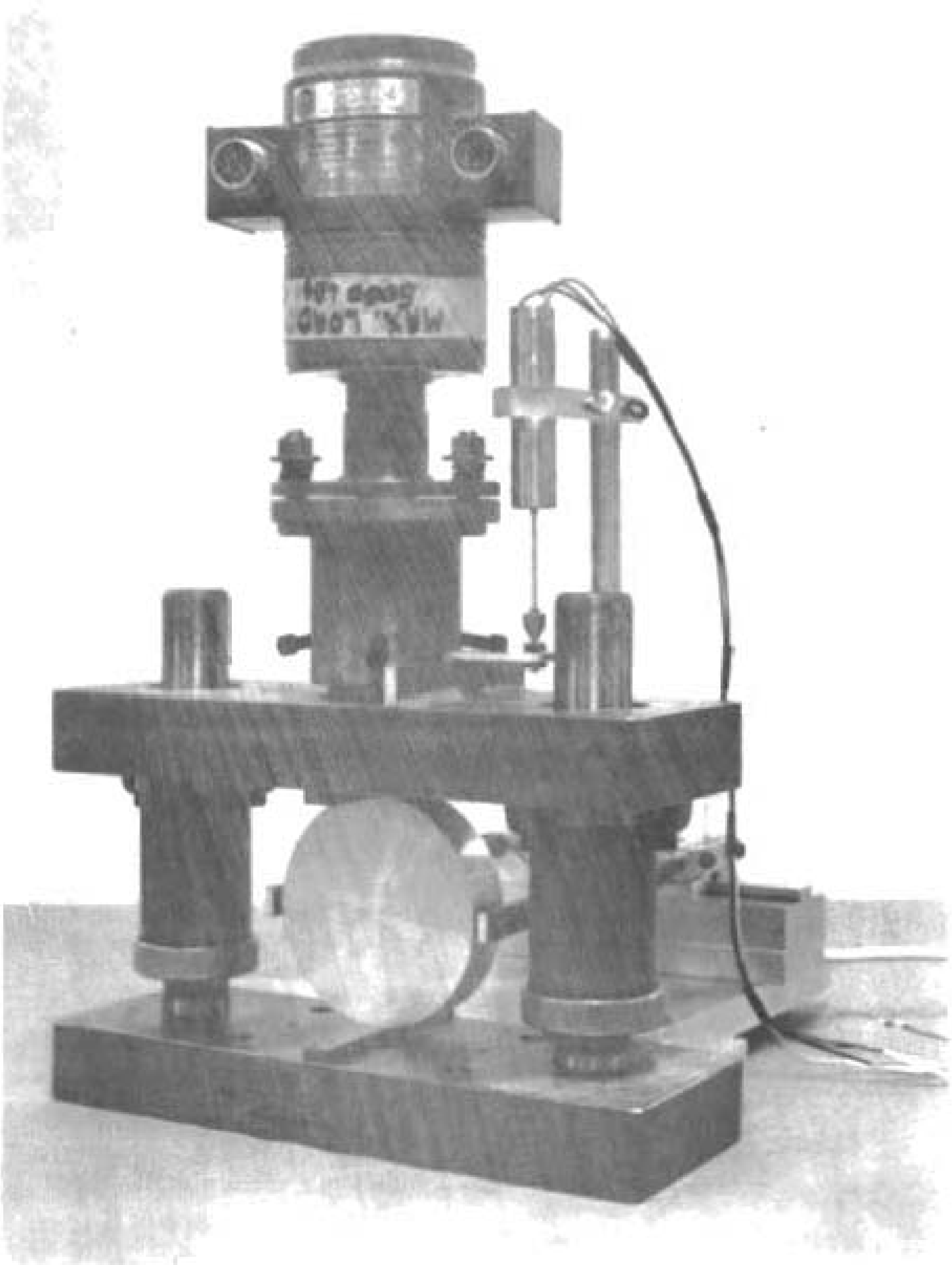

Fig 9. Indirect tensile test equipment in test mode.

Some means of continuously recording the loads and their corresponding vertical and horizontal deformations must be used since the rate of loading makes it impossible to manually record the observations. Project personnel have satisfactorily made such measurements by continuously recording the load-deformation relationships on two x-y plotters (Hewlett Packard Model 7001A).

If the Texas gyratory shear compactor is used, it is recommended that a pressure transducer be considered as a means of monitoring the load. This transducer can be inserted into the pressure system; however, the Center for Highway Research has not investigated this possibility. In addition, for materials exhibiting very small deformations per unit load it may be necessary to use equipment capable of measuring and recording deformations more precisely.

## TEST PROCEDURE

(1) Determine the height and diameter of the test specimen.

(2) Calibrate horizontal deformation device (Appendix 4).

(3) Center test specimen on loading head.

(4) Bring upper platen of die set into light contact with test specimen. Monitor load on the x-y plotter that is recording load versus vertical deformation.

(5) Place horizontal deformation device on rear platform with arms in light contact with specimen and lock arms into postion.

(6) Load specimen at a deformation rate of 2 inches per minute and record load versus vertical deformation and load versus horizontal deformation.

## CALCULATION OF TENSILE PROPERTIES

The various tensile properties can be obtained by using the procedure outlined below and the equations shown in Table 1. The analysis of an example problem is presented below.

### Procedure

(1) From the load deformation curves obtained from the indirect tensile test (Figs 10 and 11) replot the corresponding vertical and horizontal deformations up to the failure load $P_{Fail}$ (first break point) (Fig 12).

(2) Determine the deformation ratio DR , the slope of the line of best fit, between the corresponding vertical and horizontal deformations up to the failure load (Table 2).

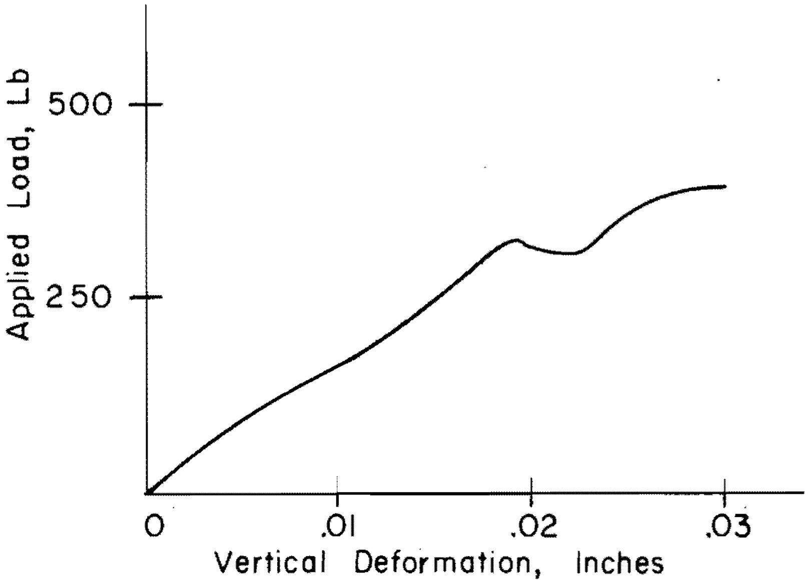

Fig 10. Load-vertical deformation curve.

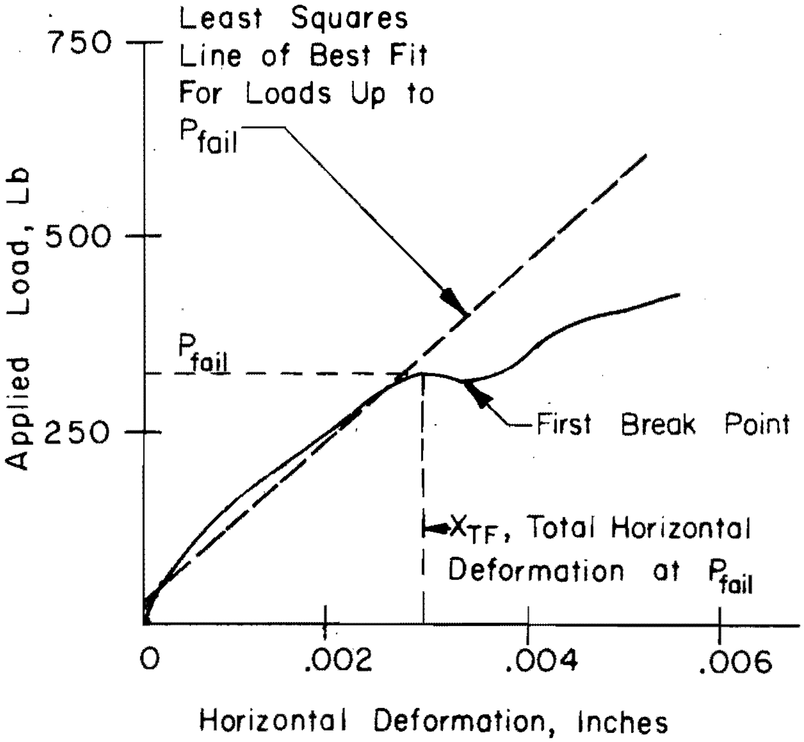

Fig 11. Load-horizontal deformation curve.

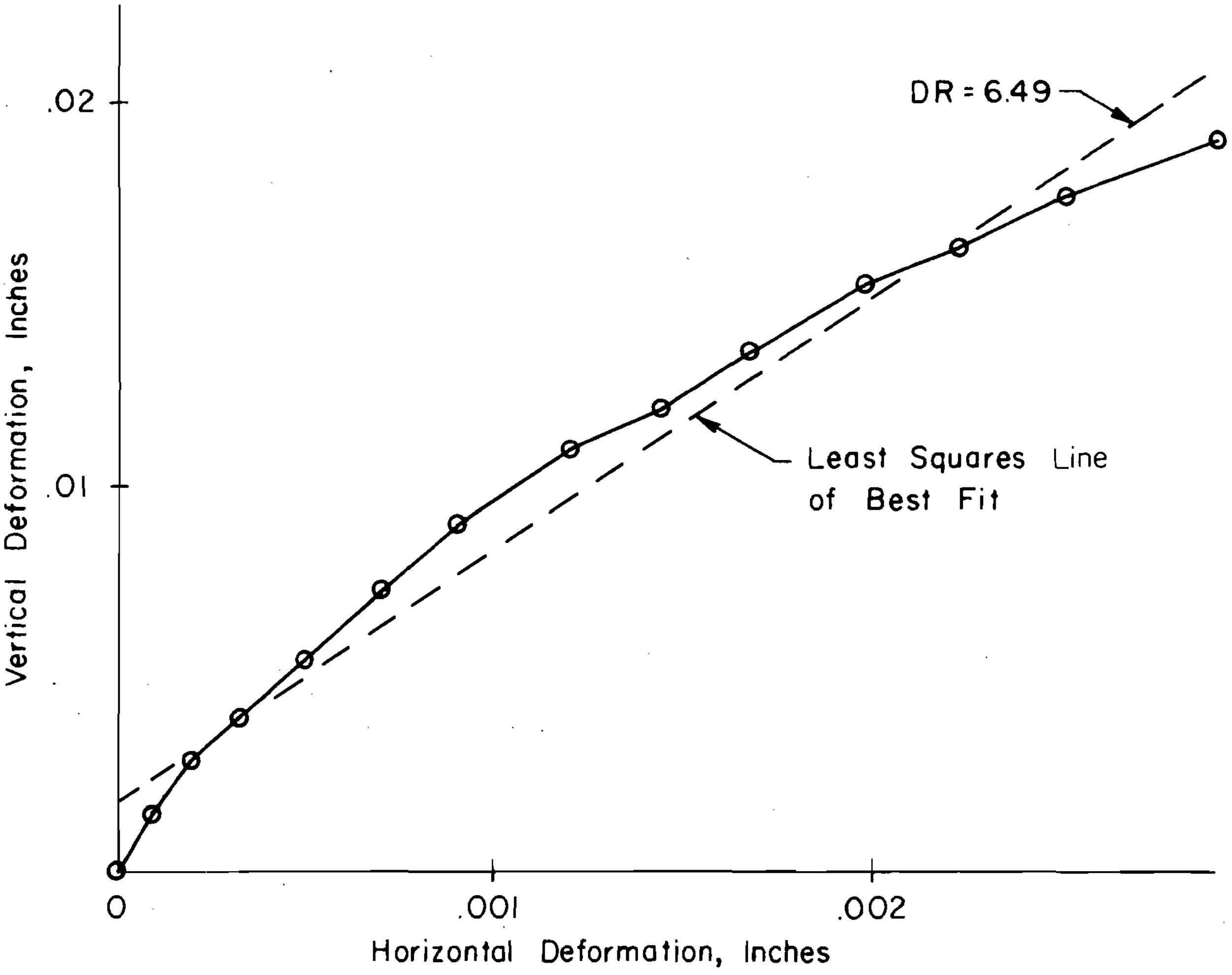

Fig 12. Characterization of relationship between vertical and horizontal deformations.

## TABLE 2. EXAMPLE CALCULATION OF DEFORMATION RATIO USING THE METHOD OF LEAST SQUARES

| Load, in Pounds | X, Horizontal Deformation, in Inches ($\times 10^{-4}$) | Y, Vertical Deformation, in Inches ($\times 10^{-3}$) | XY ($\times 10^{-5}$) | $X^2$ ($\times 10^{-6}$) |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 25 | 1.0 | 1.5 | .015 | .010 |
| 50 | 2.0 | 2.8 | .056 | .040 |
| 75 | 3.3 | 4.0 | .132 | .109 |
| 100 | 5.0 | 5.5 | .275 | .250 |
| 125 | 7.0 | 7.3 | .511 | .490 |
| 150 | 9.1 | 9.0 | .819 | .828 |
| 175 | 12.0 | 10.9 | 1.308 | 1.440 |
| 200 | 14.4 | 12.0 | 1.728 | 2.074 |
| 225 | 16.7 | 13.5 | 2.255 | 2.789 |
| 250 | 19.8 | 15.3 | 3.029 | 3.920 |
| 275 | 22.3 | 16.2 | 3.613 | 4.973 |
| 300 | 25.0 | 17.6 | 4.400 | 6.250 |
| 325 | 29.0 | 19.0 | 5.510 | 8.410 |
| $\Sigma$ | 166.6 | 134.6 | 23.65 | 31.58 |
| Average | 11.90* | 9.614* | | |

$$\text{Deformation Ratio} = \text{DR} = \frac{\Sigma xy - \frac{\Sigma x \Sigma y}{n}}{\Sigma x^2 - \frac{(\Sigma x)^2}{n}} = 6.49$$

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* These values used to determine the position of the line of best fit.

(3) Determine the horizontal tangent modulus $S_H$, the slope of the line of best fit between load P and total horizontal deformation $X_T$ for loads up to the failure load $P_{Fail}$ on the load-horizontal deformation curve (Fig 11). The solution using the least squares method is shown in Table 3.

(4) Solve the equations summarized in Table 1 to determine the various tensile properties.

Example

(1) Calculate tensile strength. From Table 1

$$S_T = 0.156 \frac{P_{max}}{h}$$

P = 325 pounds (Fig 11),

h = 1.980 inches,

D = 4 inches,

$S_T$ = 25.6 psi.

(2) Determine DR and calculate Poisson's ratio $\nu$. From Table 2

$$DR = \frac{\Sigma xy - \frac{\Sigma x \Sigma y}{n}}{\Sigma x^2 - \frac{(\Sigma x)^2}{n}} = 6.49$$

From Table 1

$$\text{Poisson's ratio} \quad \nu = \frac{0.0673DR - 0.8954}{-0.2494DR - 0.0156} = 0.281$$

(3) Determine $\left(\frac{P}{X_T}\right)$ and calculate modulus of elasticity E. From Table 3

TABLE 3. EXAMPLE CALCULATION OF HORIZONTAL TANGENT MODULUS USING THE METHOD OF LEAST SQUARES.

| | X, Horizontal Deformation, in Inches ($\times 10^{-4}$) | Y, Load, in Pounds | XY ($\times 10^{-2}$) | $X^2$ ($\times 10^{-6}$) |
|---|---|---|---|---|
| | 0 | 0 | 0 | 0 |
| | 1.0 | 25 | .250 | .010 |
| | 2.0 | 50 | 1.000 | .040 |
| | 3.3 | 75 | 2.475 | .109 |
| | 5.0 | 100 | 5.000 | .250 |
| | 7.0 | 125 | 8.750 | .490 |
| | 9.1 | 150 | 13.650 | .828 |
| | 12.0 | 175 | 21.000 | 1.440 |
| | 14.4 | 200 | 28.800 | 2.074 |
| | 16.7 | 225 | 37.575 | 2.789 |
| | 19.8 | 250 | 49.500 | 3.920 |
| | 22.3 | 275 | 61.325 | 4.973 |
| | 25.0 | 300 | 75.000 | 6.250 |
| | 29.0 | 325 | 94.250 | 8.410 |
| $\Sigma$ | 166.6 | 2275 | 398.575 | 31.583 |
| Average* | 11.900 | 162.5 | | |

$$S_H = \frac{\Sigma\, xy - \frac{\Sigma\, x\, \Sigma\, y}{n}}{\Sigma\, x^2 - \frac{(\Sigma\, x)^2}{n}} = 10.87 \times 10^4 \text{ lb/in}$$

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* These values are used to determine the position of the line of best fit.

$$S_H = \frac{\Sigma xy - \frac{\Sigma x \Sigma y}{n}}{\Sigma x^2 - \frac{(\Sigma x)^2}{n}} = 10.87 \times 10^4 \text{ lb/in}$$

From Table 1

$$E = \frac{S_H}{h}\left[0.9976\nu + 0.2692\right] = 3.017 \times 10^4 \text{ psi}$$

(4) Calculate total tensile strain at failure $\epsilon_T$. From Fig 11

$X_{TF}$ = .0029 inches

From Table 1

$$\epsilon_T = X_{TF}\left[\frac{0.1185\nu + 0.03896}{0.2494\nu + 0.0673}\right] = 1.53 \times 10^{-3}$$

## REFERENCES

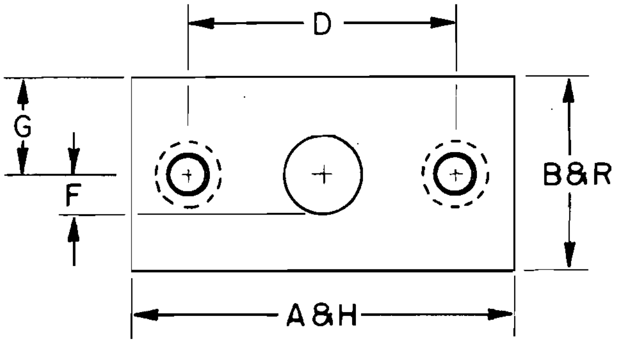
1. Hadley, William O., W. Ronald Hudson, and Thomas W. Kennedy, "Evaluation and Prediction of the Tensile Properties of Asphalt-Treated Materials," Research Report 98-9, Center for Highway Research, The University of Texas at Austin, October 1971.

2. Texas Highway Department, Manual of Testing Procedures, Vol I, Materials and Test Division, Test Method Tex-206-F, Revised Edition, 1966.

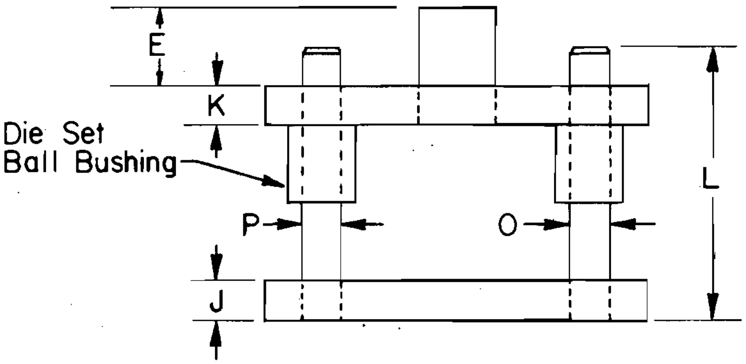
3. Hudson, W. Ronald and Thomas W. Kennedy, "An Indirect Tensile Test for Stabilized Materials," Research Report 98-1, Center for Highway Research, The University of Texas at Austin, January 1968.

# APPENDIX 1

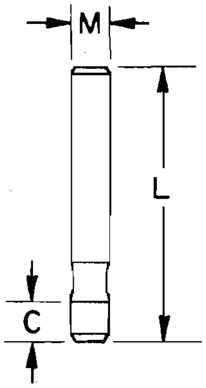
## GENERAL - SPECIAL EQUIPMENT REQUIRED TO OBTAIN TENSILE STRENGTH



Die Set - Top View



Die Set - Front View



Guide Post

| Die Space | | Thickness | | General Dimensions, in. | | | Guide Post | | | | | Shank Dimensions, in. | | | Die Set Ball Bushing (2) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Left to Right, in. | Front to Back, in. | Die Hldr, in. | Punch Hldr, in. | | | | Diameter, in. | | Length of Press Fit, in. | Length in. | Press Fit, in. | | | | Working Bore | |
| A | B | J | K | D | H | R | O | P | C | L | M | E | F | G | Nom | Tol. |
| 15¾ | 6 | 1⅜ | 1⅜ | 12¼ | 15¾ | 6 | 1¼ | 1¼ | 1¾ | 10 | .002 | 1⅞ | 1 | 3 | 1¼ | 1.2497<br>1.2500 |

(1) Guide Posts are Hardened, Ground, and Hard Chrome Plated to Listed Diameter within Tolerance of +.0003 in. to -.0000 in.

(2) Thomson Interchangeable Die Set Ball Bushings Number DS-20

Fig A1. Die set specifications.

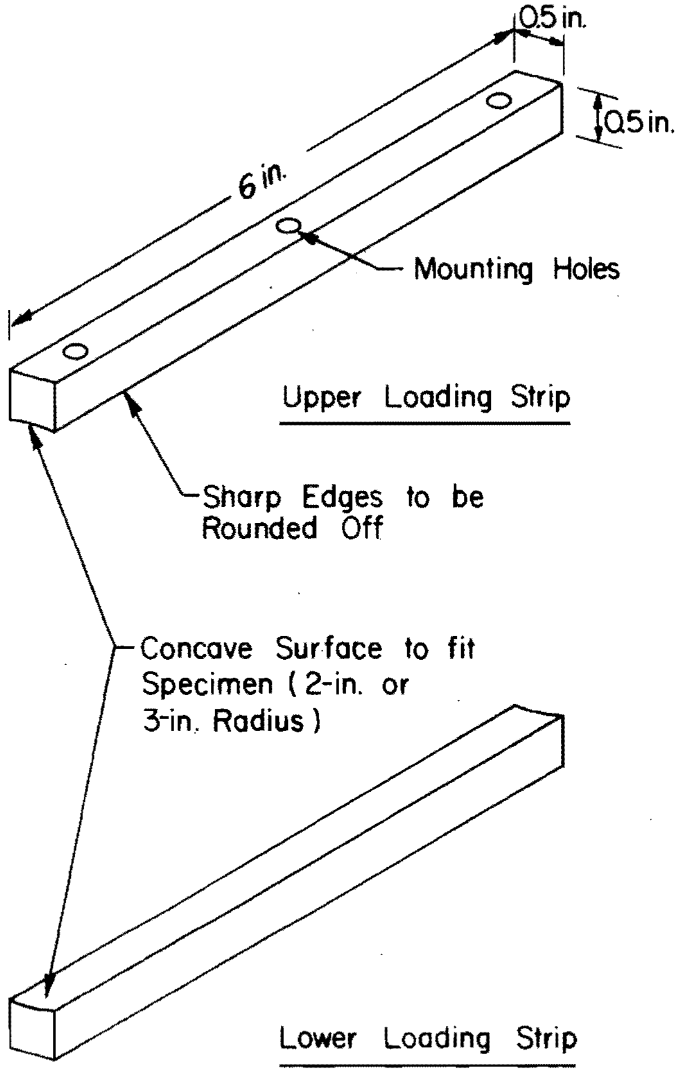


Fig A2. Upper and lower loading strip specifications.

# APPENDIX 2

# TEXAS HIGHWAY DEPARTMENT - SPECIAL EQUIPMENT REQUIRED TO OBTAIN TENSILE STRENGTH

## APPENDIX 2. TEXAS HIGHWAY DEPARTMENT - SPECIAL EQUIPMENT REQUIRED TO OBTAIN TENSILE STRENGTH

In order for the Texas Highway Department motorized gyratory press to be utilized as the loading device, an upper and lower loading plate with the correct face curvature must be constructed and attached.* The plate specifications are presented in Fig A3 and the loading strips are shown in Fig A4.

An additional modification of the gyratory press is required in order to obtain accurate load estimates from the pressure gage. A Whitey Ball Valve (Cat. No. 4354) and a Nupro Check Valve (Cat. No. B-4CA-3), both with 1/4-inch Swagelok inlet and outlet connections, should be inserted into the hydraulic pressure line leading to the pressure gages as illustrated in Fig A5. Since there is a time lag between the actual pressure and the indicated pressure, this modification holds the actual pressure in the system allowing the pressure gage to catch up. In addition this modification eliminates the need of using the drag hand which is a definite source of error. Nevertheless, the gage needles should be visually tracked during testing.

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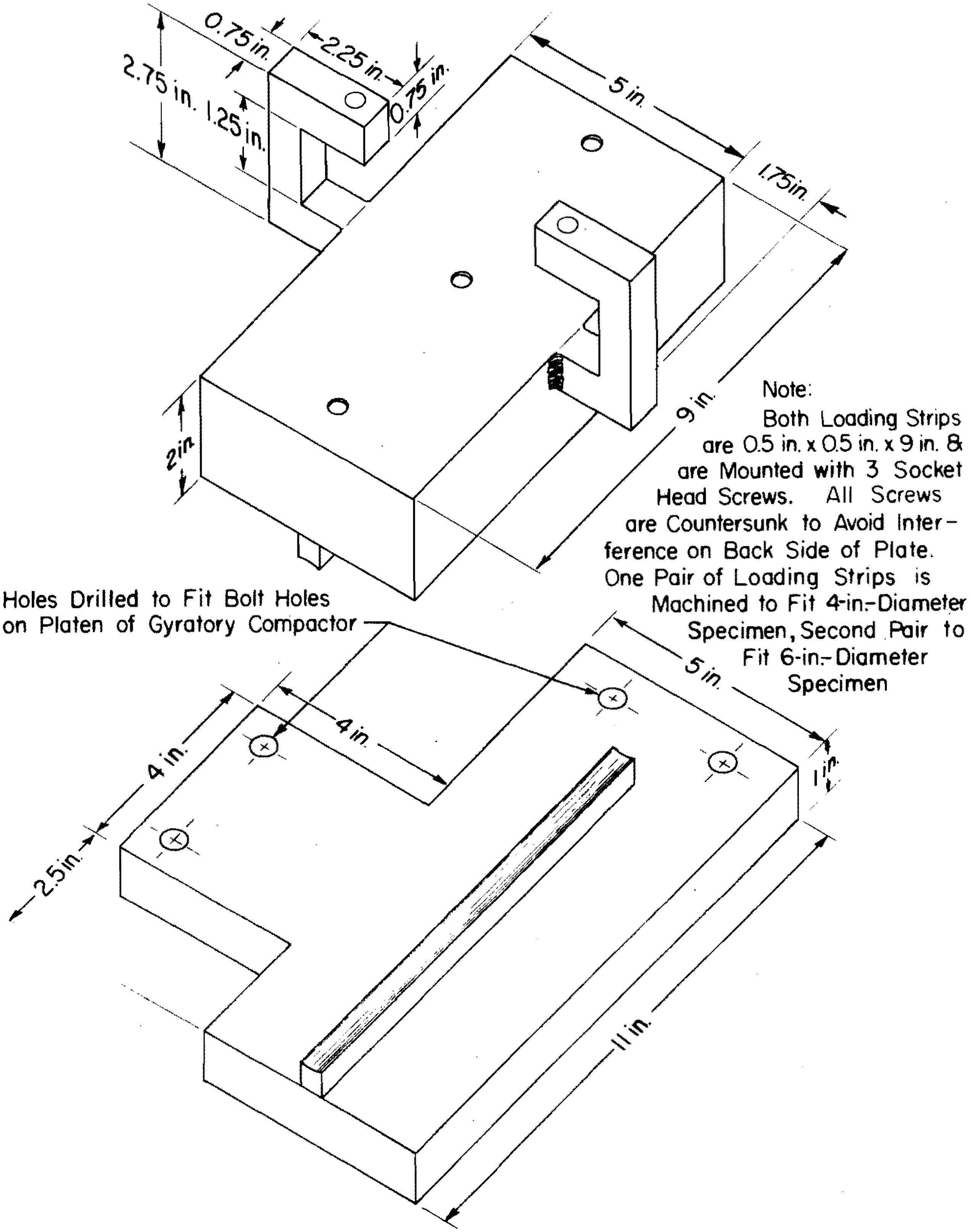
* Extreme care must be taken in aligning the upper and lower loading plate.



Note:
Both Loading Strips are 0.5 in. x 0.5 in. x 9 in. & are Mounted with 3 Socket Head Screws. All Screws are Countersunk to Avoid Interference on Back Side of Plate. One Pair of Loading Strips is Machined to Fit 4-in.-Diameter Specimen, Second Pair to Fit 6-in.-Diameter Specimen

Holes Drilled to Fit Bolt Holes on Platen of Gyratory Compactor

Fig A3. Upper and lower loading plate specifications.

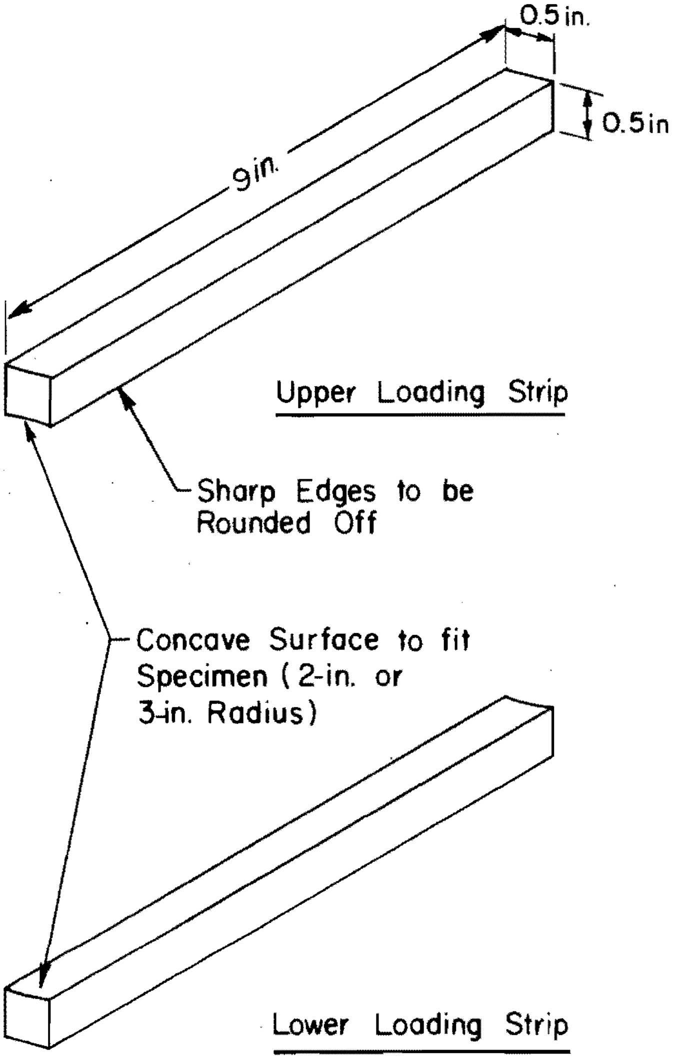


Fig A4. Upper and lower loading strip specifications.

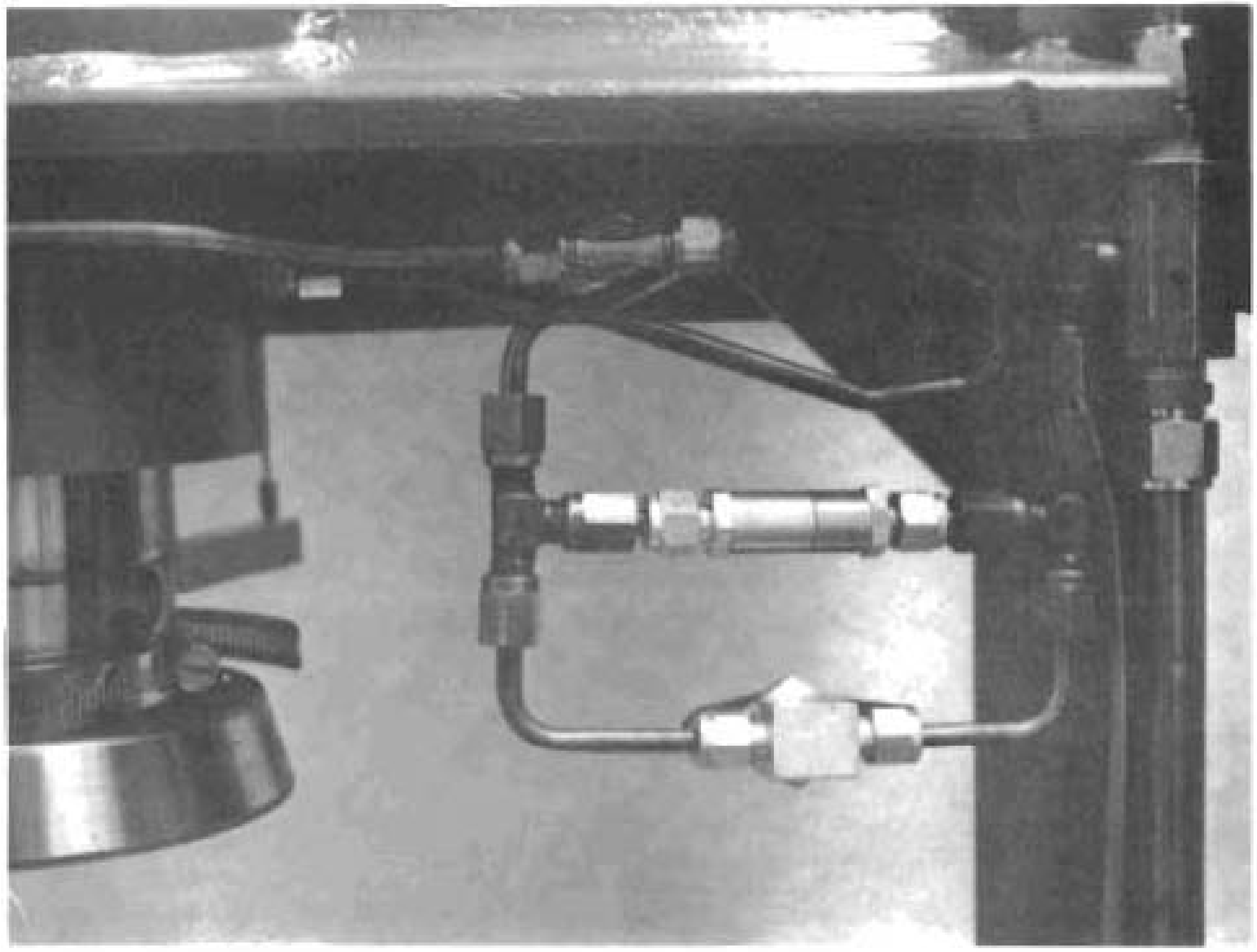


Fig A5. Modification of pressure gage system in the gyratory press.

# APPENDIX 3

## SPECIAL EQUIPMENT REQUIRED TO DETERMINE POISSON'S RATIO, MODULUS OF ELASTICITY, AND TENSILE STRAIN AT FAILURE

# APPENDIX 3. SPECIAL EQUIPMENT REQUIRED TO DETERMINE POISSON'S RATIO, MODULUS OF ELASTICITY, AND TENSILE STRAIN AT FAILURE

The special equipment required to determine the various tensile parameters is as follows:

(1) a loading device capable of applying compressive loads at a controlled deformation rate of 2 inches per minute;

(2) a guided loading head with parallel platens, such as a commercially available all-steel precision die set (Fig A1);

(3) a pair of curved-face loading strips of the proper size, which are to be attached to the upper and lower platens of the die set (Fig A2);

(4) a rear platform with a polished surface to be attached to the rear of the lower platen of the die set to support the horizontal deflection device (Fig A6);

(5) a horizontal deformation measuring device (Figs A7, A8, A9, A10, and A11);

(6) a calibrator for the horizontal deformation device (Fig A12), the dimensions for which are presented in Fig A12;

(7) an LVDT (linear variable differential transformer), such as Schaevitz Engineering Type 1000 DC-LVDT, to measure vertical deformation;

(8) a load cell to measure the applied load;

(9) three DC power supplies, such as Hewlett-Packard Model 801C, to power the load cell, the horizontal deflection device, and the LVDT;

(10) two x-y plotters, such as Hewlett-Packard Model 7001A, to continuously record load and vertical and horizontal deformation;

(11) a load cell to die set connector (Fig A13); and

(12) a digital voltmeter with which to set the various voltage requirements.

All of the above equipment except items 1, 6, 9, 10, and 12 is shown in Fig 9, arranged in a testing mode.

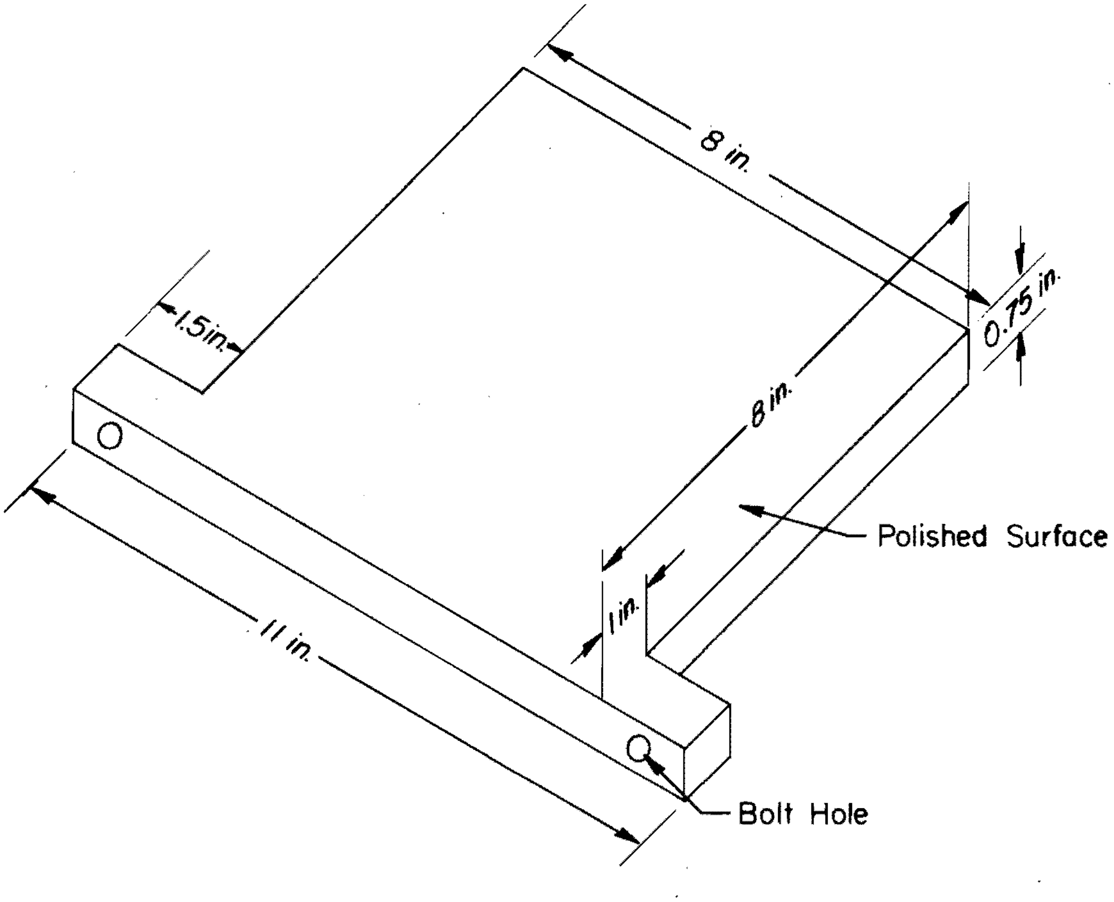
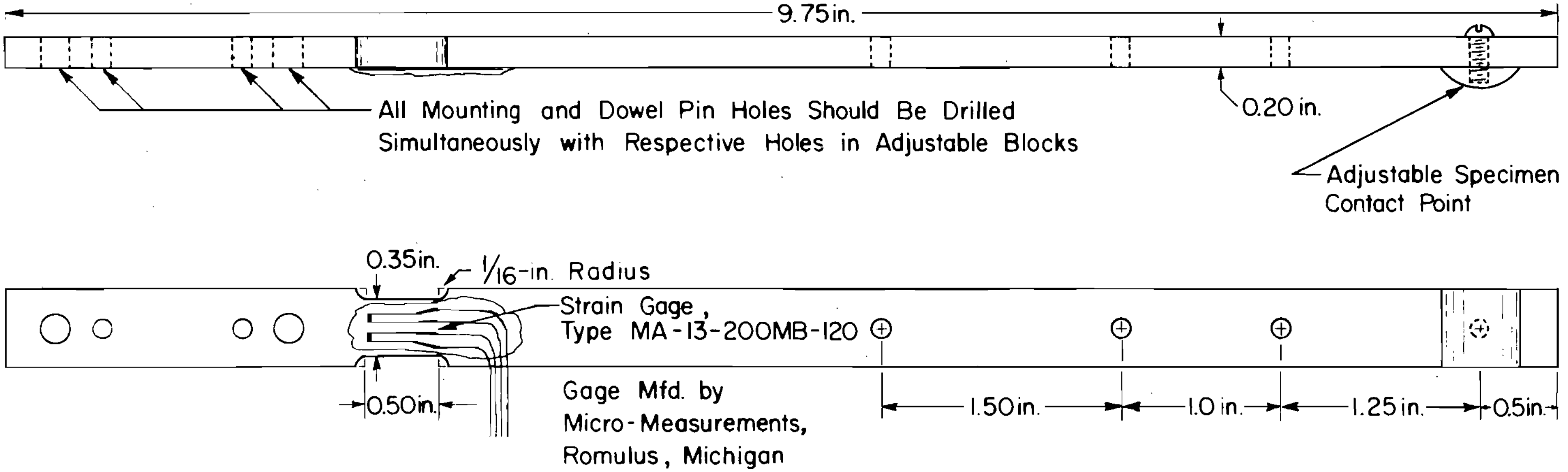


Fig A6. Rear platform to support horizontal deformation device.



Note: Two Arms Required, Made of 2024-T4 Aluminum with 2 Sets of Gages per Arm

Fig A7. Deformation arm for horizontal deformation device.

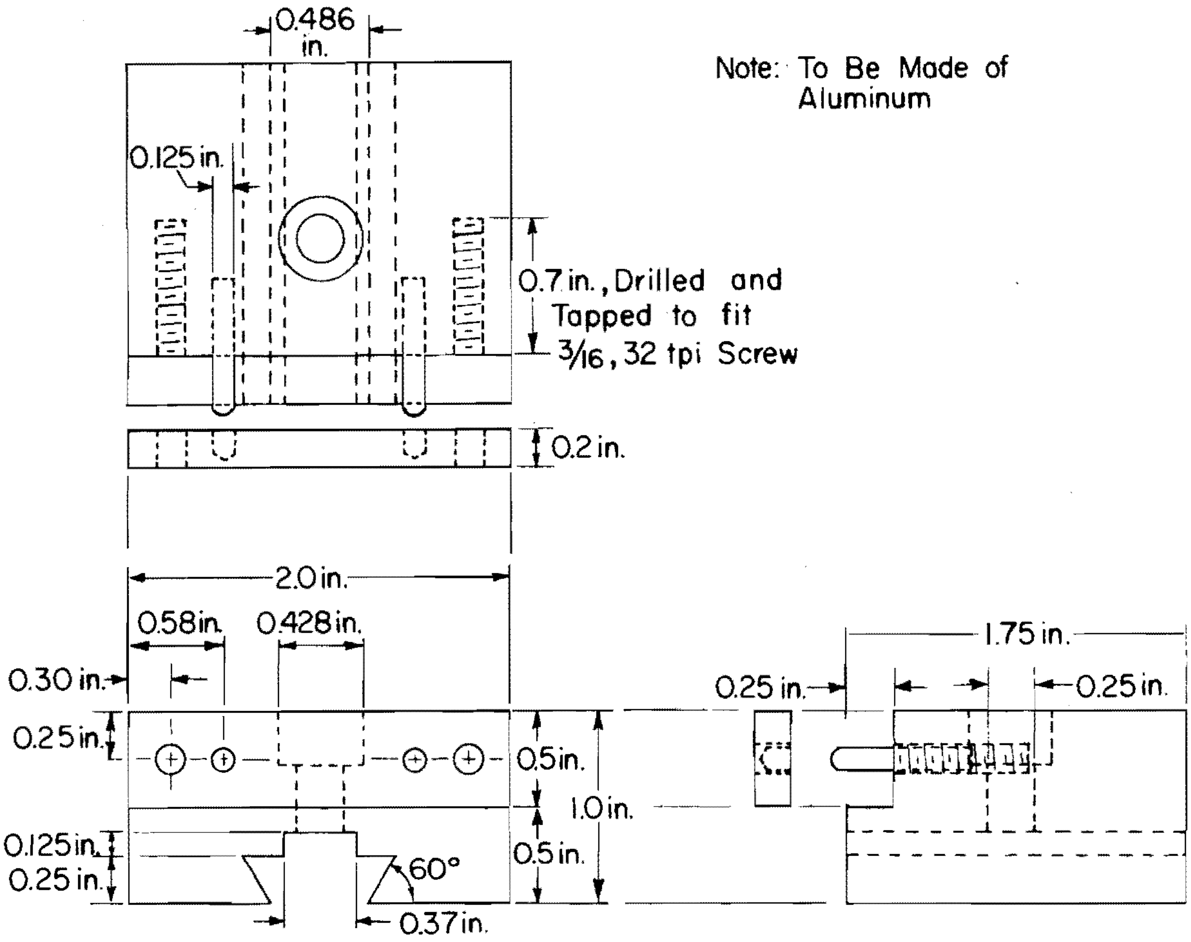
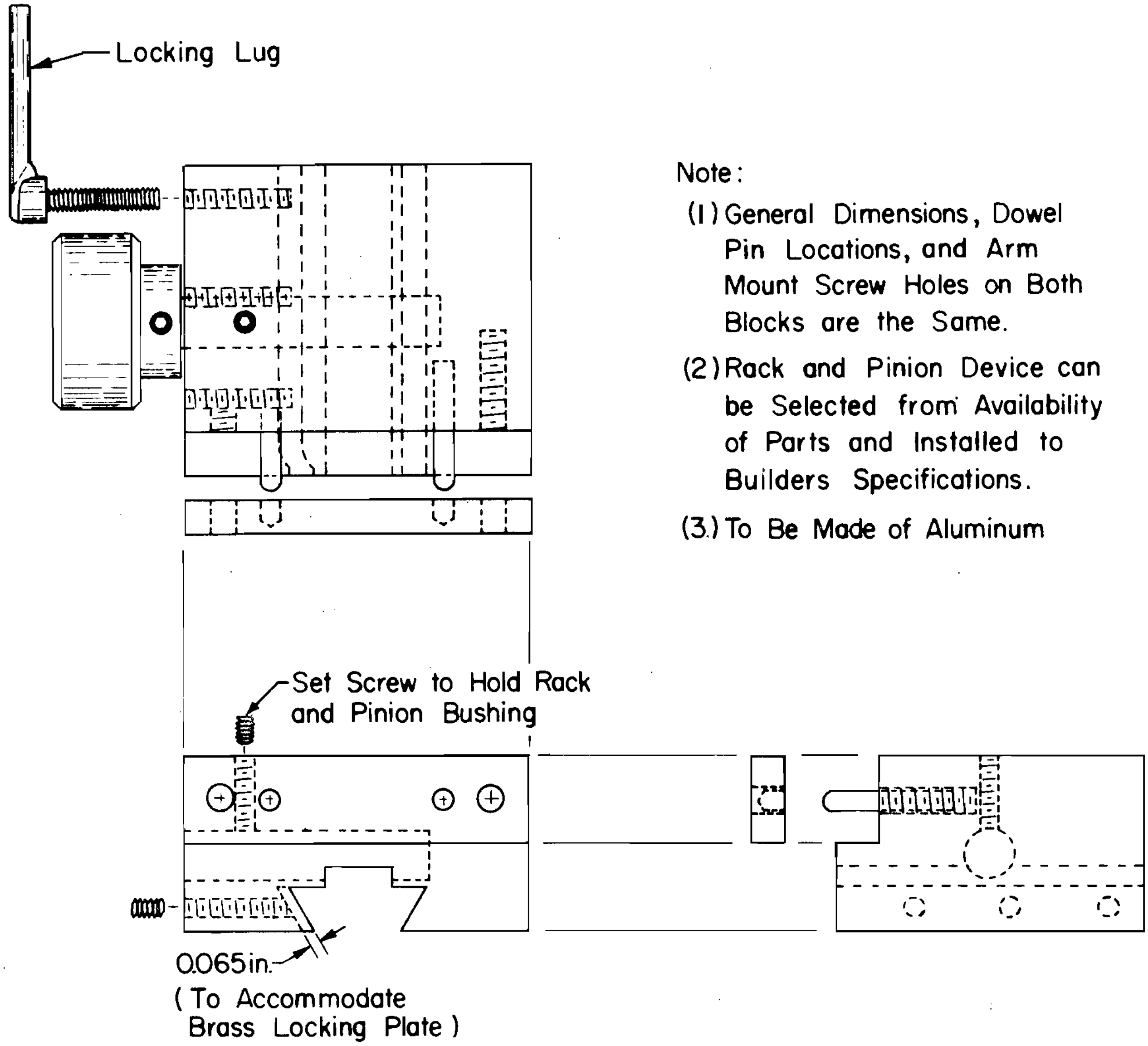


Fig A8. Coarse adjustment block for horizontal deformation device.



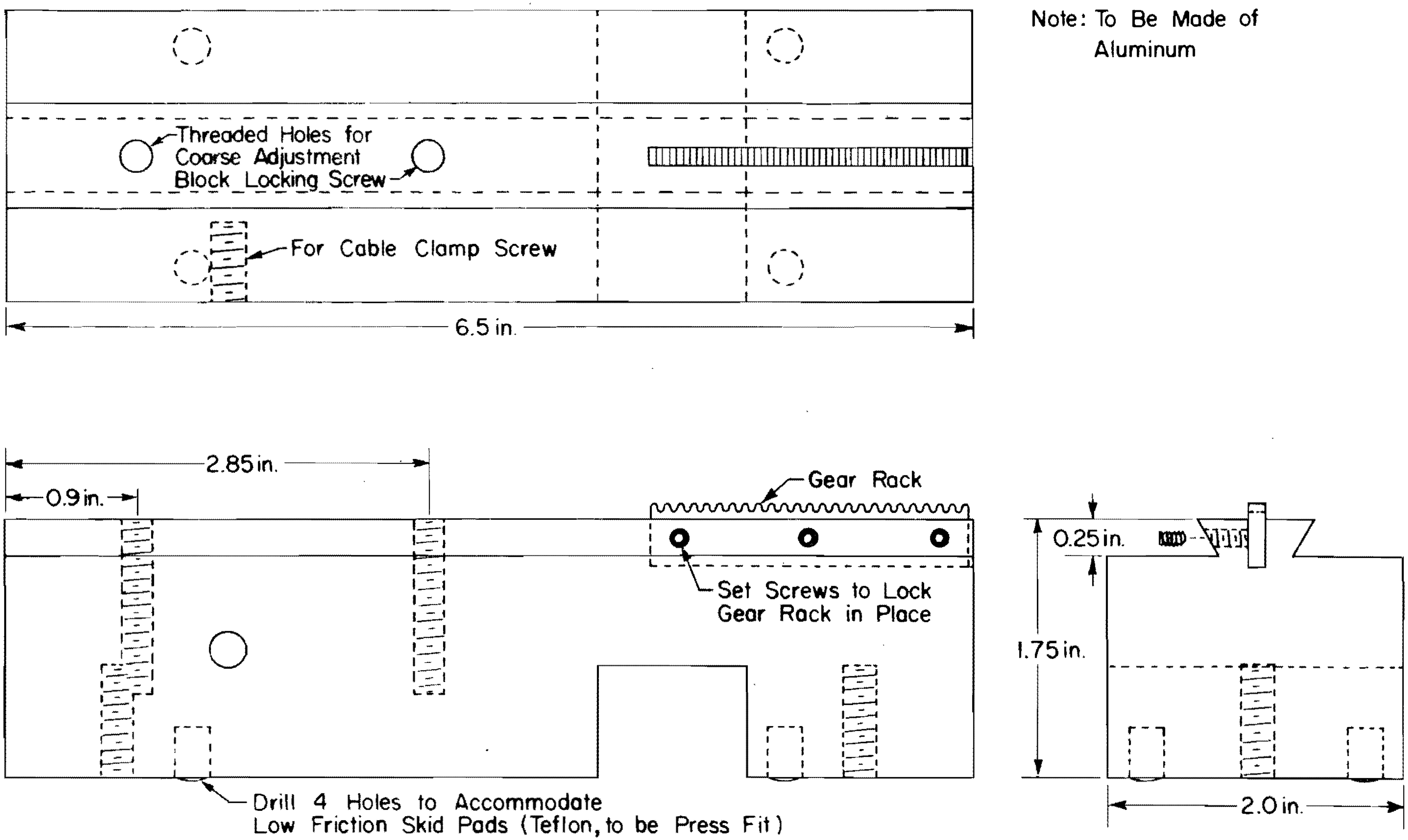
Note:

(1) General Dimensions, Dowel Pin Locations, and Arm Mount Screw Holes on Both Blocks are the Same.

(2) Rack and Pinion Device can be Selected from Availability of Parts and Installed to Builders Specifications.

(3.) To Be Made of Aluminum

Fig A9. Fine adjustment block for horizontal deformation device.



Note: To Be Made of
Aluminum

Fig A10. Base for horizontal deformation device.

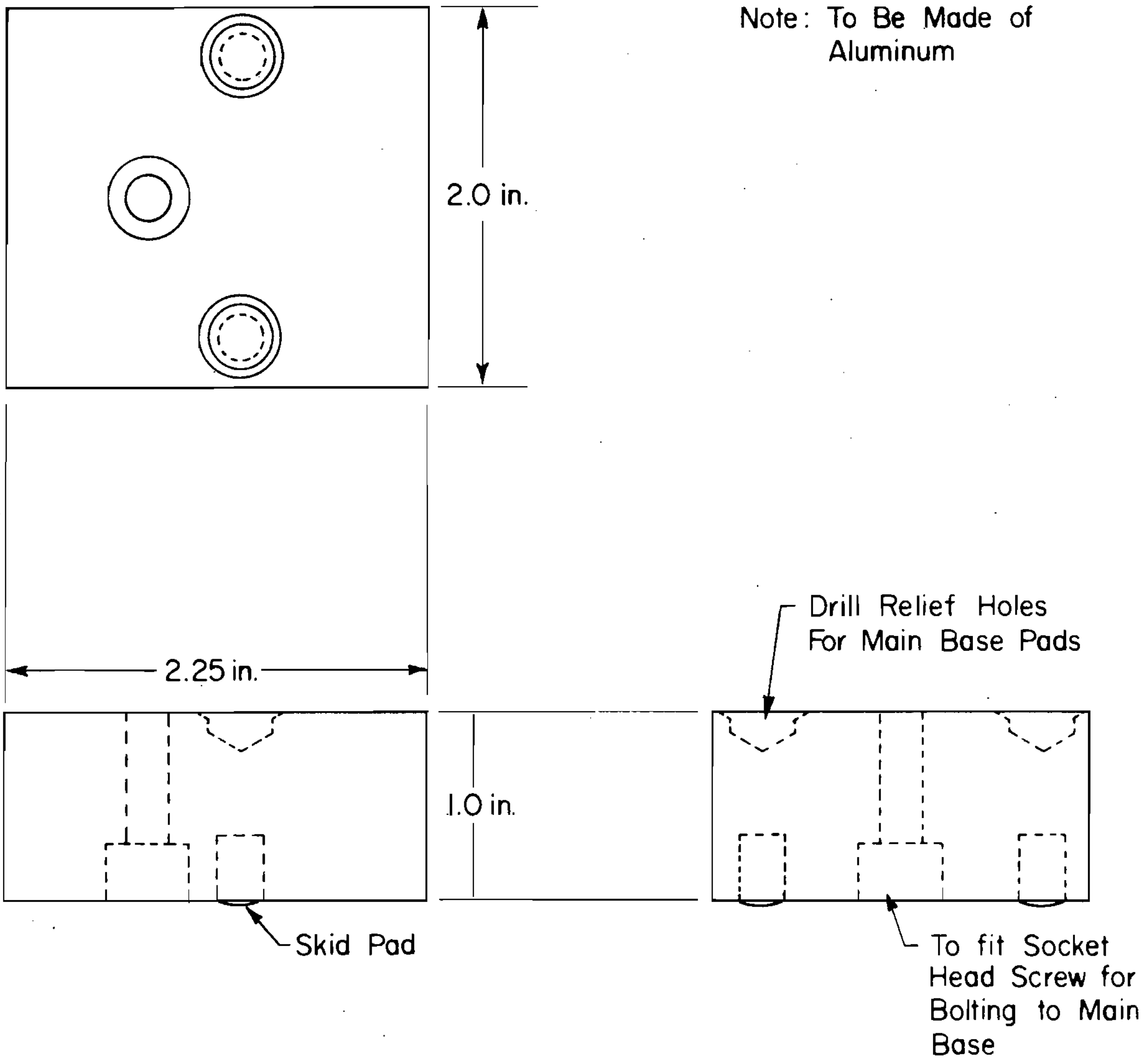
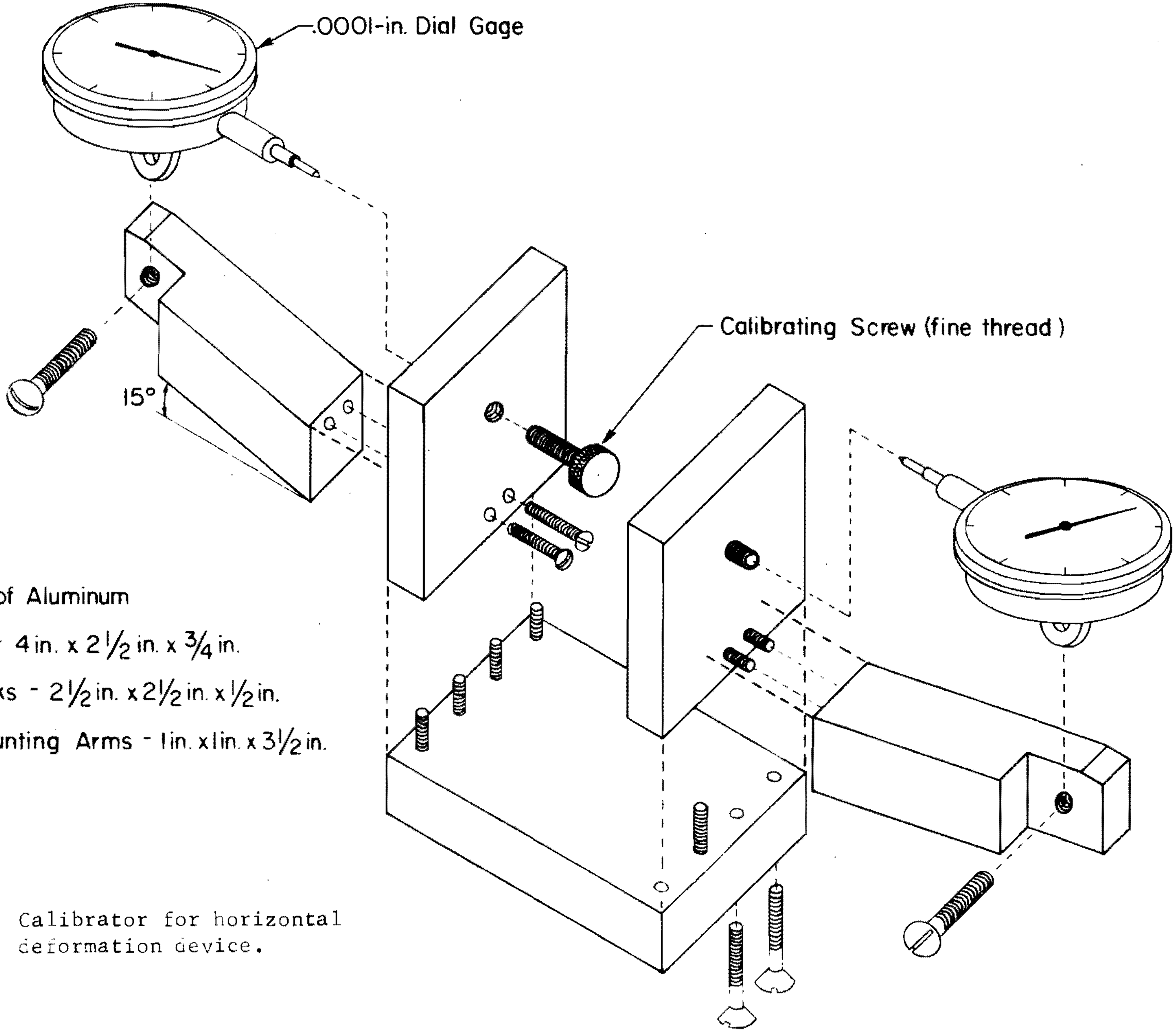


Fig A11. Base extension for horizontal deformation device.



Note:

To Be Made of Aluminum

Base Block - 4 in. x 2 1/2 in. x 3/4 in.

Vertical Blocks - 2 1/2 in. x 2 1/2 in. x 1/2 in.

Indicator Mounting Arms - 1 in. x 1 in. x 3 1/2 in.

Fig A12. Calibrator for horizontal deformation device.

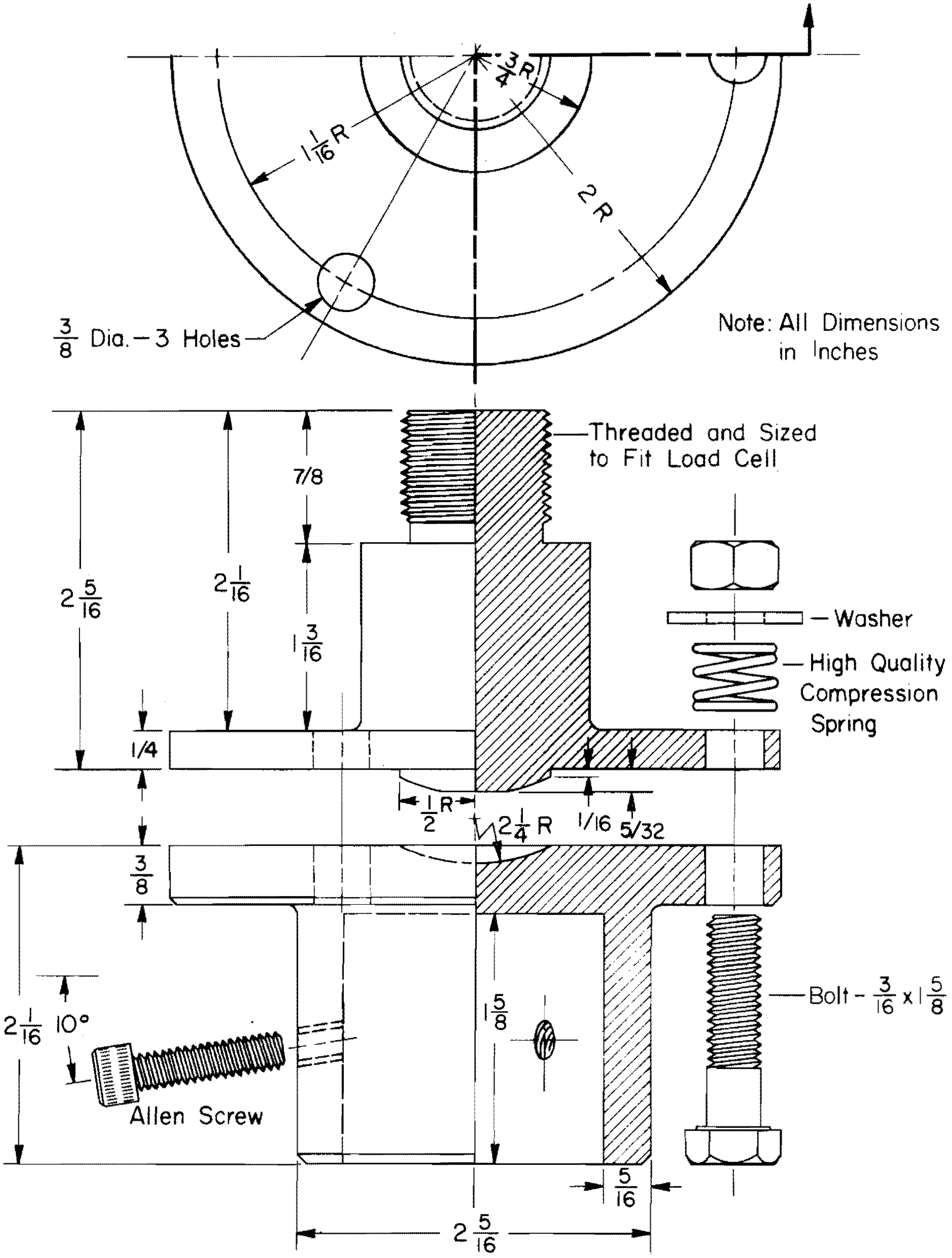


Fig A13. Connection between load cell and loadhead die set.

# APPENDIX 4

# HORIZONTAL DEFORMATION DEVICE CALIBRATION

## APPENDIX 4. HORIZONTAL DEFORMATION DEVICE CALIBRATION

Calibrate the horizontal deformation device as follows:

(1) Plug in DC power supply and recording equipment and allow approximately 20 minutes for warmup.

(2) Adjust DC power supply output to approximately 6 volts. A digital voltmeter is preferred for this adjustment.

(3) Place horizontal deformation device in calibrating position (Fig A14). Arm contacts should be centered on actuating screws and dial gage points. Caution should be exercised to assure that the arm contact points are lightly in contact with the actuating screw holder blocks.

(4) Lock arms in the above position.

(5) Connect the device to the power supply and to the recording equipment.

(6) Null the strain gage output and zero the dial gages.

(7) Select the desired MV/inch range on the recorder.

(8) Using one of the arm activating screws of the calibrator, move the arm a given amount. Check for proper movement on the recording equipment. The amount of movement may be changed by altering the applied voltage to the strain gage or by altering the range selection of the recording equipment.

(9) Calibrate the other arm in a like manner.

(10) Continue the process several times to check for repeatability.

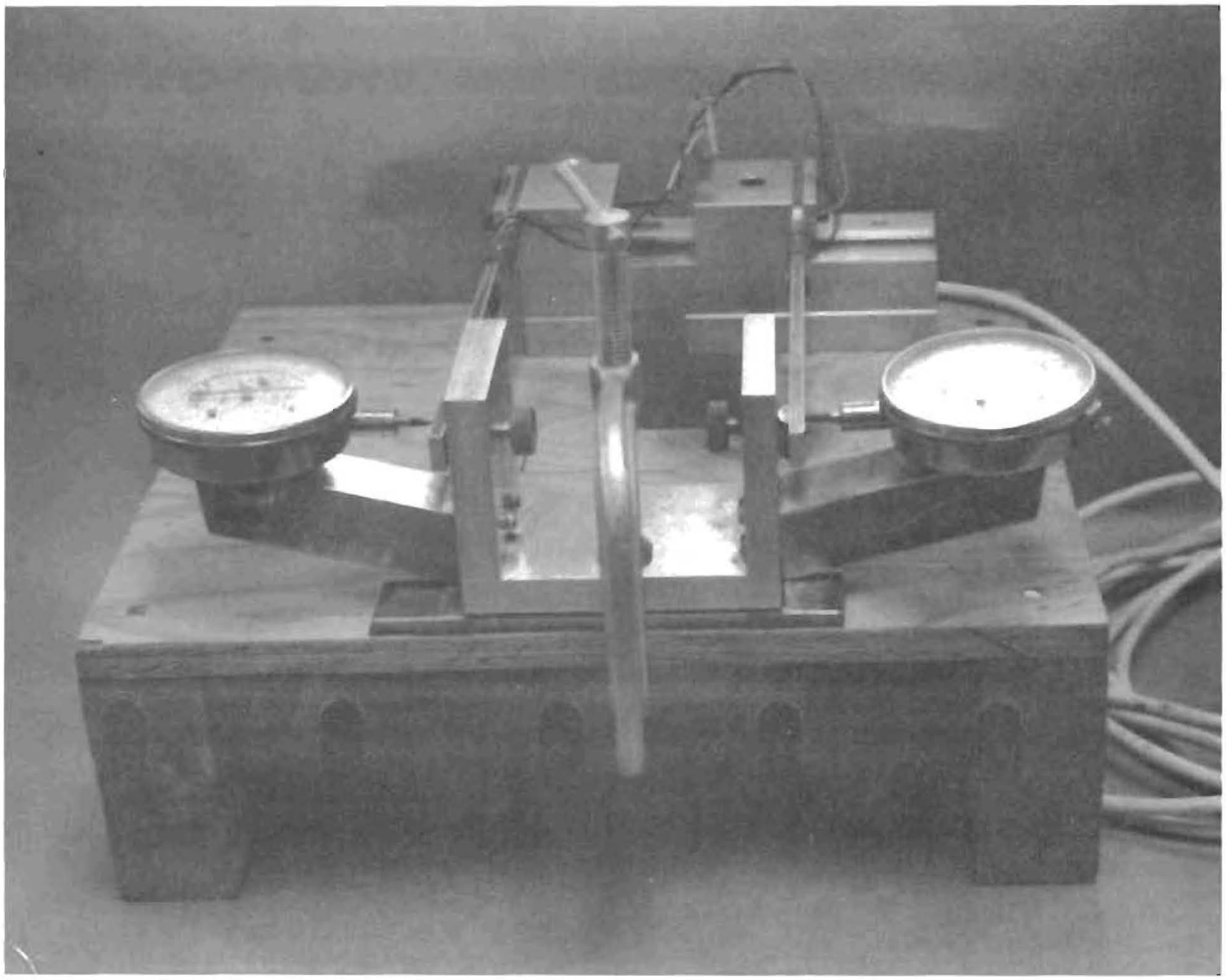


Fig A14. Horizontal deflection device and calibrator.

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