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THE LOAD TRANSMISSION TEST FOR FLEXIBLE PAVING AND BASE COURSES

PART I

A DESCRIPTION OF THE TESTING APPARATUS, OPERATING METHODS, AND ANTICIPATED USES OF TEST DATA

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THE LOAD TRANSMISSION TEST FOR FLEXIBLE PAVING AND BASE COURSES

PART I

A DESCRIPTION OF THE TESTING APPARATUS, OPERATING METHODS, AND ANTICIPATED USES OF TEST DATA

SUMMARY

The authors discuss briefly the present status of flexible paving design and describe a special testing rig which has been built for the purpose of furnishing some of the basic information necessary for a more accurate and rational approach to this problem The apparatus consists essentially of a mechanical subgrade ten feet square, with provisions for constructing a pavement test section upon the subgrade, loading the pavement section through single or multiple rigid plates or tires, and measuring the vertical stress distribution on the subgrade Results will be used for studying the effects of subgrade strength, pavement strength, pavement thickness, type of loading medium, size of loaded area, and multiple loadings

INTRODUCTION

Although flexible pavements have been used for hundreds of years, the design of such pavements still rests on an empirical basis Pavement thicknesses are determined directly from service experience or by empirical formulas which try to correlate service records with some measurable quality of the paving material, or of the subgrade upon which it rests

As long as adequate performance data are available for pavements of similar character, constructed on similar subgrades and carrying similar loads, these methods can be used with considerable confidence When it becomes necessary to design for heavier loads, for unfamiliar subgrade conditions, or for new construction materials, the need for a more rational design method becomes painfully evident This is the situation which existed during World War II, and which still exists to a great extent today.

In order to design any structure on a rational basis it is necessary to know (1) the intensity and point of application of applied loads, (2) the distribution of stresses and strains within the structure, and (3) the capacity of the structural elements to withstand the induced stresses without failure or undue deformation For pavement design, item (1) can be determined or assumed with a reasonable degree of accuracy Items (2) and (3) are very difficult to determine for subgrade or flexible paving materials because such materials are imperfectly elastic and because they do not have definite yield points as concrete and structural steel do Ever since the classic solutions of Boussinesq, able mathematicians have made computations of theoretical stress distribution through the pavement and subgrade sections These computations invariably are based upon idealized materials and loading conditions which do not exist in practice, and the results are in error by a corresponding unknown amount

A load transmission test was conceived for the purpose of supplying actual measurements of vertical stresses transmitted through a flexible surface or base course In this test the natural subgrade is replaced by a test platform of spring-supported plates which furnish a yielding support somewhat analogous to the action of a subgrade, and at the same time permit accurate determination of vertical deflections and load distribution at the bottom of the pavement section It involves a basic idea which has appealed to many investigators, but which often has been abandoned due to the expense of constructing a test rig capable of handling large test sections and due to the mechanical difficulties involved in its fabrication and operation

Valuable pioneering investigations

were reported several years ago by A T Goldbeck[1,2], Engineering Director of the National Crushed Stone Association, and by Professor M G Spangler[3,4,5,6] and his associates at Iowa State College At the present time data of a complementary nature are being obtained in test programs of the Waterways Experiment Station, the Bureau of Public Roads, and other establishments

DESCRIPTION OF TEST APPARATUS

The test installation of the Civil Aeronautics Administration is located at the Technical Development and Evaluation Center, Indianapolis, Indiana Fig 1 is a schematic representation of the testing rig

The testing platform or mechanical subgrade consists of 3,600 steel plates, each two inches square, placed side by side in 60 rows of 60 plates each Each plate is supported by a steel plunger which in turn operates against a coil spring A spring and plunger assembly is shown in Fig 2 The slender extension at the bottom of the plunger is an electrical contact for use in recording deflections It works against a small coil spring inside the plunger in order to allow relative movement of the plunger and the contact

Each spring and plunger operates within a vertical guide cylinder The bottoms of the guide cylinders are set into base plates and the tops of adjoining cylinders are welded together to insure rigidity The base is divided into three sections in order to facilitate handling during assembly The three base plates are fastened to and supported by vertical plates six inches high and three-fourths of an inch thick, spaced on 4 1/8-inch centers The vertical plates are bedded in stiff grout on a very heavy steel and concrete foundation

The openings between the vertical plates provide convenient spaces for insertion of micrometer measuring bars which measure the deflections of individual plungers Close fitting slots are provided, into which the bars are mounted and locked while deflection measurements are taken. Fig 3 shows one bar partially inserted and another entirely inserted and connected to a light panel

Each measuring bar supports 60 electrical contact points, set in two rows of 30 each, and corresponding to two half-rows of the contacts extending from the bottoms of the plungers as previously described All of the contact points on a measuring bar can be raised or lowered simultaneously by a crank at the end of the bar Vertical movement is measured to the nearest 0 001 inch by a micrometer dial

When two opposing contact points meet, the completion of the electrical circuit operates a light on a panel, indicating which plunger has made contact, and the position of the micrometer dial shows the elevation of the plunger at the time of contact Due to small differences in plunger lengths and other mechanical variations the point of contact under zero load varies for each plunger Therefore it is necessary to take readings before and after loading, the differences between these readings being the actual deflections of the individual elements Deflections up to 1 3/4 inches can be measured

The loading platform or mechanical subgrade, which is approximately ten feet square, is surrounded by a well reinforced plank bulkhead for the purpose of providing lateral support to the test section A thin rubber sheet is placed over the subgrade be-

[1] A T Goldbeck, "Studies of Subgrade Pressures under Flexible Road Surfaces", Proceedings Highway Research Board, Vol 19, p 164 (1939)

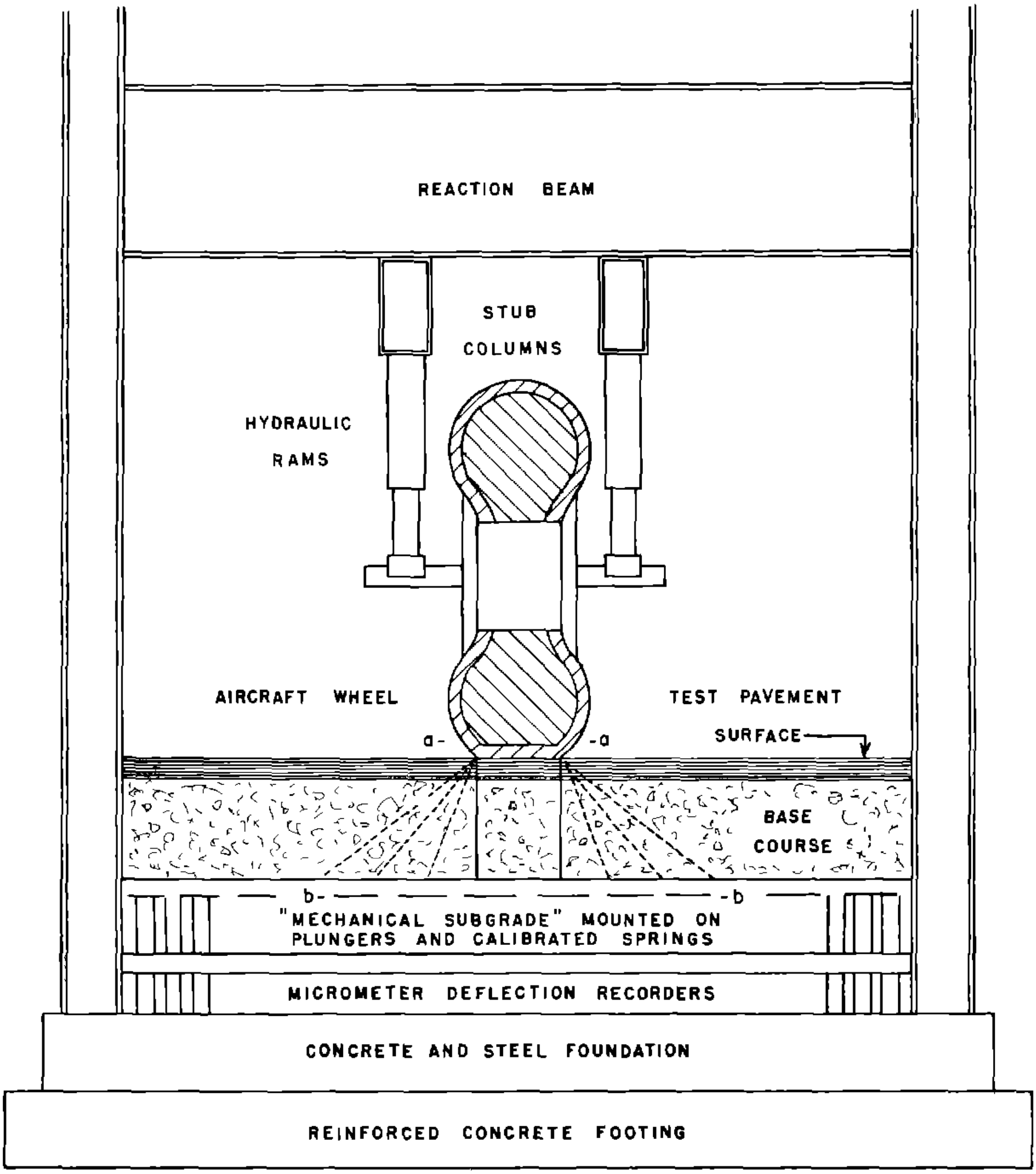
[2] A T Goldbeck, "A Method of Design of Non-rigid Pavements for Highways and Airport Runways", Proceedings Highway Research Board, Vol 20, p 258 (1940)

[3] M G Spangler, "Preliminary Experiments on the Distribution of Wheel Loads Through Flexible Pavements", Proceedings Highway Research Board, Vol 18, Part I, p 162 (1938)

[4] M G. Spangler, "Wheel Load Stress Distribution Through Flexible Type Pavements", Proceedings Highway Research Board, Vol 21, p 110 (1941)

[5] M G Spangler, "The Structural Design of Flexible Pavements", Proceedings Highway Research Board, Vol. 22, p 199 (1942).

[6] M G Spangler and H O Ustrud, "Wheel Load Stress Distribution Through Flexible Type Pavements", Proceedings Highway Research Board, Vol 20, p 235 (1940)



NOTE
A WHEEL LOAD APPLIED TO THE PAVEMENT SURFACE OVER AN AREA a--a IS TRANSMITTED AND DISTRIBUTED THRU THE SURFACE AND BASE COURSE THIS PRODUCES VARYING PRESSURES AND DEFLECTIONS OVER A LARGER AREA b--b ON THE SUBGRADE. IN THIS TEST, THE NATURAL SUBGRADE IS REPLACED BY A "MECHANICAL SUBGRADE" OR FLOORING COMPOSED OF 3600 SMALL STEEL PLATES THESE ARE MOUNTED ON PLUNGERS AND CALIBRATED SPRINGS IN SUCH A MANNER AS TO SIMULATE A SUBGRADE OF THE DESIRED STRENGTH AND TO PERMIT MEASUREMENT OF THE UNIT PRESSURES TRANSMITTED TO THE SUBGRADE

Fig 1 Load Transmission Testing Rig

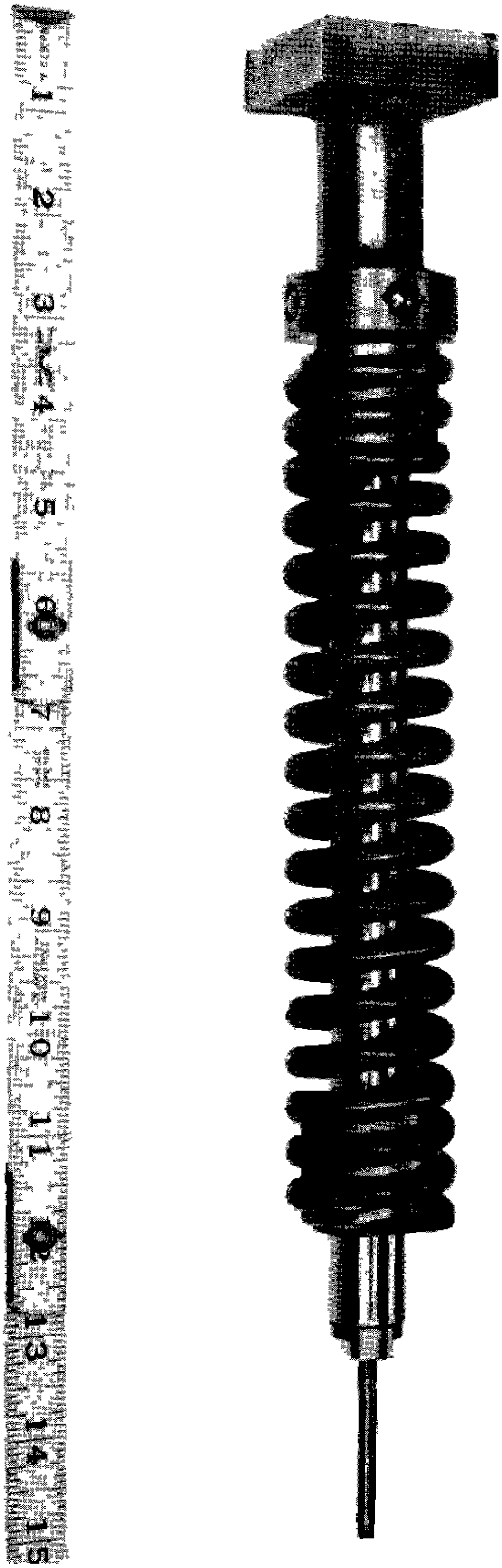


Fig 2 Spring and Plunger Assembly

fore constructing the pavement section in order to prevent the infiltration of dirt between the small steel plates which comprise the individual subgrade segments Loading is accomplished through hydraulic jacks reacting against a steel beam, which in turn is connected to the steel and concrete foundation by a heavy steel framework The present capacity of the loading system is about 250,000 pounds

Fig 4 is a general exterior view of the entire apparatus, including the foundation, supporting framework, reaction beam, hydraulic jacks, pump, bulkhead, and a portion of the deflection recording apparatus Fig 5 shows the mechanical subgrade in some detail, and Fig 6 shows a wheel in place on the bare subgrade Details of the pressure manifold, pressure gauges, and extra jacks for dual wheel loading also are illustrated in this figure

OPERATION

Operation of the test consists essentially of constructing a pavement slab on the mechanical subgrade, placing a load on the slab, and measuring the deflection of each subgrade segment Applying the spring rate constant to the measured deflection gives the load on each segment, and the sum of these loads should equal the applied load Supplementary measurements are taken to show the loaded areas of tires, tire deflections, and deformations of the paving surface

Testing operations will be varied to show the effect of (1) the loading medium (tire or rigid plate), (2) loaded area, (3) unit loading pressure, (4) multiple loads, (5) subgrade resistance, (6) strength of surfacing or base course, and (7) thickness The first tests are being conducted on the more common base and subbase materials, such as gravel, sand, stone, and slag These will be used singly, and in combination with each other, both with and without bituminous surfacings Construction of test sections follows standard practice as closely as possible Satisfactory compaction is obtained by means of commercial vibratory compactors Subgrade strengths will be varied from 25 to 160 psi per inch deflection by using different sets of springs

Under present practice each pavement section is subjected to an increasing series

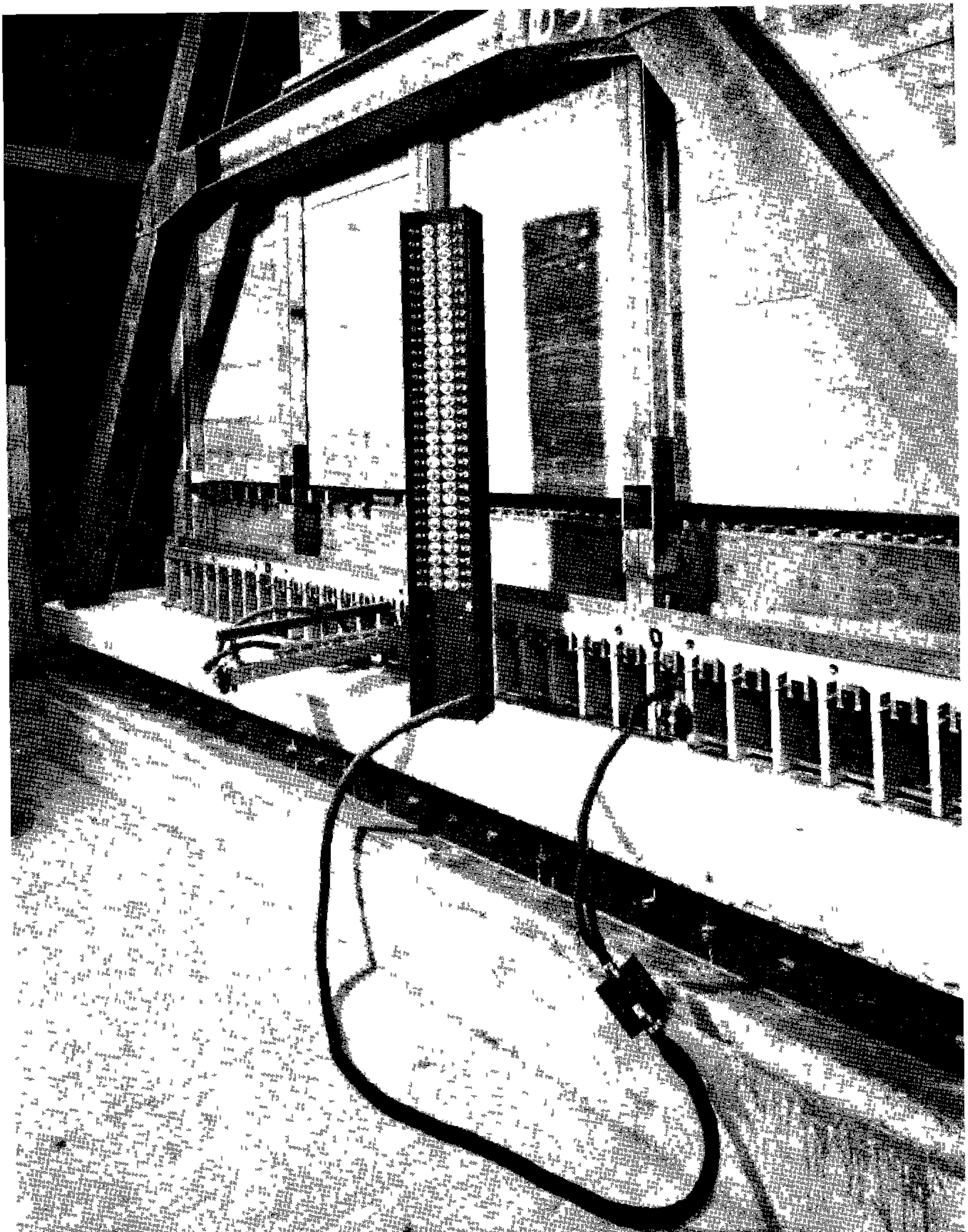


Fig 3 Deflection Recording Equipment

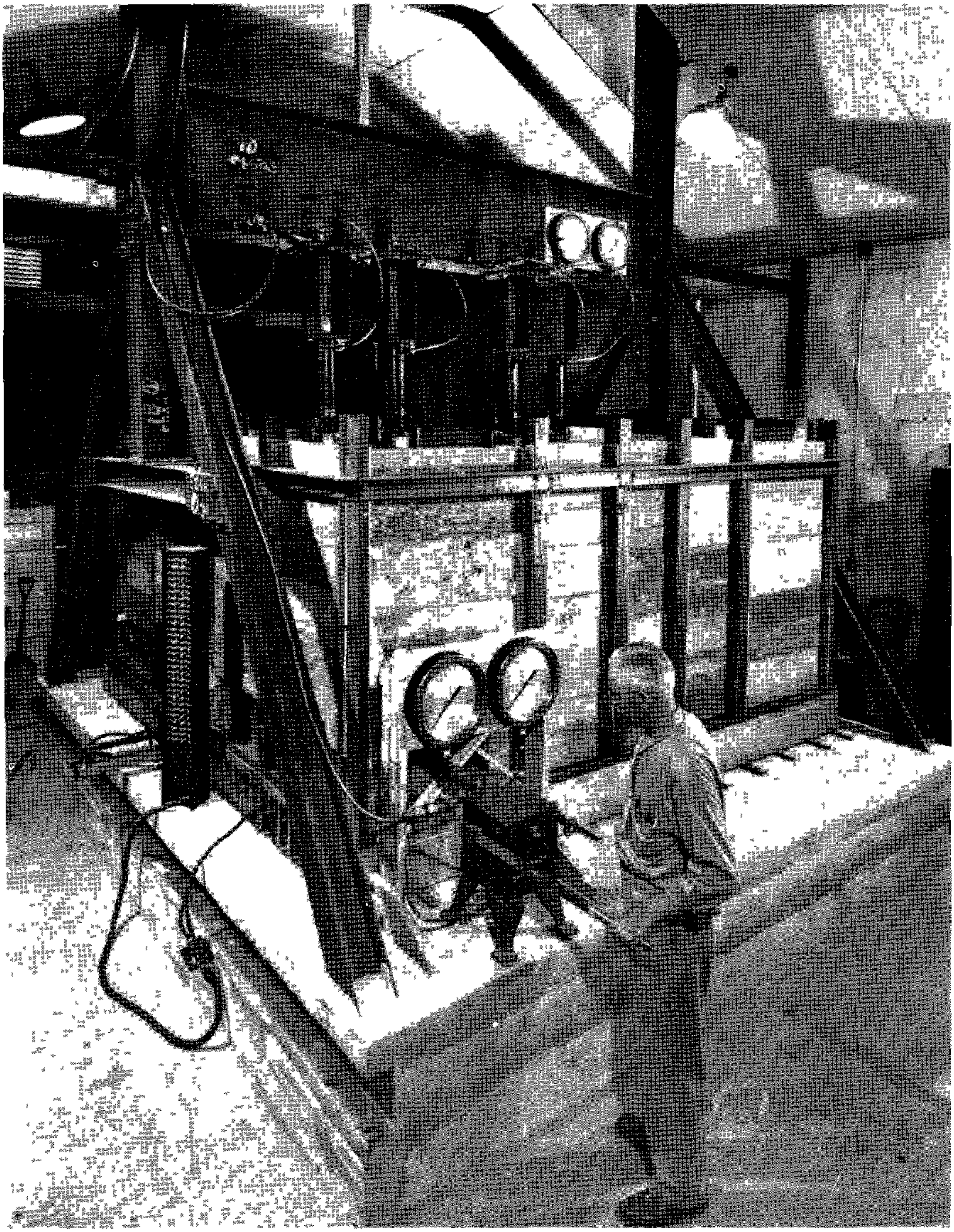


Fig 4 General Exterior, Load Transmission Apparatus

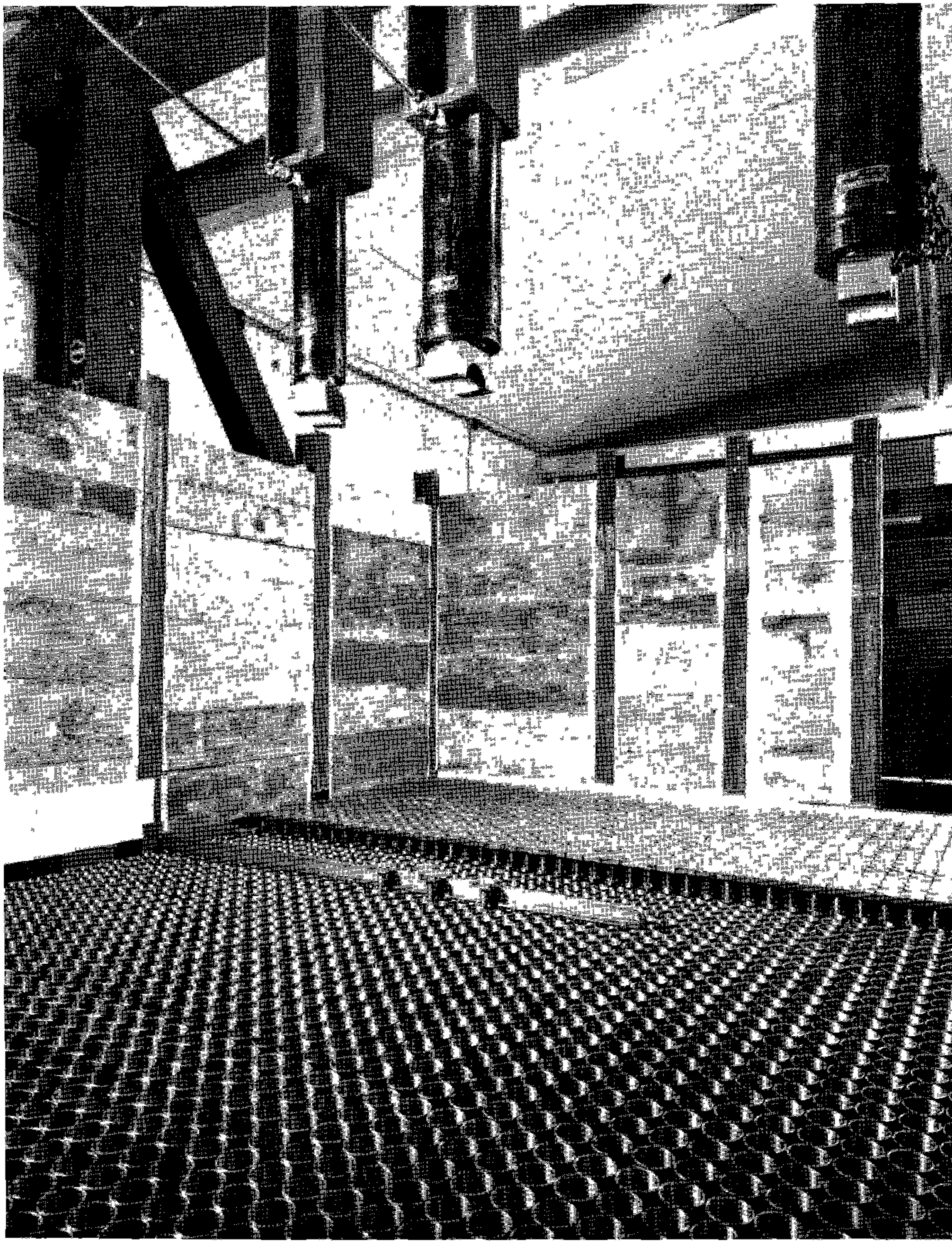


Fig 5 Partial Assembly of Mechanical Subgrade

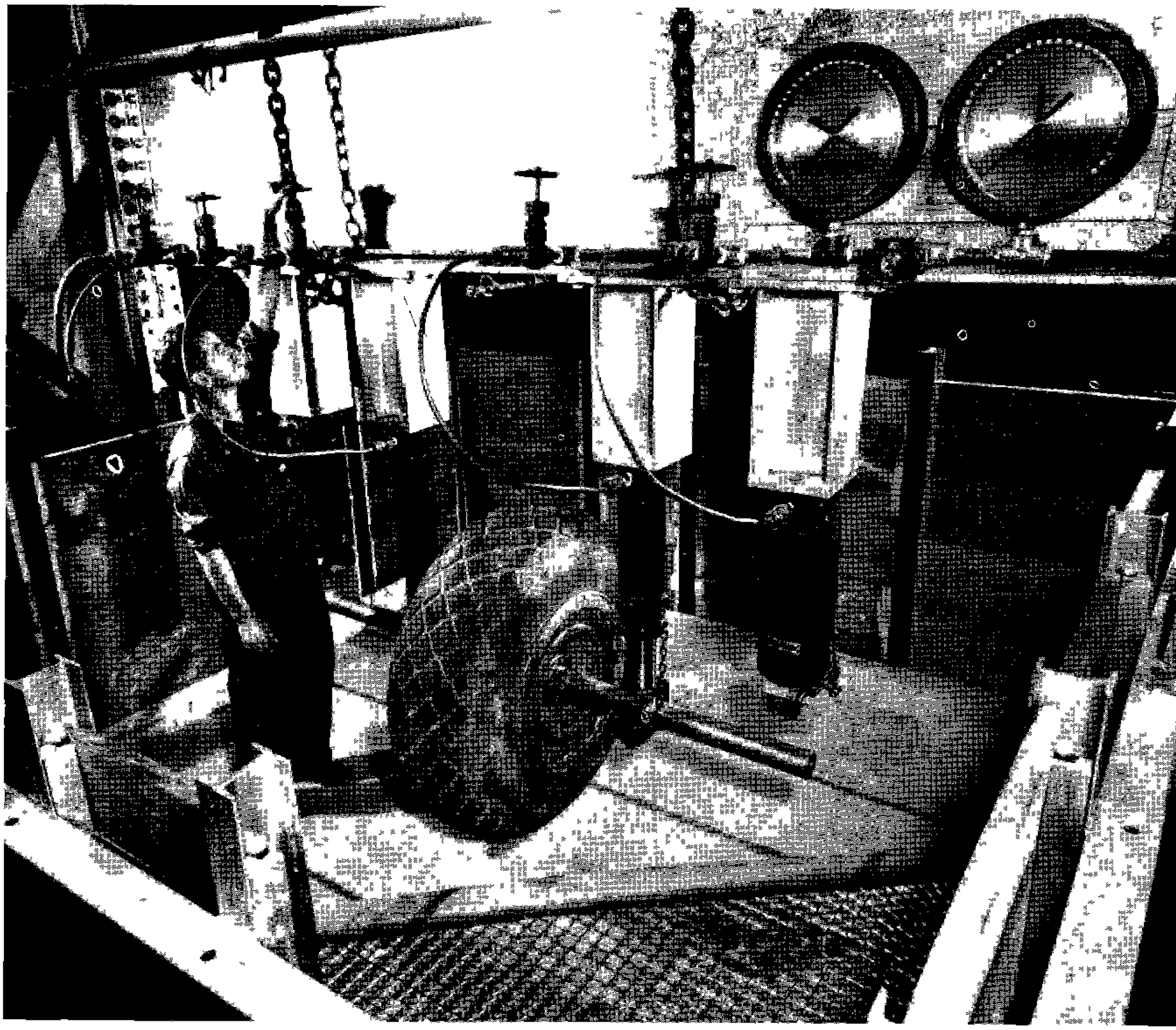


Fig 6 Aircraft Wheel in Place for Loading Bare Subgrade

of loads until there is apparent failure or excessive deformation, or until the limit of the loading apparatus has been reached No definite criterion for failure has been established

Recording the deflections is rather a tedious procedure with the present equipment, requiring about 30 man-hours for one reading of all 3,600 plunger positions There also is the possibility of some plastic movement in the test section during the long period required for manual recording It is hoped, therefore, that automatic equipment can be developed to expedite this operation Pending the development and fabrication of such equipment it has been found that much time can be saved on some tests by taking readings only at certain selected points Once the general pressure contour pattern has been established for a given loading condition, readings taken along the two major axes are sufficient to show the changes due to increasing loads or variations in pavement thickness

The granular materials and mixtures used in the load transmission apparatus also are being tested in triaxial compression The triaxial specimens are 10 inches in diameter and 20 inches high, as it was felt that smaller specimens would be unsatisfactory for mixtures containing large aggregate The triaxial test apparatus is illustrated in Fig 7

ANTICIPATED USES OF TEST DATA

The load transmission test does not in itself constitute a new design method It is simply a means of studying the action of large sections of flexible paving and base courses constructed and loaded under closely controlled laboratory conditions Expressed in the simplest possible terms the apparatus is designed to measure the dissipation of concentrated vertical loads through a flexible paving slab supported by an elastic artificial subgrade

For the present at least the test results can not be applied directly to a design problem even if the bearing power of a natural subgrade is determined by a plate bearing test or other means This is due to the fact that unit subgrade bearing power may vary with loaded area, surcharge, and other factors Also, the action of the artificial subgrade is not strictly comparable to that of a natural subgrade as it is perfectly elastic and as it does not permit lateral displacement

Nevertheless, the tests should give a qualitative indication of the comparative effectiveness of various materials and mixtures in distributing concentrated loads, in addition to showing the effects of variations in unit load, loaded area, paving thickness, and other factors This apparatus also should be a convenient means of studying the combined effect of multiple wheel loadings It also offers a means of comparing the effects of actual wheel loads with those applied through rigid plates

By applying loaded tires to the bare mechanical subgrade it will be possible to determine the actual load distribution on top of the pavement By applying the same loads through progressively greater thicknesses of paving material it may be possible to get a better picture than we now have of the shape and extent of the bulb of pressure beneath the loaded area This would enable mathematicians to check their previously computed patterns of stress distribution, and might lead to a really rational design formula

An effort will be made to establish a correlation between the triaxial data and the load transmission data This would make it possible to predict the performance of a new material on the basis of the simpler triaxial test

The design and fabrication of the load transmission apparatus has been a time-consuming operation, and only 30 tests have been run to date Half of these were of an exploratory nature, or were designed to check the operation of the apparatus These tests have indicated that the over-all accuracy of the testing rig is acceptable and it is believed that it will provide data of highly practical value to airport and highway paving designers

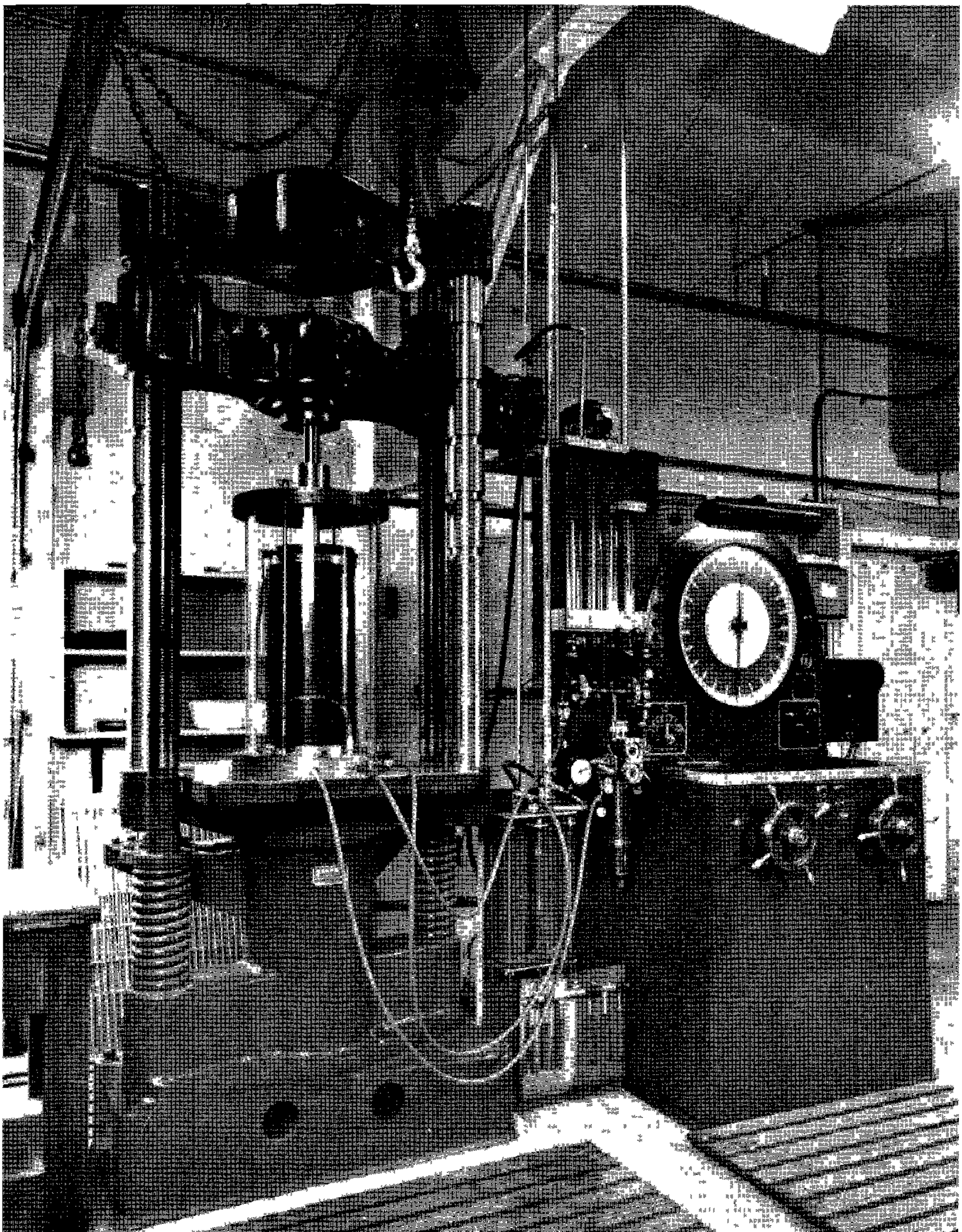


Fig 7 Triaxial Test Apparatus