MISCELLANEOUS PAPER S-74-3

SMALL APERTURE TESTING FOR AIRFIELD PAVEMENT EVALUATION

by

J. W. Hall, Jr., D. R. Elsea

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Sponsored by Office, Chief of Engineers, U. S. Army

Conducted by U. S. Army Engineer Waterways Experiment Station
Soils and Pavements Laboratory
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ARMY-MRC VICKSBURG, MISS.

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Foreword

The investigation reported herein was sponsored by the Office, Chief of Engineers, under the O&MA program, Project No. 4DM78012AQ61, Task 02, "Engineering Criteria for Design and Construction," Work Unit 003, "Nondestructive Testing of Pavements - Small Aperture." The investigation was conducted during the period July 1970-June 1972.

Personnel of the U. S. Army Engineer Waterways Experiment Station (WES) Soils and Pavements Laboratory who were actively engaged in the planning, testing, and reporting phases of this study were Messrs. A. H. Joseph, J. W. Hall, Jr., and D. R. Elsea. The work was performed under the general supervision of Messrs. J. P. Sale and R. G. Ahlvin, Chief and Assistant Chief, respectively, of the Soils and Pavements Laboratory. This report was prepared by Messrs. Hall and Elsea.

Directors of WES during the conduct of this investigation and the preparation and publication of this report were BG E. D. Peixotto, CE, and COL G. H. Hilt, CE. Mr. F. R. Brown was Technical Director.

Contents

Conversion Factors, British to Metric Units of Measurement

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
pounds per square inch	0.6894757	newtons per square centimeter
pounds (mass) per cubic foot	16.018498	kilograms per cubic meter
pounds (mass) per cubic inch	27.679911	kilograms per cubic centimeter

Summary

The high intensity of aircraft operations on most military airfields prohibits the closing of runways and other pavement facilities in order to measure the physical properties of the pavement necessary to evaluate its load-carrying capability. Also, the introduction of multiple-wheel heavy gear load aircraft coupled with an ever increasing number of aircraft operations has emphasized the need to know the load-carrying capability of pavement structures and to anticipate future pavement performance. The objective of this study was to develop techniques for determination of the required pavement properties that can be used with a minimum of pavement destruction and interference with aircraft operations.

As a result of this study, a small aperture technique was developed to obtain CBR strength values and samples used to determine moisture, density, and classification of the pavement components through a 6-in.-diam core hole. Equipment and test procedures are discussed. Data obtained by the small aperture method are shown to agree well with those obtained by conventional test procedures. A nuclear density device developed especially for this study is discussed, and data are presented that show the accuracy of the device.

The small aperture tests were not found to have a time advantage, but manpower requirements were cut in half. The tests can be performed between traffic operations, and most aircraft can operate over the 6-in.-diam core hole.

SMALL APERTURE TESTING FOR AIRFIELD PAVEMENT EVALUATION

Introduction

Background

1. The advent of today's multiple-wheel heavy gear load aircraft has created an increased need to determine the load-carrying capability of airfield pavements. Present Corps of Engineers evaluation techniques require lengthy closing of a facility to traffic while large test pits are excavated in the pavement structure to determine the properties of the component layers. Because of the large volume of aircraft operations on most airfields, it is nearly impossible to close a major facility, such as a primary runway, long enough to complete a test pit.

2. The double-edged problem of increased aircraft loads and larger volumes of traffic has pointed out the need for a nondestructive method for obtaining information required for pavement evaluation that would minimize interruption of aircraft traffic. Input for evaluation includes the thickness and physical characteristics of each layer of the pavement, such as strength, water content, and density. Samples must also be obtained for identification and classification of each material.

Purpose and scope

3. The objective of this study was to develop equipment and procedures for determining pavement and soil properties at depths under pavements through small access holes, thus eliminating the requirement for excavation methods currently used. Survey of the data requirements indicated that, while the data could not be obtained by completely nondestructive methods, the tests could be performed in a small aperture in the pavement. In the past, CBR tests had been performed through small core holes, although the accuracy of this procedure had not been verified. Studies were initiated to develop equipment and techniques for small aperture testing. Development of equipment represented the main effort of the study. After equipment was selected and satisfactory test techniques were developed, tests were performed to correlate with those

used to obtain data from conventional test pits. A pavement evaluation procedure was written based on existing evaluation criteria[1-6] with input from the small aperture tests.

Development of Equipment and Test Techniques

4. The equipment development phase constituted the main effort of the study. Various pieces of equipment were studied, but only the equipment selected and its modifications will be discussed.

5. It was determined from the overall requirements that properties of the layers of either a rigid or a flexible pavement structure could be adequately determined through a 6-in.-diam* hole. Most aircraft can operate over a 6-in.-diam hole; an easily installed metal cap could be used to close the hole if required for aircraft equipped with small tires. One specification for the testing equipment was the capability for rapid removal when required by traffic control.

Drill rig

6. Studies indicated that a standard core drill was adequate for creating the small aperture. A small, trailer-mounted drill rig (photo 1) was selected for cutting the core hole through the pavement and advancing the hole to the required depths. All controls of this rig are in easy reach of the operator. The trailer-mounted rig was chosen for its maneuverability and ease of operation, but a truck-mounted rig would be adequate.

7. For both coring and testing operations, a stable work platform is necessary. Trial operations of the drill rig indicated that the hand-operated leveling jacks were time-consuming and difficult to use. Hydraulic lifting jacks were installed that produced the necessary stability for the work platform.

8. An important feature that is required on a rig used for small aperture work is a sliding-base arrangement. This allows coring of

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* A table of factors for converting British units of measurement to metric units is presented on page ix.

pavements, removal of the drill assembly from the hole to perform the desired tests, and then automatic realignment of the drill assembly for further advancement of the hole. Equally important is the drill stroke of the rig so that unnecessary changing of the chuck can be eliminated. A 36-in. stroke will allow drilling into the subgrade layer of most airfield pavements without rechucking. For faster cutting to depths greater than 36 in., hydraulic-operated automatic chuck assemblies can be obtained.

Coring and cutting techniques

9. A 6-in.-diam core hole was found to be the optimum size to provide adequate space to perform the tests on underlying pavement layers and yet to result in a minimum disturbance to the pavement. The pavement layer was cored using a thin-wall diamond core barrel with water pumped into the core barrel to flush out the cuttings (photos 2 and 3). The core-catcher tool shown in photos 4 and 5 was used to remove the pavement core. The excess drill water was immediately removed from the hole using a suction device such as the one shown in photo 6.

10. Attempts to use compressed air to flush out the cuttings were not successful. Generally, the drill water only penetrated a fraction of an inch into the underlying layer, and this material was removed as discussed below. In areas where the underlying layer is known or suspected to be highly susceptible to small amounts of moisture, the water supply can be turned off just before cutting completely through the pavement. This, of course, may require cutting one core to determine the pavement thickness, then a second one for testing purposes.

11. Further advancement of the test hole was made with the modified earth auger shown in photo 7. The auger was 5-1/2 in. in diameter and had a flat end with a squared-off cutting edge. The cutting edge was hardened to prevent wear when augering hard aggregates.

12. Caution was used in the auger operation not to cut into the next layer of the pavement structure. The base and subbase layers were removed a few inches at a time, and the material removed was examined to determine when the next layer was encountered. Generally, there was a distinct change in color or aggregate gradation between layers, as

in photos 8 and 9. Photo 10 shows the technique used to clean material from the auger without permitting material to fall back into the hole.

13. The cleanout device shown in photo 11 was developed for cutting slightly into the soil to provide an undisturbed surface and for removal of loose material. A handle is turned to close the opening in the cleanout tool so that all loose material can be removed. This device is applicable primarily to fine-grained materials. Photo 12 shows the cleanout tool being used.

Testing equipment and procedures

14. The strength of various pavement components is determined with the California Bearing Ratio (CBR) test. The small aperture procedure uses the CBR test on both flexible and rigid pavements as will be discussed further in this report. Once the pavement layer and drill water had been removed, the CBR test was performed on the underlying layer. When a thin layer of the material became wet due to the drill water, the wet material was removed either with the cleanout tool or with a small trowel. When a granular material was encountered, such as a crushed-stone base course, a thin layer of fine sand was used as a leveling course to provide uniform loading beneath the CBR piston.

15. Attempts were made to use the down pressure of the drill rig to operate the CBR test, but the vibration of the engine affected test results. Therefore, a conventional CBR loading jack was adapted to be quickly attached to the drill rig frame. This was done with the sliding base of the rig moved away from over the test hole. The CBR jack was mounted to a beam, which in turn was mounted to the rig. Photo 13 shows the CBR setup on the rig. Additional weight could be added to the drill rig frame as needed to provide ballast for testing high-strength materials.

16. Adjustments were made to allow centering of the CBR piston in the hole. After completion of the CBR test on the first level, the hole was advanced to the surface of the next layer, and the cleanout tool was used to clean loose material and to obtain an undisturbed area for the next CBR test. The standard CBR test performed in a test pit requires the use of surcharge weights placed around the CBR piston to

replace the overburden material that is removed when excavating the test pit. In order to evaluate the effects of not using the surcharge weight ordinarily used around the CBR piston, comparison tests were performed in the 6-in.-diam core hole with and without the surcharge. It was determined that the surcharge weight is not necessary in the small aperture tests.

17. At each CBR test location, determination of water content and density of the material is also desirable for evaluation purposes. A sample of the material taken during the augering operation was placed in a container for water content determination. Also, samples were obtained in the same manner for identification and classification in the laboratory.

18. Conventional methods of density determination with the sand cone or water balloon equipment were not adaptable to small aperture testing. Therefore, nuclear density devices were investigated, and a special nuclear density apparatus was developed for WES by a commercial source. The device is shown in photos 14 and 15. A nuclear source (cesium) placed in one core hole and a detector tube in a second hole were used to measure the density of a 2-in.-thick layer. The two CBR holes were spaced from 11 to 14 in. apart. Density determinations can also be made from undisturbed samples of fine-grained soils obtained with a Shelby tube sampler.

Comparison of Small Aperture and Conventional Evaluation Test Procedures

CBR data

19. After all modifications were made to the small aperture equipment and test procedures, comparative tests were performed using the small aperture test (SAT) method and the conventional test pit procedure. These tests were performed on lean clay, heavy clay, and sand subgrades and on crushed-stone and shell base courses. Plate 1 presents a comparison of CBR values obtained by both methods. As noted in the plate, some of the data were obtained from actual pavement structures, and some were taken on unsurfaced soils. This was necessary in order to

obtain data for a range of material types.

20. Each point in plate 1 represents an average of three values. The SAT CBR values tend to be slightly higher than conventional values. Therefore, a line of best fit is shown in plate 1 so that SAT CBR data can be corrected into terms of conventional values for use in evaluation and design curves. A correlation coefficient of 0.98 shows that the SAT CBR can predict the conventional CBR with a high degree of reliability. There is some scattering of the data, but generally there is good agreement between the SAT and conventional methods. Variations do occur in a group of CBR tests on the same material using the conventional test pit procedure. This is particularly true of granular materials with high CBR's. Actually, there appears to be less disturbance of the underlying layers with the SAT method than with conventional test pits. The excavation with jackhammers and hand tools is very difficult, and some disturbance to underlying layers does occur. Also, the SAT CBR's are measured with the natural overburden on the pavement layers, and no surcharge weights are necessary.

<u>Density data</u>

21. The nuclear density device discussed earlier was not available in time for complete field testing during this study. However, calibration tests in the laboratory and limited tests on sand asphalt mix, concrete block, magnesium, and aluminum showed that the gage is extremely reliable and accurate. A comparison of nuclear density with the actual density of these four materials is shown in plate 2. Actual densities of the materials were obtained from laboratory specific gravity tests.

<u>Time-cost comparisons</u>

22. The time required to drill and complete the tests on one SAT hole was approximately 1 to 1-1/2 hr. This time, of course, varied according to the number of pavement layers, thickness of the wearing course, etc. However, if three holes are used in lieu of one test pit, then the time required by the two methods is about the same.

23. Even though there is no apparent total time advantage, the SAT can be performed between traffic operations or at night when traffic

is normally light. Also, the small holes can be left open with no interference to most aircraft traffic. In areas where the open holes would be hazardous to aircraft with small tires, such as fighter aircraft, the holes can be permanently repaired with fast-setting cement or with hot- or cold-mix asphaltic materials. Repair of the excavations made for conventional test pits is not nearly so simple. Also, repair of conventional test pits in rigid pavement requires at least a 7-day curing period when repaired with a concrete mixture.

24. The SAT technique requires two technicians as compared with three to four technicians required for excavation and testing of conventional test pits, which are generally 2 by 4 ft.

Pavement Evaluation Procedure

25. This report is not intended to be a complete evaluation manual. Rather, it provides an improved procedure for determining the physical properties of pavements to be used with conventional evaluation criteria. Prior to making a pavement evaluation, existing manuals for evaluation[1-6] should be consulted to obtain guidance in selection of test locations and the criteria for evaluation. The small aperture technique does require great care in testing, and the procedure outlined in this report should be followed carefully.

Procuring the data

26. Information required for the pavement evaluation is obtained from both in-place field tests and laboratory tests. Equipment and field testing techniques have been described in some detail in preceding paragraphs.

Field tests

27. Field testing involves coring through the pavement surface and obtaining the core sample and determination of the CBR, moisture content, and density at the surface of each underlying layer and/or at 6-in. intervals. Tests should be continued into the subgrade layer. A set of three holes should be made at each test location to provide a check against unreasonable values. The holes should be spaced from

12 to 14 in. center to center in order to use the nuclear density device. Careful measurement of the thickness of each layer should be made to the nearest 1/4 in. A sufficient amount of the base, subbase, and subgrade materials can be obtained from three test holes for classification tests, but additional holes may be necessary for taking samples for moisture-density relationships.

Laboratory tests

28. Samples of the various pavement layers and pavement types are tested in the laboratory to provide further information for evaluation of the facilities. Quality of the bituminous pavement surfacing is determined by a comparison of the density and voids in the pavement cores with recompacted samples of the pavement according to the Marshall procedure for bituminous mixtures.[3] The flexural strength of a rigid pavement slab is necessary input for evaluation. Since the small aperture technique does not produce beams for determination of the flexural strength, the 6-in.-diam cores are tested for tensile splitting strength. A typical tensile splitting test setup is shown in photo 16. The procedure for this test is given in ASTM Test Method C 496-64T.[7] The relationship[8] shown in plate 3 is used to obtain the flexural strength from tensile splitting test results. This relationship was derived from a simple regression of 199 tests and showed a correlation coefficient of 0.857.

29. Classification data consisting of Atterberg limits, gradation, and specific gravity should be obtained on disturbed samples of the base, subbase, and subgrade materials. Also moisture-density-CBR relationships should be developed for each of these materials.

Selecting values for evaluation

30. Flexible pavements. For evaluation purposes, a CBR value is assigned to each pavement layer and subgrade for each facility to be evaluated. These CBR values are obtained from test results on that facility, but are not necessarily the average values. A good method of selecting the CBR value for each pavement component is to take the lower quartile value from a cumulative distribution plot. The CBR values measured with the SAT procedure are corrected to conventional CBR's

through use of the correlation shown in plate 1. Because of certain inherent difficulties in performing in-place CBR tests on some base course materials, the guidance given in reference 3 should be followed in assigning CBR values to these materials. The thicknesses of the individual pavement layers are required for the evaluation. The minimum values measured are generally used unless a wide variation is obtained in thicknesses and strengths on a given pavement facility. In this case, the facility (such as a taxiway, runway interior, apron, etc.) would be evaluated for each set of data obtained. The evaluation for that facility would be the conditions that produced the lowest allowable load.

31. Rigid pavements. Quantities used in determination of the allowable loads for rigid pavements are slab thickness, flexural strength of the portland cement concrete (PCC) slab, and the modulus of subgrade or base reaction k . The modulus of subgrade reaction for airfield pavements is obtained from plate bearing tests using a 30-in.-diam plate. Because a plate bearing test cannot be made in a small aperture, a correlation is used to obtain the modulus of subgrade reaction from the CBR. Plate 4 gives the approximate correlation used by the Corps of Engineers.[9] When a base course exists beneath a rigid pavement, the CBR is not determined on the base course but is determined on the subgrade just below the base. The subgrade modulus k for the subgrade is determined from plate 4, and that value is increased by use of plate 5 to account for the additional strength contributed by the base. The increase in the k value from plate 4 is dependent on the thickness of the base layer. The method of obtaining the flexural strength of the PCC from tensile splitting tests on the core samples has already been discussed. The thickness of the PCC slab should be measured to the nearest 1/4 in.

Evaluation

32. Evaluation curves for rigid and flexible pavement as well as overlay pavements are given in previously referenced manuals. The small aperture technique and the correlations given in this report provide all quantities necessary for making airfield evaluations. Applicable guidance given in the referenced manuals should be followed carefully.

Conclusions

33. Much of the effort under this study was expended in equipment development and modification, but a complete pavement testing procedure was also developed. The following conclusions have been drawn from the overall study.

- a. The small aperture technique using a 6-in.-diam core hole is satisfactory for obtaining field test results and laboratory samples necessary for making airfield evaluations.
- b. The 6-in.-diam hole does not create an operational problem for most aircraft. The small aperture tests can be made between traffic operations and during slack traffic periods such as during nighttime.
- c. Results from CBR tests using the small aperture technique appear to be slightly higher than those obtained by conventional methods. A correlation was made between CBR values obtained by the two methods. The surcharge weights are not necessary for the small aperture CBR tests. Accuracy of small aperture results is felt to be as good as that of conventional results.
- d. Each small aperture test requires 1 to 1-1/2 hr field work, which is approximately one-third the time required for conventional test pits. However, since three small aperture tests are used to replace each test pit, the technique does not represent a time advantage. However, manpower requirements are cut approximately in half.
- e. Preliminary studies made with a specially developed nuclear density apparatus indicate that density determinations can be made in a set of two 6-in.-diam core holes with a high degree of accuracy.

Recommendations

34. The small aperture technique and the nuclear density device are recommended for use in future airfield evaluation tests and should be incorporated into existing pavement evaluation manuals. Further study is recommended for evaluation of the field performance and durability of the nuclear density device and of the validity of the relationship between CBR and subgrade modulus. These recommended studies do not constitute a major effort and could be performed in a short time period.

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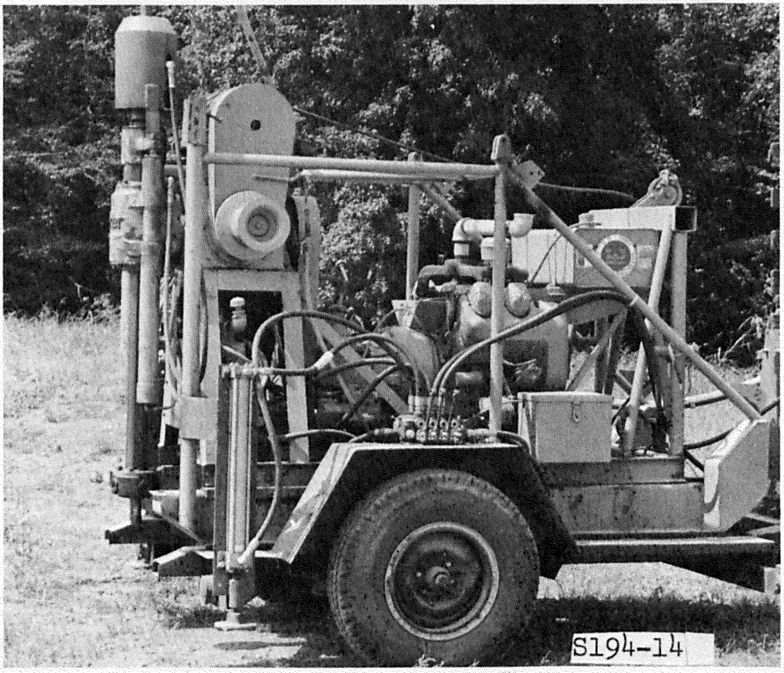


Photo 1. Trailer-mounted drill rig

Photo 2. Coring the pavement layer

Photo 3. Close-up of pavement core drill

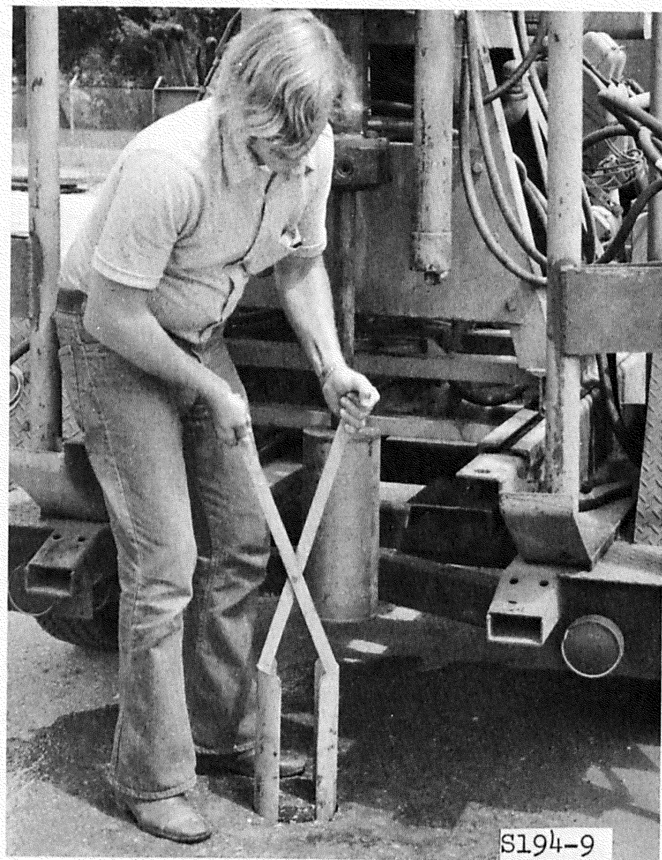


Photo 4. Removing a pavement core

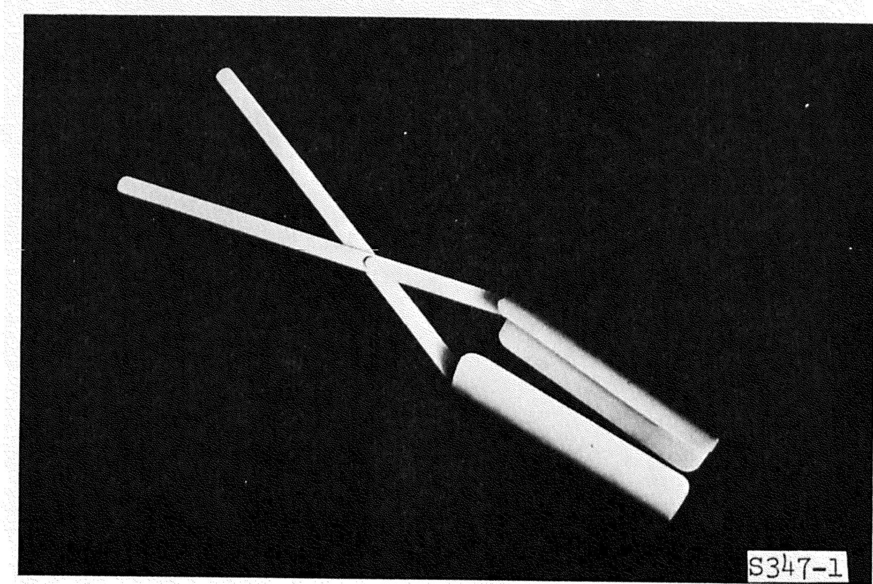


Photo 5. Core-catcher tool

Photo 6. Removing drill water from core hole

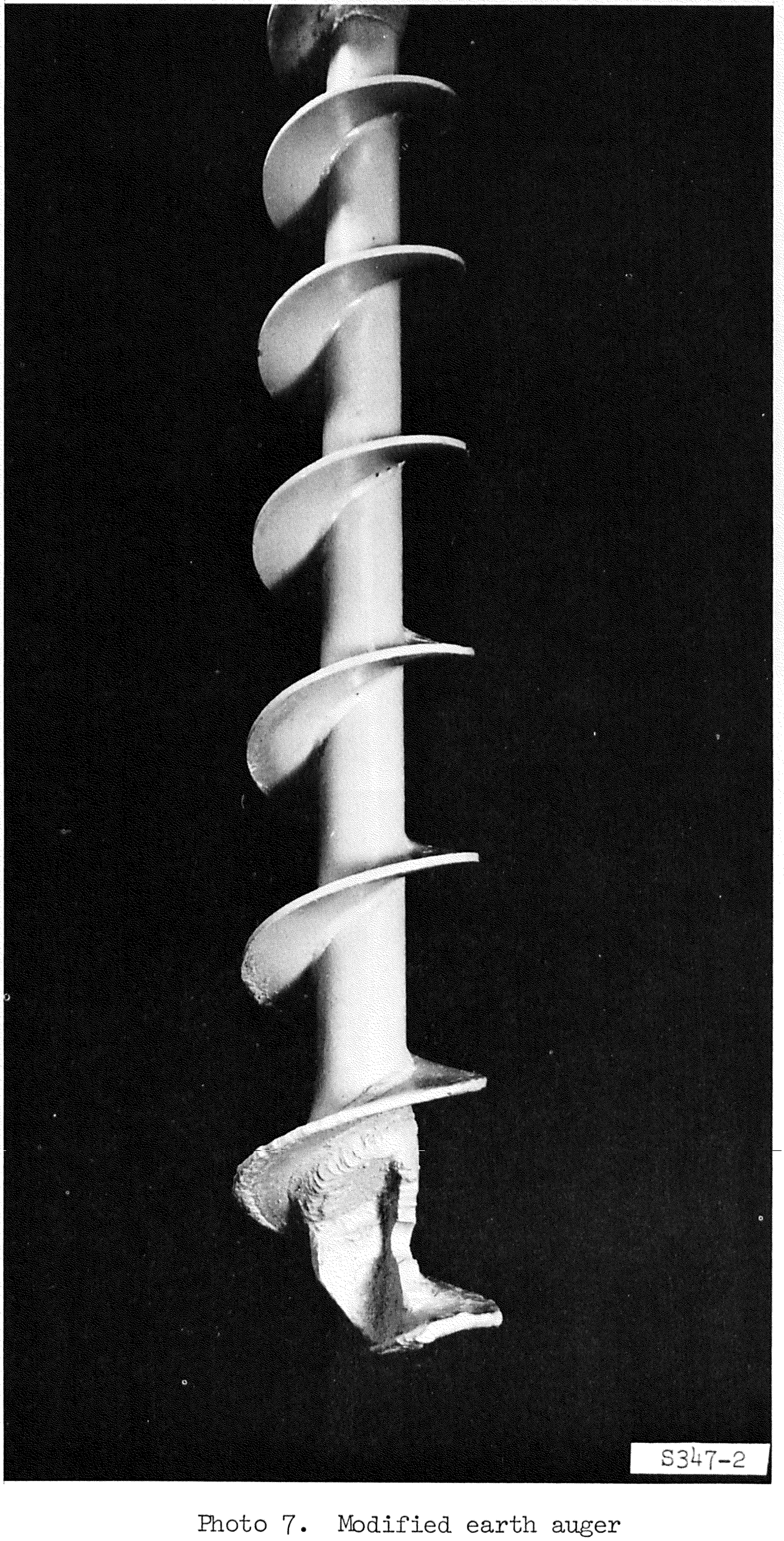


Photo 7. Modified earth auger

Photo 8. Material augered from base course

Photo 9. Material augered from subbase course

Photo 10. Shovel under auger
to prevent fallback

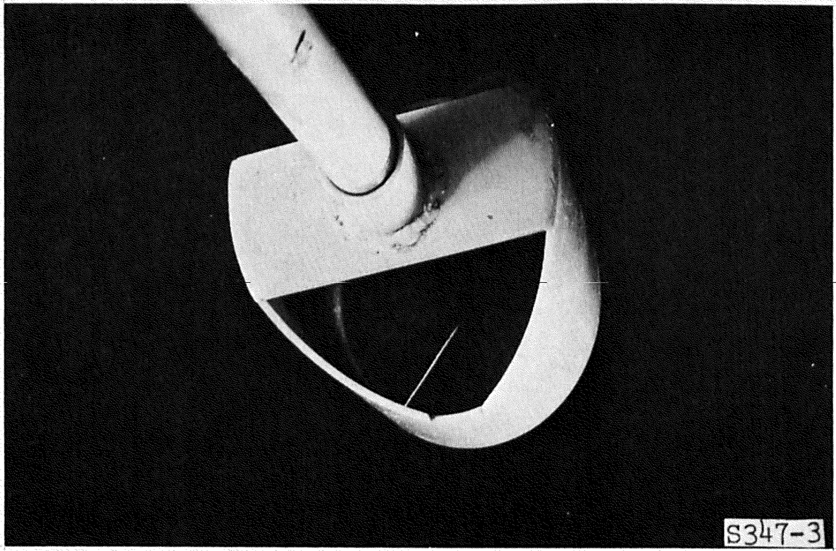


Photo 11. Cleanout device

Photo 12. Cleanout tool in use

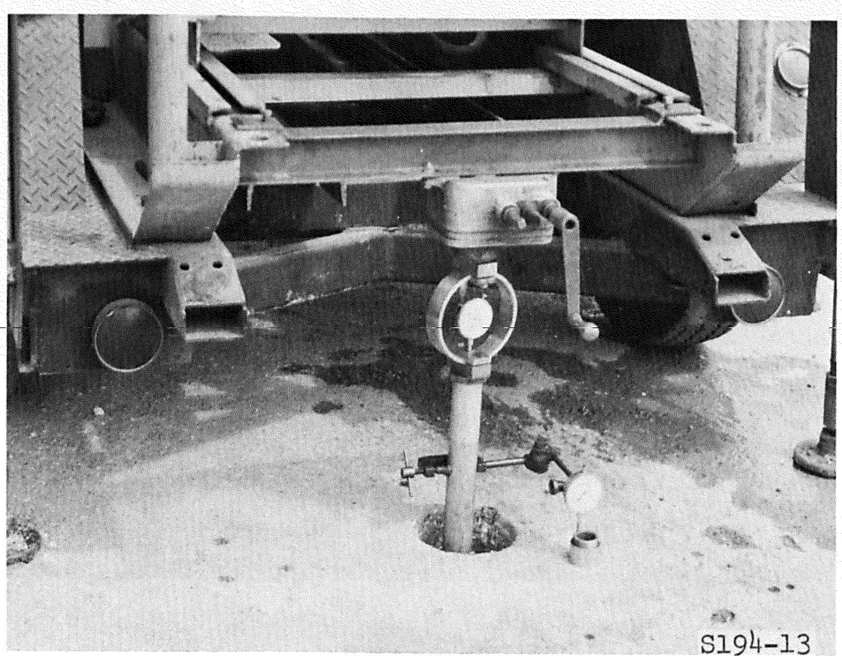


Photo 13. CBR test setup in small aperture

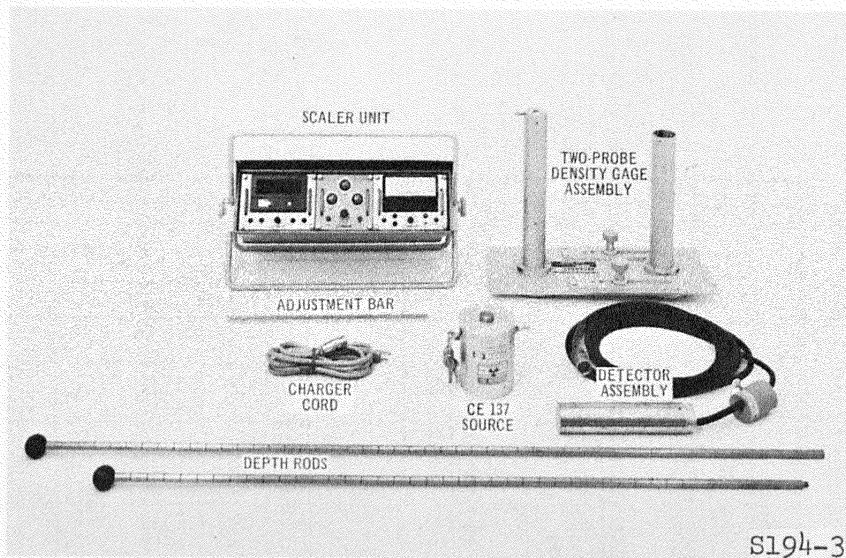


Photo 14. Components of nuclear device for density determinations

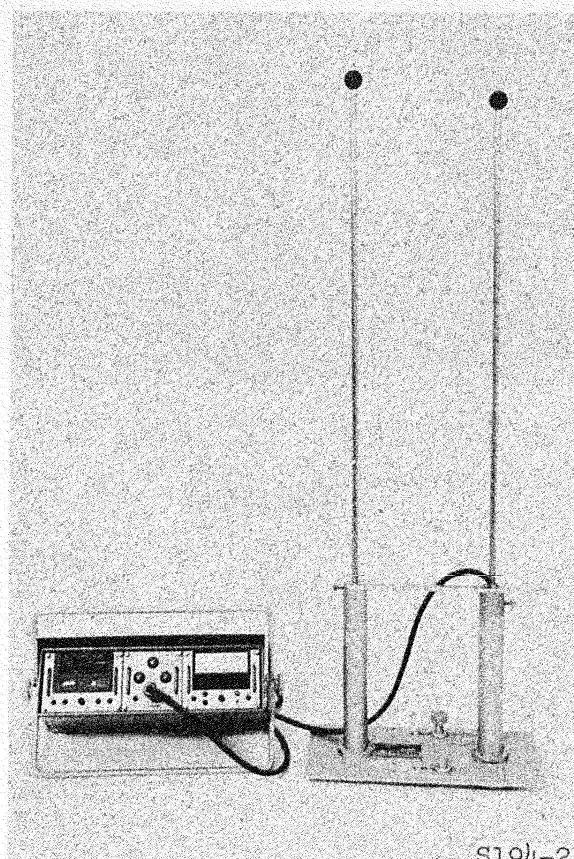


Photo 15. Nuclear device assembled for density determination

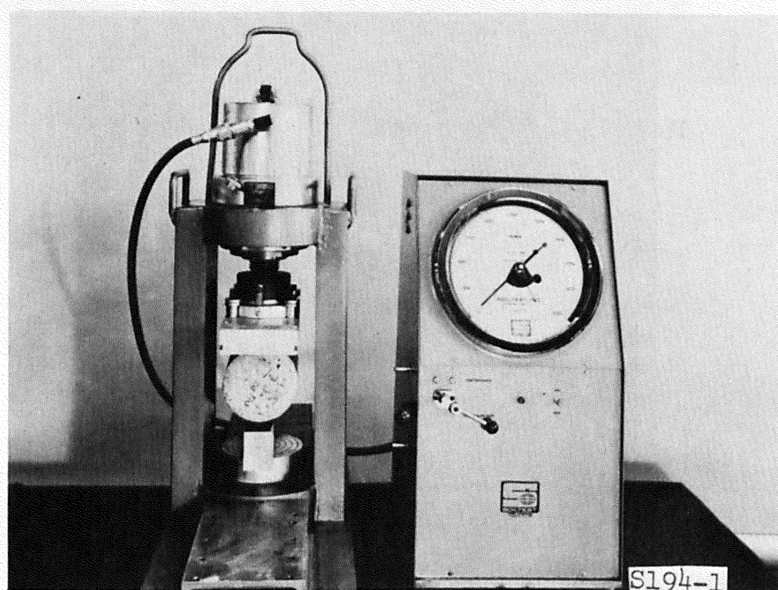
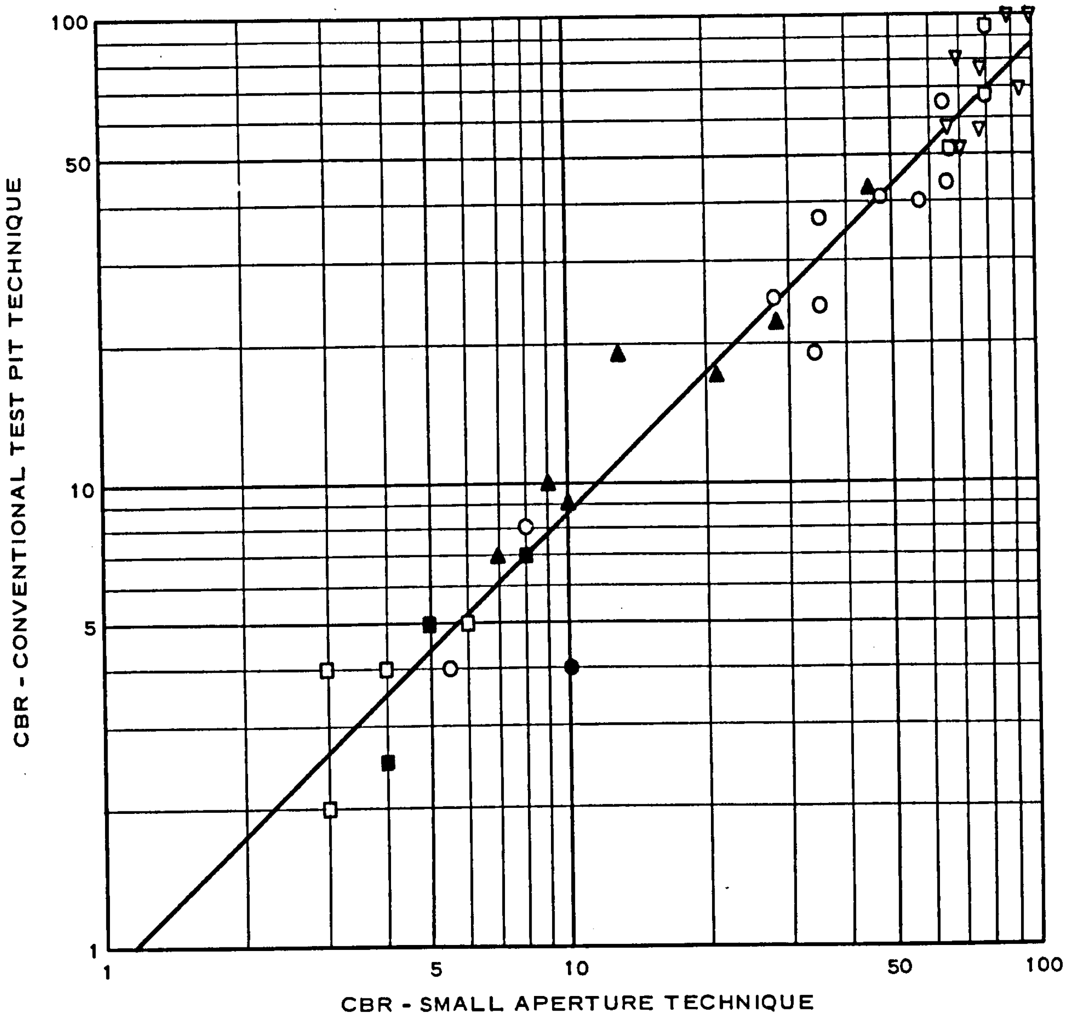


Photo 16. Setup for tensile splitting test of portland cement concrete pavement core



LEGEND

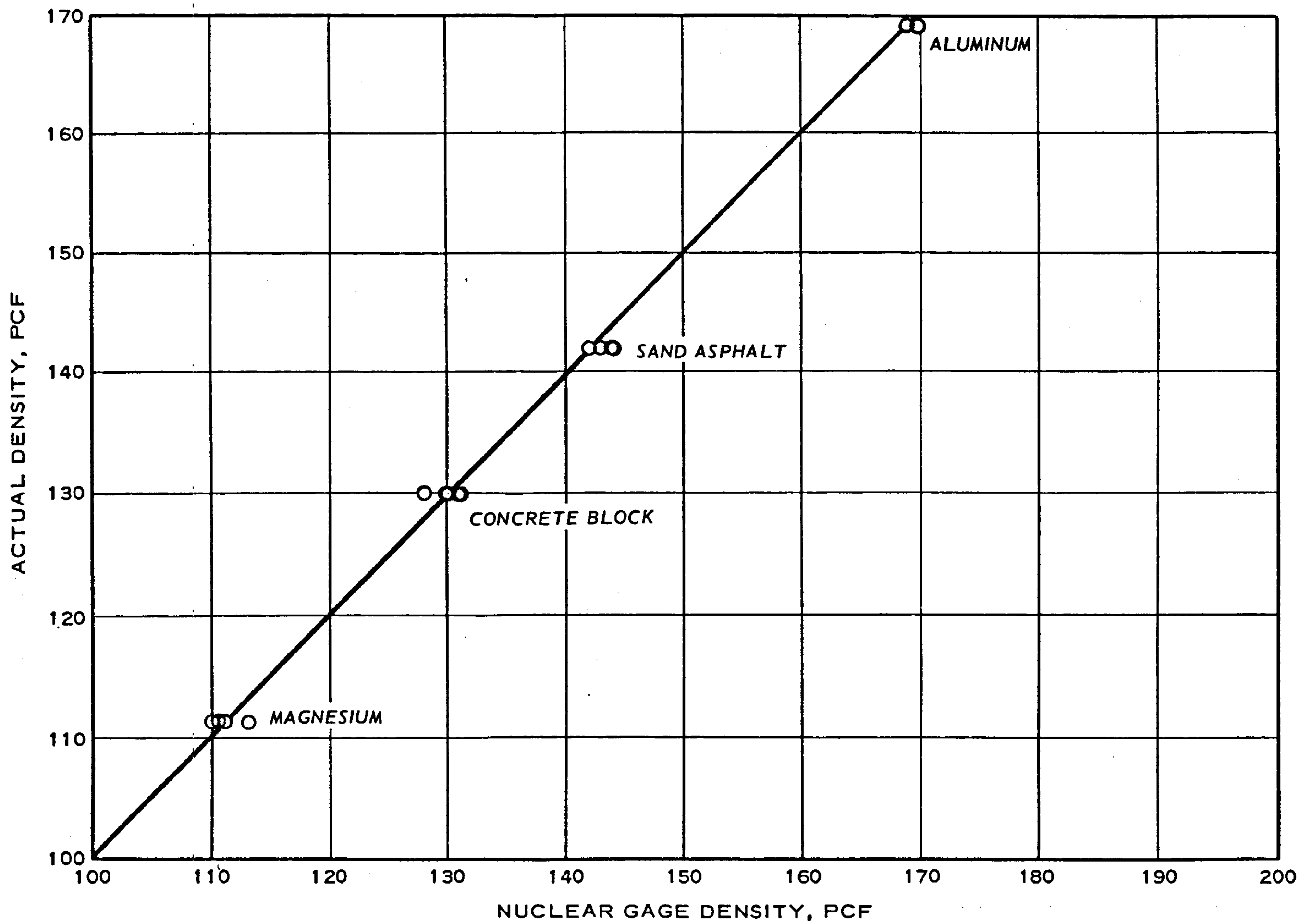
- O SAND
- □ CLAY (CH)
- Δ CLAY (CL)
- ∇ SHELL BASE
- ▢ CRUSHED-STONE BASE

NOTES: OPEN SYMBOLS DENOTE TESTS PERFORMED ON PAVEMENT STRUCTURE.

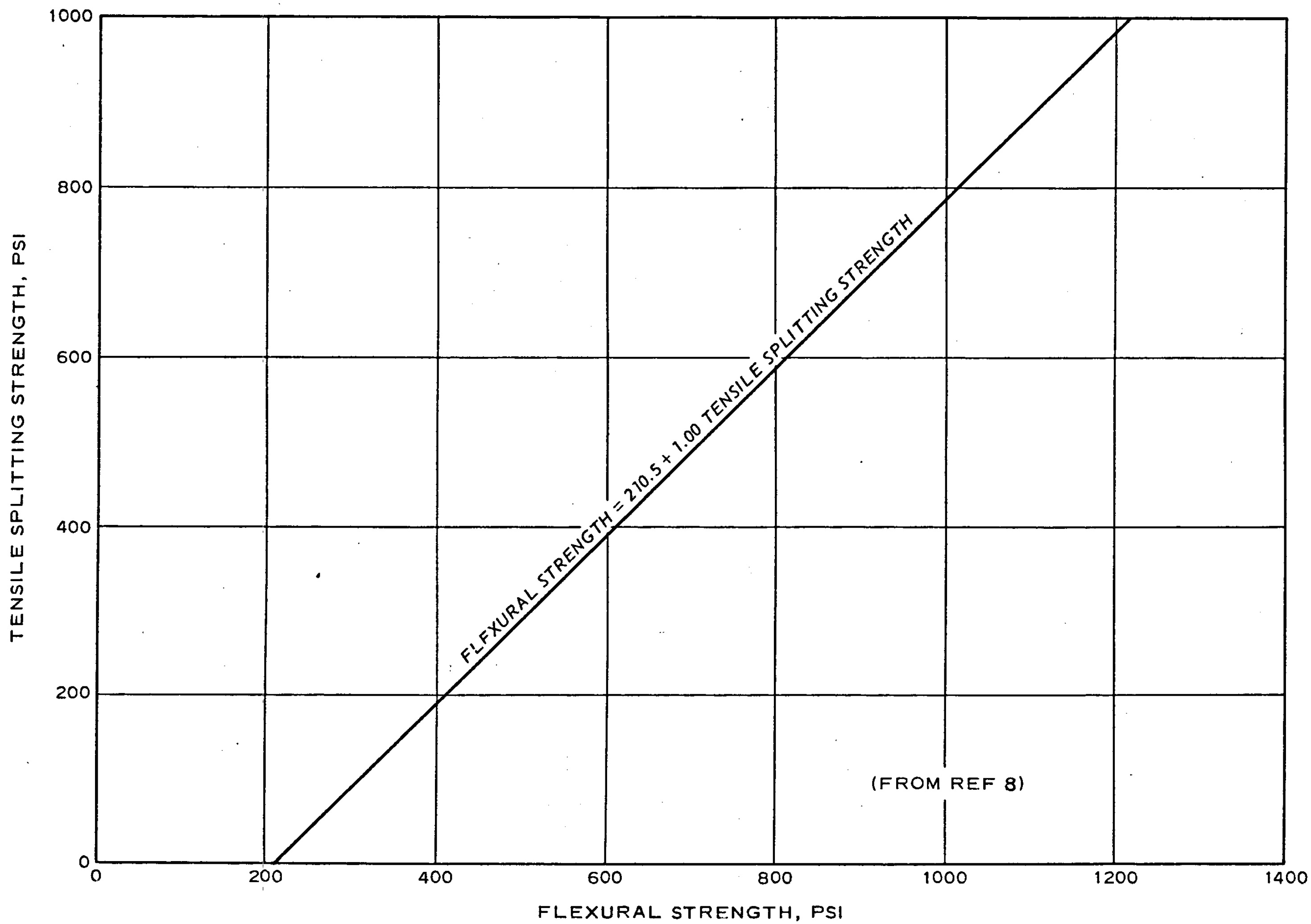
CLOSED SYMBOLS DENOTE TESTS PERFORMED ON UNSURFACED MATERIAL.

SMALL APERTURE VS CONVENTIONAL TEST PIT TECHNIQUES

COMPARISONS OF CBR RESULTS

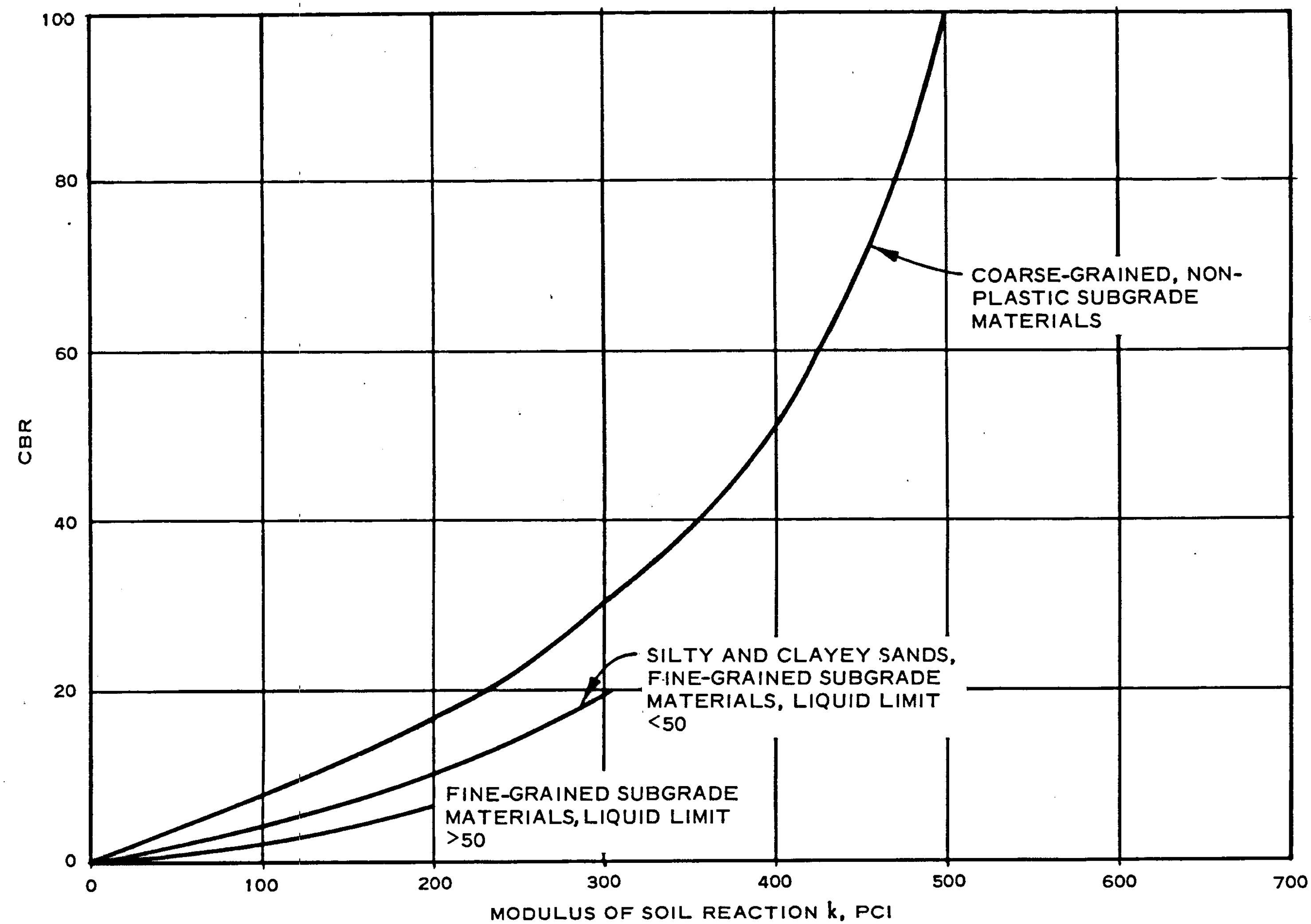


NUCLEAR GAGE DENSITY VS
ACTUAL DENSITY



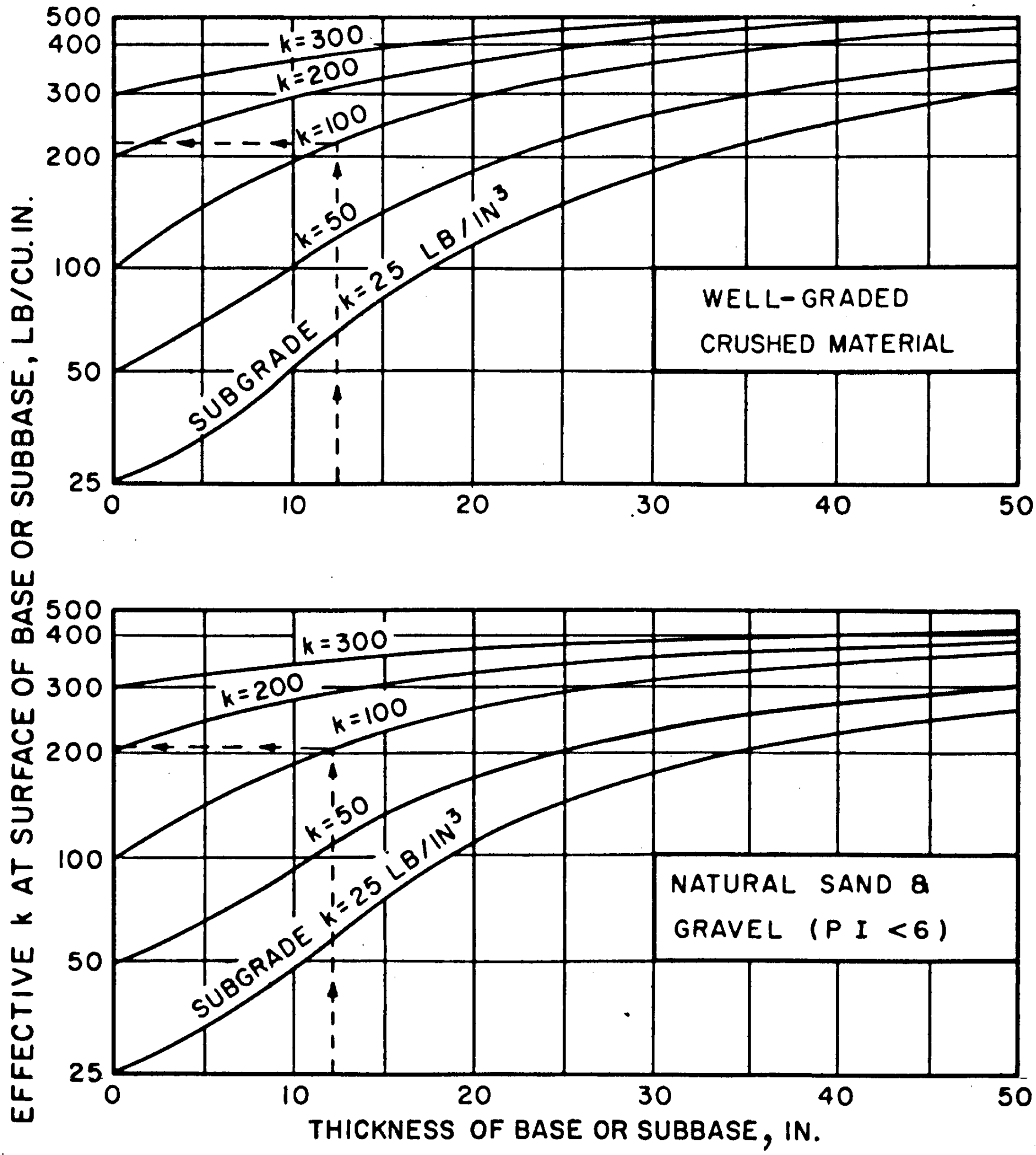
RELATIONSHIP OF TENSILE-SPLITTING
STRENGTH AND FLEXURAL STRENGTH

PLATE 4



NOTE: FROM REFERENCE 9

RELATIONSHIP OF CBR AND MODULUS OF SUBGRADE REACTION k



NOTE: FROM REFERENCE 10

EFFECT OF BASE OR SUBBASE THICKNESS ON MODULUS OF SOIL REACTION k

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13. ABSTRACT

The high intensity of aircraft operations on most military airfields prohibits the closing of runways and other pavement facilities in order to measure the physical properties of the pavement necessary to evaluate its load-carrying capability. Also, the introduction of multiple-wheel heavy gear load aircraft coupled with an ever increasing number of aircraft operations has emphasized the need to know the load-carrying capability of pavement structures and to anticipate future pavement performance. The objective of this study was to develop techniques for determination of the required pavement properties that can be used with a minimum of pavement destruction and interference with aircraft operations. As a result of this study, a small aperture technique was developed to obtain CBR strength values and samples used to determine moisture, density, and classification of the pavement components through a 6-in.-diam core hole. Equipment and test procedures are discussed. Data obtained by the small aperture method are shown to agree well with those obtained by conventional test procedures. A nuclear density device developed especially for this study is discussed, and data are presented that show the accuracy of the device. The small aperture tests were not found to have a time advantage, but manpower requirements were cut in half. The tests can be performed between traffic operations, and most aircraft can operate over the 6-in.-diam core hole.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Aperture testing						
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