Technical Report Documentation Page

1. REPORT No.
642604

2. GOVERNMENT ACCESSION No.

3. RECIPIENT'S CATALOG No.

4. TITLE AND SUBTITLE
Compaction Testing of Cohesionless Gravels

5. REPORT DATE
September 1968

6. PERFORMING ORGANIZATION

7. AUTHOR(S)
Smith, Travis and Maxwell, W.S.

8. PERFORMING ORGANIZATION REPORT No.
642604

9. PERFORMING ORGANIZATION NAME AND ADDRESS
State of California
Department of Public Works
Division of Highways
Materials and Research Department

10. WORK UNIT No.

11. CONTRACT OR GRANT No.

12. SPONSORING AGENCY NAME AND ADDRESS

13. TYPE OF REPORT & PERIOD COVERED

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Development of a procedure for testing the compaction of cohesionless gravel is discussed. The field in-place measurement, was studied using a stainless steel casing inserted into the earthwork surface to facilitate digging a fixed volume hole and to prevent hole wall cave-in.

The second phase consisting of a control test was also investigated. A rodded sample procedure was utilized as a more realistic control test for gravel materials. While the in-place measurement proved acceptable, additional investigation of the entire procedure is necessary to establish reasonable acceptance limits and necessary additional background.

17. KEYWORDS

18. No. OF PAGES:
23

19. DRI WEBSITE LINK
http://www.dot.ca.gov/hq/research/researchreports/1968/68-19.pdf

20. FILE NAME
68-19.pdf

This page was created to provide searchable keywords and abstract text for older scanned research reports.
November 2005, Division of Research and Innovation

HIGHWAY RESEARCH REPORT

COMPACTION TESTING OF COHESIONLESS GRAVELS

FINAL REPORT

September, 1968

68-19

STATE OF CALIFORNIA

TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 642604

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, *Governor*

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

5900 FOLSOM BLVD., SACRAMENTO 95819

September 1968

Final Report
M&R No. 642604

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

COMPACTION TESTING OF COHESIONLESS GRAVELS

TRAVIS SMITH
Directed Investigation

WILLIAM S. MAXWELL
Principal Investigator

Assisted By
Randall J. Springer

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

REFERENCE: Smith, Travis and Maxwell, W. S., "Compaction Testing of Cohesionless Gravels," State of California, Department of Public Works, Division of Highways, Materials and Research Department, Research Report No. 642604, September 1968.

ABSTRACT: Development of a procedure for testing the compaction of cohesionless gravel is discussed. The field in-place measurement, was studied using a stainless steel casing inserted into the earthwork surface to facilitate digging a fixed volume hole and to prevent hole wall cave-in.

The second phase consisting of a control test was also investigated. A rodded sample procedure was utilized as a more realistic control test for gravel materials. While the in-place measurement proved acceptable, additional investigation of the entire procedure is necessary to establish reasonable acceptance limits and necessary additional background.

KEY WORDS: Compaction, construction materials, backfill, compaction control, compaction tests, construction control.

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

TABLE OF CONTENTS

	Page
Introduction	1
Objective	1
Summary and Conclusions	1
Recommendations	1
Historical Review	2
Preliminary Investigation	4
Fundamentals of Relative Volume Concept	5
Obtaining Earthwork Test Sample	5
Test Mold Compaction	6
Testing Wet Silt Soils	6
Additional Considerations	7
Figures 1 - 3	
Photos 1 - 9	

List of Figures

1. Effect of Water Content on Rodded Density
2. Test Mold and Casing
3. Sequence of Test Operations

List of Photos

1. Insertion of Casing
2. Start Driving the Casing
3. Start Driving the Casing
4. Casing in Final Position
5. Plywood Spacer Ring in Position
6. Starting Sample Excavation
7. Completing Sample Excavation
8. Completing Sample Excavation
9. Sample Compacted in Test Mold

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

Introduction

The relative compaction of cohesionless gravel cannot be ascertained by the excavated sample-sand volume earthwork density and impact test maximum density procedures of Test Method No. Calif. 216, the current conventional method for the determination of relative compaction. As the earthwork density sample is excavated the excavation collapses to preclude sand volume measurement, and when many cohesionless gravels are compacted in the impact test apparatus degradation often results in an unrealistic test maximum density. When it is feasible to determine the earthwork density with nuclear gages or other devices instead of the sand volume apparatus the unrealistic impact test maximum density invalidates the test end result.

While various methods for assessing cohesionless gravel compaction were investigated in the past the limited use of such material was not considered to justify a special test. Furthermore, when placed in thin layers the density of the readily compacted gravels was thought to be adequate without test verification. Ever increasing construction production rates of recent years focused attention on the time and costs involved in placing structure backfills, and some contractors apparently decided the expense of importing pea gravel was less than the cost of compacting local soils to the usually specified 95% relative compaction. The impracticality of stationing an inspector at each structure backfill to enforce loose layer thickness not exceeding the specified 0.67 ft and the lack of a test to assess the densification of thicker layers may have influenced their decisions. Whatever the reason a definitely increased placement of pea gravel has posed a testing problem.

Objective

The research project under report was initiated to devise a means of field appraisal of cohesionless gravel compaction.

Summary and Conclusions

A simple and expeditious relative volume test which appraises the compaction of cohesionless gravel without recourse to densities, weighings, conversions or computations, and without regard for water contents or optimum water content was developed. With the elimination of weighing scales, drying ovens and similar cumbersome laboratory equipment a complete determination may be performed at the earthwork test site with the end result reportable in 20 to 30 minutes. Another compaction testing innovation is the marking of a test apparatus indicator with an acceptable zone rather than relying on a single and sometimes controversial percent relative compaction value to denote a passing or failing test.

Recommendations

The project investigators were unable to locate a sufficient number of gravel placements in progress to determine to their complete satisfaction the field construction densification obtain-

ClibPDF - www.fastio.com

able with a wide variety of gravels, water contents and compactive efforts. This complicated the defining of the acceptable zone limits for the test apparatus indicator. While it is believed the zone as established will prove satisfactory it is recommended the test be adopted as tentative and placed in service in areas of high pea gravel activity. The objective being to achieve the highest densification attainable with a sincere effort by the contractor, but not beyond practical reach, the acceptable zone may be verified, or adjusted if so dictated by extensive field findings, prior to the inclusion of the test method in manuals and routine specifications.

Historical Review

Pea gravels having long been used for structure backfill in San Diego and other locations in District 11 of the California Division of Highways considerable local attention has been given to the relative compaction testing of cohesionless materials. In 1958 the District 11 Materials Engineer, Mr. P. E. Ruplinger, reported on inserting a steel tube into a gravel backfill and excavating a sample from within the tube, and with a more ingenious method wherein a mixture of casting plaster and water was poured on an 8" diameter disc placed on the surface of the backfill. As the mixture overflowed around the circumference of the disc it penetrated the voids in the gravel to a depth of 5" in an annular pattern and following the hardening of the plaster a sample was excavated from within the cemented zone. After the volume of the resulting excavation was measured by routine sand volume procedure the weight and density of the excavated sample were determined in customary manner. To circumvent the degradation of the impact test maximum density determination of Test Method No. Calif. 216 Mr. Ruplinger applied the hand rodding ASTM Test Method No. C29-55T.

Later in 1958 the Materials and Research Department engaged in a rather extensive study of earthwork density determinations incorporating concrete sand, Ottawa silica sand and two pea gravels of different gradation. While a sample may normally be excavated from wet sand earthwork without collapse of the excavation wall, there have been incidents of the sand volume apparatus sinking into wet sand far enough to alter the volume measurement, and when the sand was being poured the apparatus has on occasion tilted due to differential sinking. For this reason the sands were included in this study primarily concerned with pea gravels.

Two rings 12" in diameter by 3" in height and 10" x 3", respectively, were fabricated from steel well casing. The gravels and sands were placed in turn in a large test mold in a loose condition and subsequently in a compacted state. Attempts to push the rings into the gravel were encouraging when it was in the loose condition but when it was compacted difficulty was encountered in forcing the rings to their full depth and displacement of the gravel was obvious. The rings were abandoned.

ClibPDF - www.fastio.com

After exploratory trials with the casting plaster and water mixture to develop the proper consistency for penetration and distribution satisfactory results were obtained when the pea gravel was wet, but when it was in an air dry condition the penetration of the mixture was not uniform and not acceptable. In an effort to reduce the 30-minute delay awaiting the hardening of the casting plaster experimentation was carried on with polyesters, sodium silicate-calcium chloride mixtures, and paraffin with volatile solvents in lieu of the plaster. It was concluded the casting plaster was superior to the other cementing agents and the procedure was suited to wetted pea gravels. When tried with the sands the plaster was filtered out in the top inch leaving only the water to penetrate deeper which eliminated further consideration of this usage. A wide, shallow ring of the plaster mixture may be used after hardening to form a supporting base for the sand volume apparatus to prevent it sinking into the sand, but it would seem easier to simply place a thin metal flange under it to distribute the weight.

In 1961 the Materials and Research Department conducted an evaluation of the hand rodding ASTM Test Method No. C 29-55 T. By a somewhat circuitous route the rodded densities of river sand, concrete sand, two gradations of pea gravel from the San Diego area and one from the Sacramento area were referenced to corresponding California Impact Test densities. In terms of percent relative compaction 100% by ASTM was found to represent a lower control than 95% by California. When the ASTM rodded compaction was supplemented with vibration the results were comparable to those of California.

In 1963 Mr. Harlan Emerson and Mr. Walter Hartnett of District 11 fabricated and applied a unique earthwork density apparatus. A 21-gauge wall thickness stainless steel casing was formed by cutting off the bottom of a restaurant steam table food container. Using a driving device constructed for the purpose the casing was driven into a pea gravel backfill and a known volume sample was excavated from within the casing with the aid of a specially designed fixed-reach scoop. After weighing the sample the backfill density was computed and related to the hand-rodded ASTM density of a portion of the sample to derive the relative compaction. The difficulty heretofore encountered in forcing heavy gauge casings into compacted gravels and the disturbance of the area were minimized with the 21-gauge casing, and the more durable stainless steel overcame the crumpling which had been experienced on various occasions with tin cans and similar light gauge casings. In 1964 the Materials and Research Department tried the apparatus with several pea gravels compacted in large laboratory test molds and found it to be entirely workable. As this approach to cohesionless earthwork compaction testing appeared to be the most appropriate of any known to the investigators it was selected for the research project.

ClibPDF - www.fastio.com

Preliminary Investigation

While consideration had in the past been given to a means of determining cohesionless earthwork density and to the laboratory control test, i.e., ASTM vs. California Impact, the project investigators were handicapped by a lack of knowledge of actual construction earthwork densities attainable with various gravels, compactive efforts and water contents essential for the establishment of a realistic control standard. To gain such knowledge attention was first centered on construction compaction with whatever type of compacting equipment was available on the contracts visited, and when feasible with varying compactive efforts and water contents. Comprehensive sampling of the earthwork so constructed was conducted with a slightly modified Emerson-Hartnett apparatus. The excavated earthwork samples were transported to the laboratory where they were compacted in test molds to determine the test density on which to base the relative compaction.

Much of the cohesionless earthwork in progress involved narrow trench backfills lacking working space for multiple testing encompassing varying material and placement conditions. As a result there occurred a significant time interval between suitable test sites. The investigators were not fully satisfied with the inclusiveness of the obtainable field data, but the likelihood of additional sites within a reasonable time was so indefinite it was decided to conclude the project without further delay.

The hand-rodded ASTM procedure initially followed for the laboratory test mold compaction of the earthwork samples calls for the material to be in air dry condition at the time of rodding. Meeting this requirement obstructs the testing with aeration or drying device reduction of sample water content. When a series of exploratory tests were performed to disclose the importance of the water content each of the gravels under study was found to be more susceptible to the presence of water than had been anticipated. A bulking action was evidenced by the rodded density being the highest when the water content was less than 1% and thereafter decreasing with increases in the water, as illustrated in Figure 1.

The unforeseen magnitude of the influence of the water content negated part of the prior work and somewhat complicated the prosecution of the project. While the bulking action was neutralized by supplementing the rodding with a tamping procedure the investigators were still confronted with a density relationship test leaving much to be desired in testing simplification and expedition. The problem was resolved by applying the relative volume concept which had previously been applied to Test Method No. Calif. 216, the conventional relative compaction test, to eliminate all density, water content and oven-drying considerations.

ClibPDF - www.fastio.com

Fundamentals of Relative Volume Concept

The relative volume concept entails the relating of the volume which a given quantity of material occupies in the earthwork under test to the volume which the same quantity of the same material occupies when compacted by a laboratory test procedure.

To apply the concept to pea gravel backfills a cylindrical casing open at both ends is inserted in the backfill. The gravel within the casing is removed to a prescribed depth from the top of the casing and then compacted in a laboratory test mold having an inside diameter identical to that of the casing from which the gravel was removed. With identical casing and mold diameters the depth the gravel occupied in the casing related to the height of the same gravel when compacted in the test mold will indicate the gravel relative volume, as compacted in the backfill and in the test mold.

While the relative volume may be determined and reported in terms of percent relative compaction, the design of the apparatus developed for the relative volume testing of pea gravel permits a direct evaluation of the densification of a backfill, as presented in Figures 2 and 3. It will be noted in Figure 3 the gravel is not removed to the full depth of the casing.

Obtaining Earthwork Test Sample

Workmen walking on the surface and moving hoses, cables and other equipment generally leave the surfaces of cohesionless backfills in a loose and rough condition for a depth of several inches. This material may be easily removed with a hand shovel to a depth below the surface sufficient to avoid any effects of surface disturbance or aeration. The casing is then inserted in the backfill by first pushing down with both hands while applying about a 1/8 to 1/4 turn alternately counterclockwise and clockwise motion, which will usually achieve a penetration of 3" to 4" of the casing. A driving device is then used to drive the casing the balance of the way by raising a 10-lb sliding hammer approximately 24" and dropping it. The sole purpose being to drive the casing; the hammer weight, drop distance or number of blows are not critical. The procedure is illustrated in Photos 1, 2 and 3.

It will be observed in Photo 4 the surface of the gravel within the casing is flat and flush with the casing rim whereas during the inserting of the casing the surface of the contained gravel tends to be loose and higher in the center than around the circumference. The condition in Photo 4 indicates the gravel in the casing came into contact with the plywood disc of the driving device which imposed a compactive effort on the gravel. In addition it is very difficult to drive the casing flush with the surface of the surrounding backfill without over-driving it slightly below the backfill surface. To over-

ClibPDF - www.fastio.com

come these deficiencies the plywood spacer ring shown in Photo 5 is placed around the casing prior to driving it. This provides clearance between the driving device disc and the raised center of the gravel surface readily discernible in Photo 5. It also minimizes over-driving of the casing. The ring was omitted in the photographs to better display the details of apparatus and operations.

The excavation of the gravel from within the casing to a depth 2" above the predetermined total depth of excavation may be accomplished with a soup ladle as in Photo 6. Thereafter the excavation is completed with the special design fixed-reach scoop appearing in Photo 7. Skill must be applied in using this scoop to avoid disturbing the gravel below the plane of final excavation. When the casing is flush with the backfill surface as in Photo 4 the crosspiece of the fixed-reach scoop tends to drag on the gravel surrounding the casing as evident in Photo 8. This results in a jerky action of the scoop which is especially annoying when leveling and smoothing the bottom of the excavation. The plywood ring of Photo 5 provides an excellent surface for the crosspiece to slide on. For the purpose of Photos 6, 7 and 8 the excavated gravel was placed in a container to be transported to the field laboratory for test mold compaction.

As an alternate handling the excavated gravel may be placed directly in the test mold and compacted at the test site with the end result reportable within a few minutes. This mode of handling is especially advantageous where the field laboratory is a considerable distance from the test site, or when two operators are conducting a series of tests over a large area with one operator taking care of the test sample excavation and the other operator the test mold compaction.

Test Mold Compaction

The gravel removed from within the casing is placed in the test mold in three equal thickness layers. Each layer is rodded 25 times with a 1/2" diameter hemispherical tip round rod. A steel disc with a center guide rod for the hammer of the casing driving device is placed on the surface of the final layer and two blows of the hammer dropping 4" are delivered to the disc. With the hammer seated on the disc a straightedge is positioned across the top of the mold and touching the hammer. If the straightedge places within the acceptable zone marked on the hammer the backfill compaction meets specifications. If it is above the acceptable zone the backfill compaction is rejected. A light color tape was placed over the acceptable zone on the hammer for better contrast and illustration in Photo 9.

Testing Wet Silt Soils

Overly wet, visually unstable silts have often tested well above the specified minimum percent relative compaction in

ClibPDF - www.fastio.com

excavated sample-sand volume measurement testing. Experienced personnel are of the opinion that during the excavating of the earthwork sample the wall of the excavation tends to move inward, and by the time the sand volume measurement is performed the excavation volume is significantly smaller than it would have been had the wall remained in place. The smaller than valid volume leads to a high and erroneous percent relative compaction result.

Part of the excavation wall movement may be attributed to displacement by testing personnel kneeling or standing adjacent to the wet and unstable excavation during the excavating and sand pouring operations. Forming a bridge on which to kneel or stand by placing a plank across two 4" x 4" blocks located about 2' from the excavation site has frequently improved the test results but has not fully resolved the problem. As yet no way has been found to measure the actual wall movement or volume reduction of the excavation.

It would appear the cohesionless gravel casing may be applied to wet silts if rock is not present in size and amount sufficient to prevent the insertion of the casing or to damage it. The rodded test mold compaction used for the gravel is definitely not suitable for silt but the conventional impact compaction is appropriate. The earthwork sample volume by the casing method should be employable in the same manner as is the volume measured by the sand volume apparatus, in the relative volume procedure outlined in the report titled, "Wet Weight Relative Compaction Testing Utilizing Relative Volume Concept."

Additional Considerations

The proposed cohesionless gravel test apparatus is simple and relatively inexpensive compared to testing devices in general. While the casing and the test mold could be especially fabricated for the purpose, it is doubtful the cost in small quantities could match the $18.00 price of the two readily available restaurant containers. The shop charge to cut one container to form the casing should be nominal. Surprisingly, the casing is not damaged appreciably by repeated driving into pea gravel and the rest of the apparatus is completely trouble free. Attempts to drive the casing into larger gradation gravels and into soil containing rock have not proven successful and such adaptions should be approached with caution to prevent damaging the casing.

Nuclear gages will probably prove suitable for cohesionless gravel density determination if the hole for the transmission mode detector can be formed and retained open to accept the detector. This is only a part of a complete test leaving the test mold compaction to be performed and reverting to density

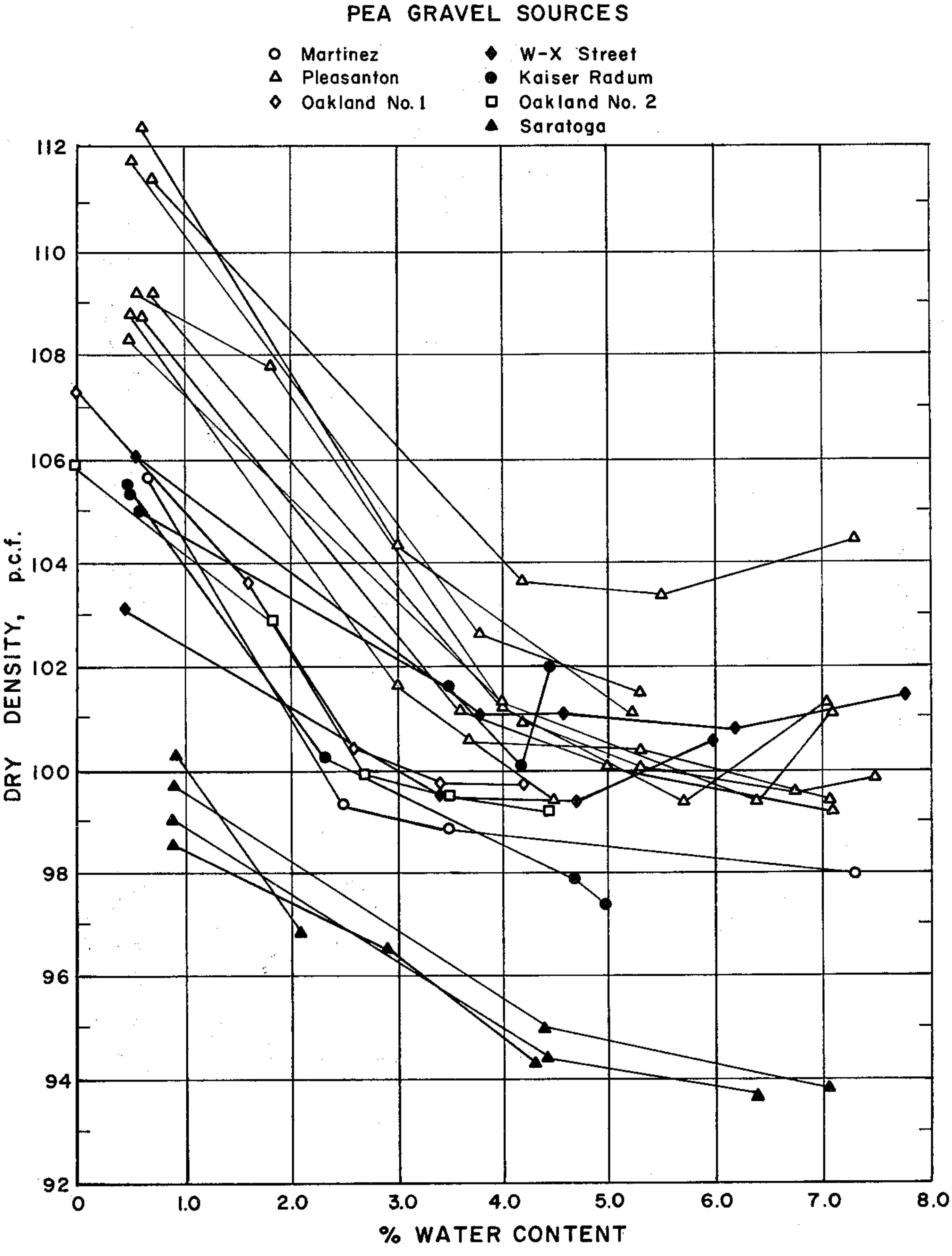
ClibPDF - www.fastio.com

testing will necessitate weighing and oven drying operations. Considering the time required for frequent nuclear gage calibrations, standard count checks, repairs, etc., it is unlikely the nuclear time per test will be less than the casing method relative volume test, and there is no similarity in initial capital investment or maintenance costs. The casing method is a specialized and limited use test which is intended to complement rather than compete with the general application sand volume and nuclear gage earthwork determination methods.

ClibPDF - www.fastio.com

Figure 1

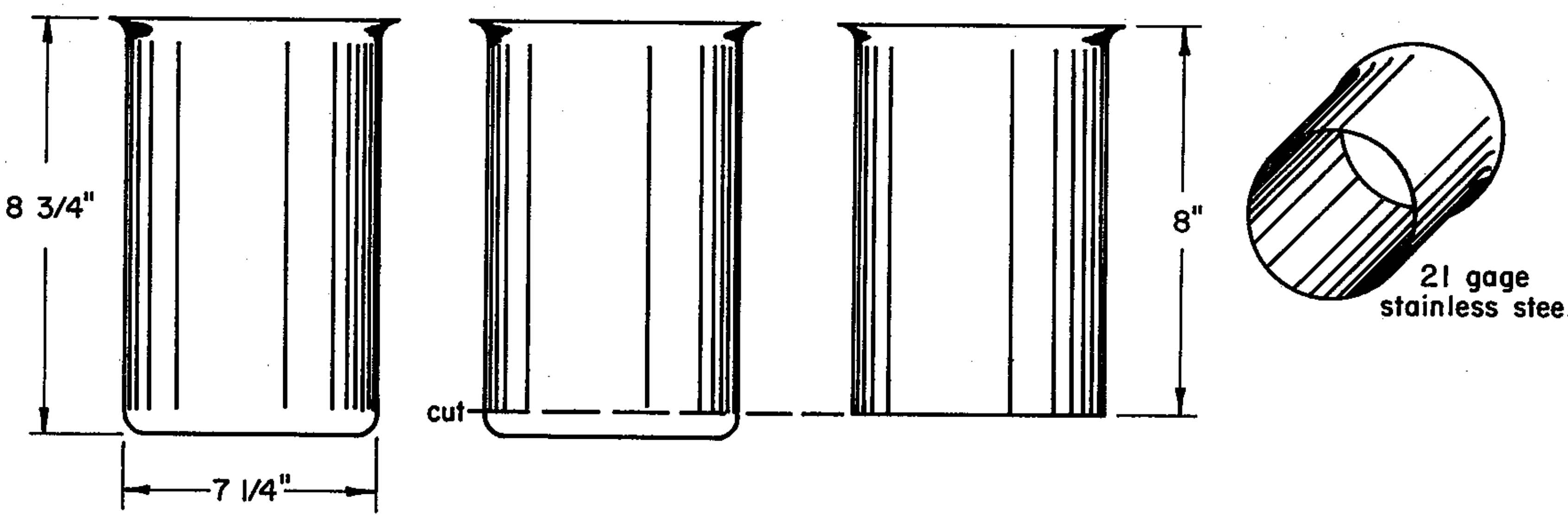
EFFECT OF WATER CONTENT ON RODDED DENSITY



ClibPDF - www.fastio.com

TEST MOLD AND CASING

Two identical restaurant steam table food containers are available from restaurant supply firms under trade name of Bain Marie ST-6



TEST MOLD

One container remains intact to serve as the test mold

CASING

The bottom of the other container is cut off to form the casing

Figure 2

ClibPDF - www.fastio.com

SEQUENCE OF TEST OPERATION

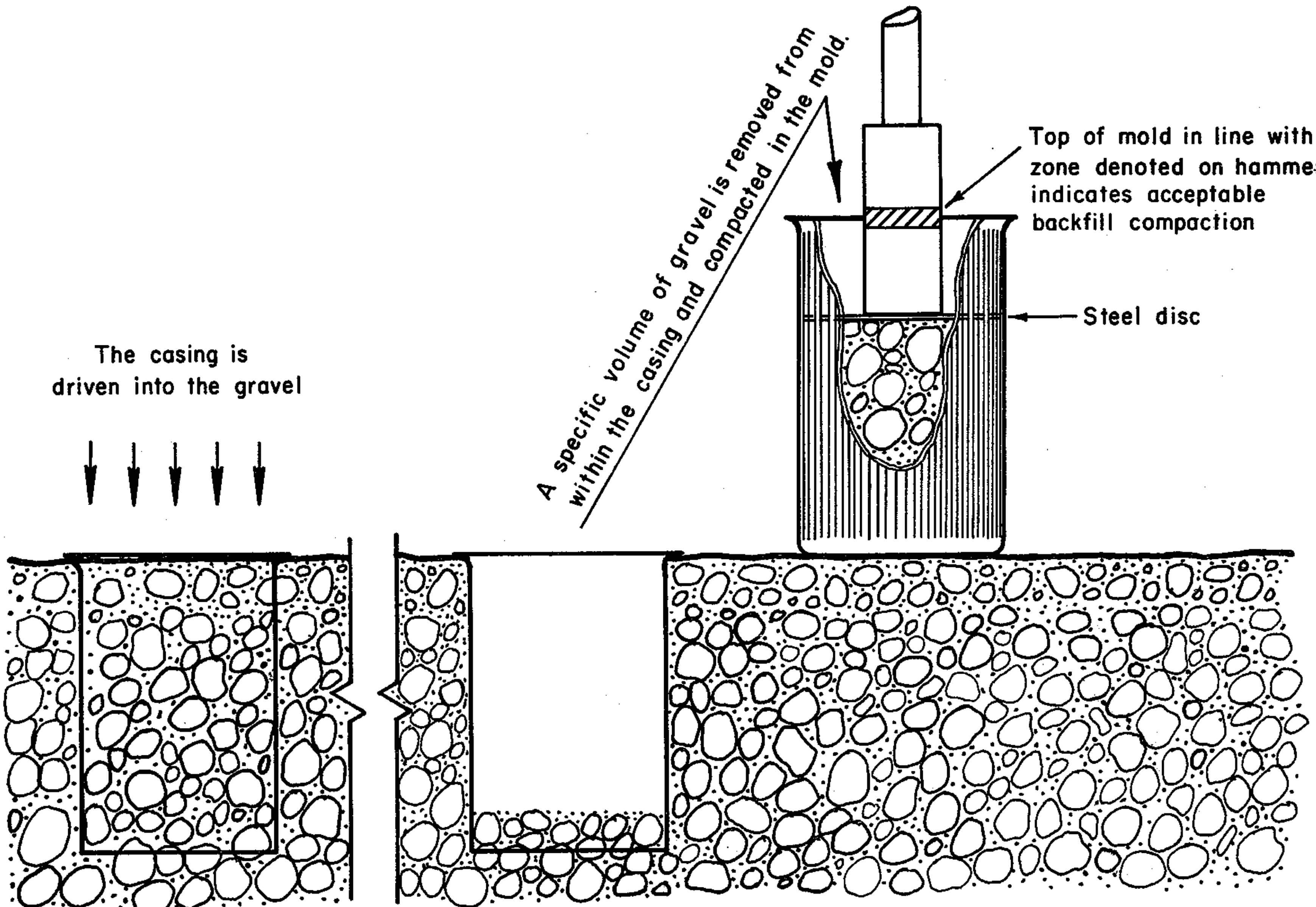


Figure 3

ClibPDF - www.fastio.com

ClibPDF - www.fastio.com

Photo 1. Starting the insertion of the casing by hand manipulation

ClibPDF - www.fastio.com

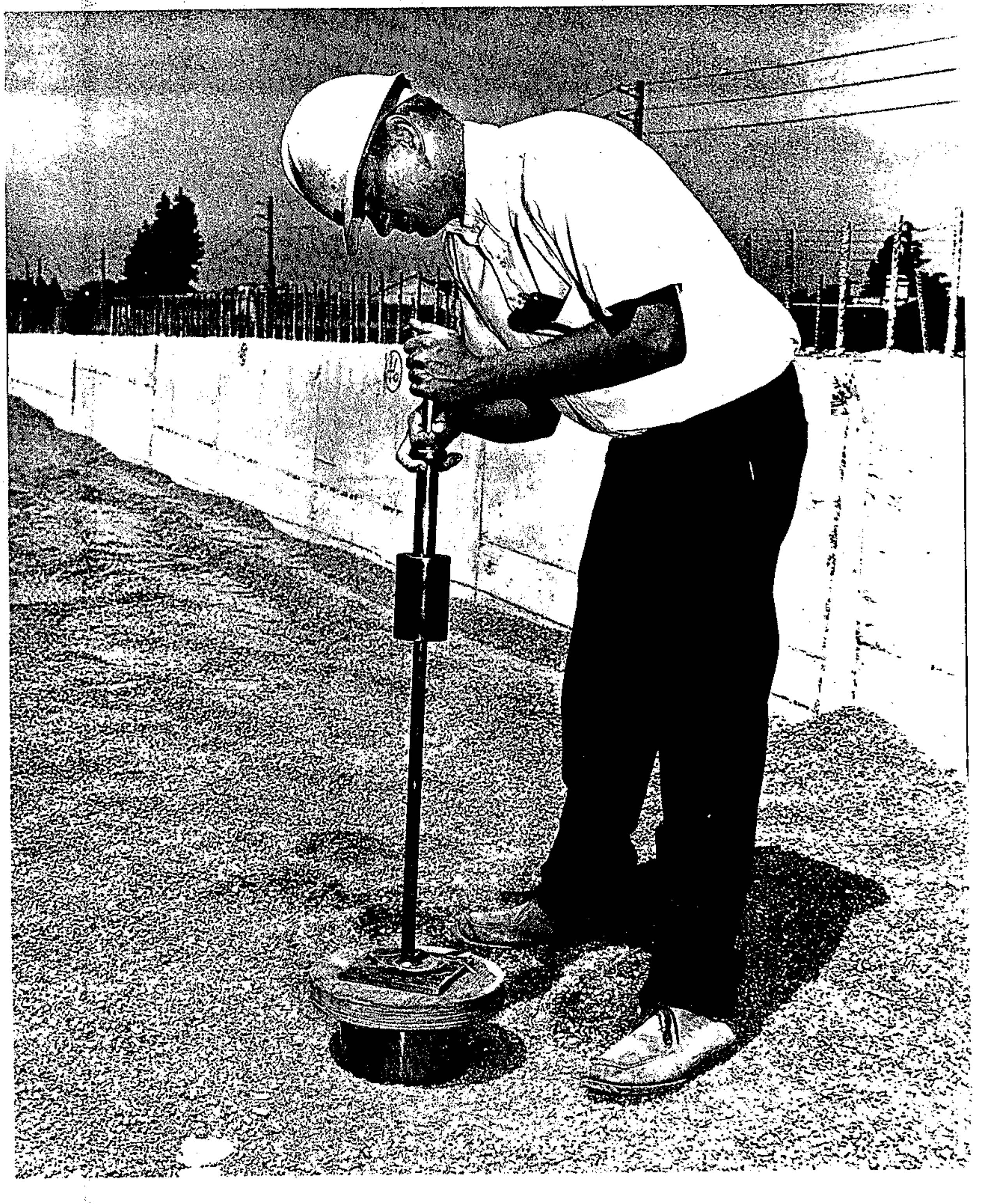


Photo 2. Raising the driving device hammer

ClibPDF - www.fastio.com

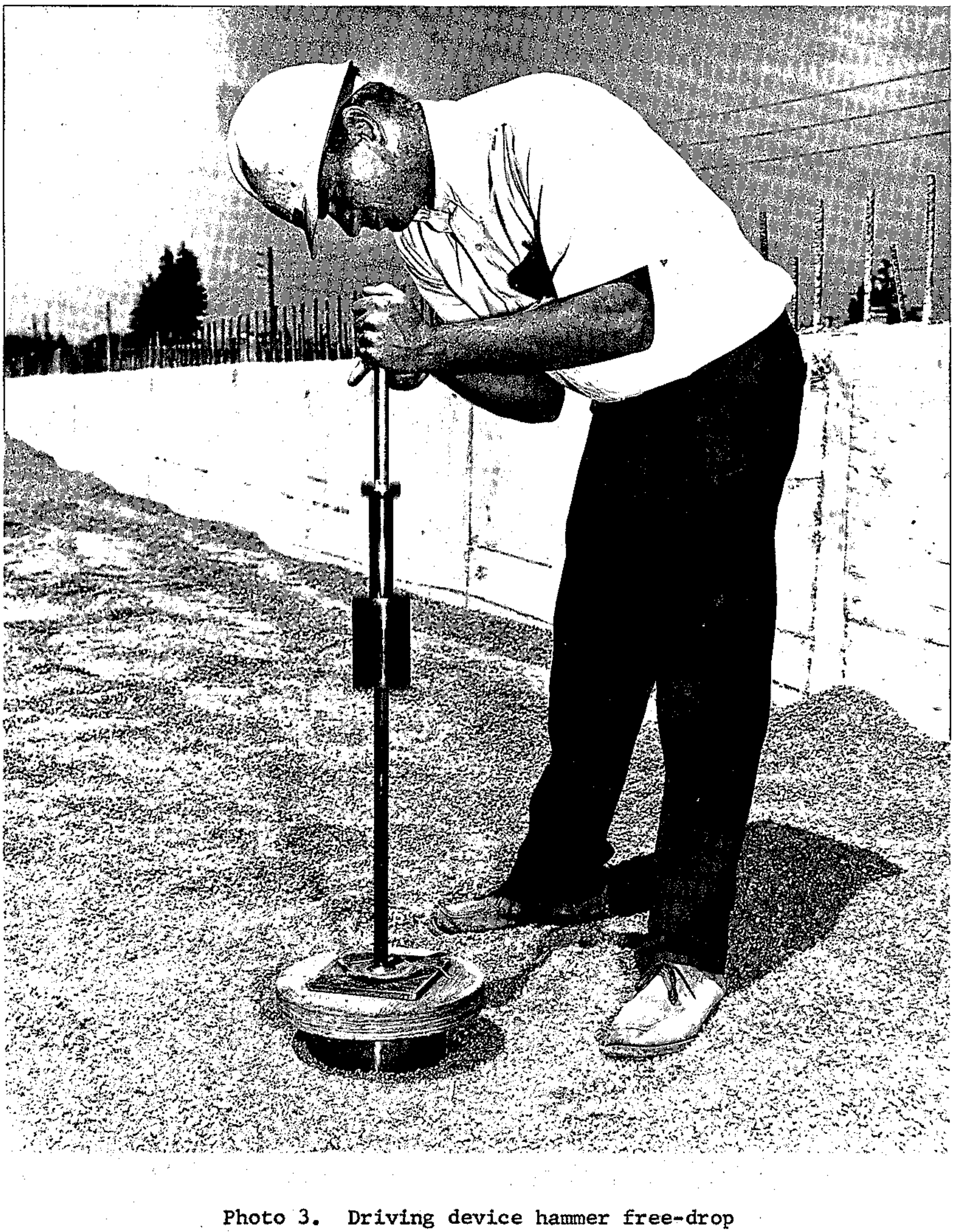


Photo 3. Driving device hammer free-drop

ClibPDF - www.fastio.com