EXAMPLE OF TRAINING NOTES

THE DETERMINATION OF THE IN-PLACE DENSITY AND MOISTURE CONTENT OF SOILS AND GRAVELS BY NUCLEAR METHODS

Subject Number: T02-01-008

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Purpose of this course:

Learners found competent against this course will be able to safely execute the testing required for the determination of the in-place density of soils and gravels by nuclear methods.

For those with extensive experience in the execution of this test in the work place, this course can be used to prepare the learner for recognition of prior learning evaluation.

For the new entrant, this course describes the execution of the test for the development of appropriate skills.

For education and training providers this course provides guidance for the training of learners.

For employers this course enables employee skills to be developed.

This course has been developed to provide support and reference material for the execution of the test.

Learning assumed to be in place:

Learners should be able to read, write and speak in English.

Exit level outcomes:

On successful completion of this course learners in the positions of Assistant Materials Tester, Materials Tester and Senior Materials Tester are able to:

1. Receive instructions form the supervisor.
2. Recognise and select the apparatus needed for the execution of the test.
3. Prepare and load the vehicle for transport of the apparatus to site.
4. Prepare the testing area and nuclear gauge.
5. Take a moisture sample on site.
6. Handle all apparatus with care
7. Execute the work in a safe manner.

In addition to the above the position of Materials Tester and Senior Materials Tester are able to:

8. Supervise the work of the Assistant Materials Tester.
9. Execute and record the standard counts for a nuclear gauge.
10. Understand and execute the safety requirements.
11. Execute and record the in-place density and moisture content test using a nuclear gauge.
12. Determine and record the masses for the moisture content by oven dry methods.

In addition to the above the position of Senior Materials Tester is able to:

13. Arrange for the test to be carried out.
14. Supervise the work of the Assistant Materials Tester and Materials Tester.
15. Interpret the standard count readings.
16. Calculate the dry density of the material tested.

Strategic Skills Priority: Develop Technical Competencies
Education & Training Priority: Laboratory & Soils

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TENTATIVE METHOD FOR DETERMINING THE IN-PLACE DENSITY AND MOISTURE CONTENT OF SOILS AND GRAVELS BY NUCLEAR METHODS

1. SCOPE

This method describes the in-place determination of the density and moisture content of a compacted layer by nuclear methods.

Definition

The in-place dry density of a material is the dry mass per unit volume of the material expressed in kilograms per cubic metre. The in-place moisture content (m/v) is the mass of water per unit volume of the in-place material expressed in kilograms per cubic metre. (In this method moisture content will refer to this definition.) This moisture content can be converted and expressed as percentage moisture per mass of dry material (m/m).

2. APPARATUS

2.1 A nuclear system complete with accessories and stored in a suitable transit case as supplied by the manufacturer. A detailed description of each unit and principles of operation should be given in the manual for the nuclear instrument.

2.2 Other equipment needed to do the test, e.g. bedding sand for leveling site if necessary, bedding plate, paint brush, etc.

2.3 Safety: Radiation levels and shielding must com ply with government regulations. The equipment should also have safety features such as an automatic source retraction mechanism. Please note that nuclear apparatus must be registered with the Atomic Energy Board.

3. METHOD

3.1 Standardization of equipment

3.1.1 The following checks shall be made before any instrument is used:

(a) The warm-up time must be in accordance with the manufacturer's specifications.
(b) The power supply must be properly charged (a low power level should be indicated by an audible warning or any other suitable indicator).

(c) The metering or display system must be checked for correct functioning.

3.1.2 Laboratory check

(a) Check the instrument on the reference unit at the pre-selected reference spot at the main laboratory before the instrument is taken into the field.
(b) Sufficient readings must be taken on the reference standard as recommended by the manufacturer.

(c) If more than the prescribed number of readings fall outside the calibration limits, a second set of readings should be taken. If more than the prescribed number of these readings fall outside the limits, the instrument should be referred back to the manufacturer.

(d) A permanent record should be kept of the readings taken on the reference unit.

3.1.3 Field check

A reference spot must be selected in the field against which daily checks can be made before and after routine tests. Two readings must be taken and they should fall within the field calibration limits set by the manufacturer. If one reading is outside the limits a second set of readings must be taken. If this second set of readings is not within the limits, another field reference spot must be selected. Care should be taken to ensure that other objects, such as vehicles, walls or other nuclear instruments, are not in the immediate vicinity (at least 10 m away).

3.2 Preparation of test site

3.2.1 Flush backscatter measurements

The gauge must be properly bedded on the surface of the material for all flush count measurements. A bedding of finely-graded sand (passing the 0,600 mm sieve) should be strewn lightly over the site. The surface gauge should then be bedded on the surface by moving it backwards and forwards over the site. The bedding sand should only serve to fill the surface voids. A continuous layer of sand over the material must be avoided.

3.2.2 Direct transmission mode of measurement

The drill rod is placed through the guide in the bedding plate and then driven into the ground at least 50 mm deeper than the desired depth of measurement. Care must be taken not to damage the hole when withdrawing the drill rod.

3.3 Moisture and density measurements

(a) Three methods exist for determining the density of a material. These are the:
    (A) flush backscatter method;
    (B) the air-gap count ratio method; and
    (C) the direct transmission method.

(b) The moisture content (m/v) of a material can only be determined by the flush backscatter method.

3.3.1 Method A - Flush backscatter (FBS)

The following procedure should be used to carry out the flush backscatter density and moisture count measurements.

(a) Bed the surface gauge ensuring that it is flush with the surface of the material.
(b) Activate the nuclear instrument (ensure that the source is not in the retracted position).
(c) Read and record moisture and density readings after the counting period has ceased. (Record in 1 and 3 of Form A10(b)T/1 .)
(d) The source must then be retracted and the gauge turned through 180E. Re-bed on the same test point. Repeat procedures (b) and (c). (Record in 1 and 3 of Form A10(b)T/1.)

3.3.2 Method B - airgap count ratio method (ACR)

This method is applied for instruments using this facility. The following procedure is followed:

(a) Bed the surface gauge ensuring that it is flush with the surface of the material.
(b) Activate the nuclear instrument (ensuring that the source is not in the retracted position).
(c) Read and record the moisture and density readings after the counting period has ceased. (Record in 1 and 3 of Form A10(b)T/1 .)
(d) The source must then be retracted and the gauge turned through 180E. Re-bed on the same test point. Repeat procedures (b) and (c). (Record in 1 and 3 of Form A10(b)T/1.)
(e) After retracting the source of the surface gauge, lift it gently off the test site. Care must be taken so as not to disturb the bedding sand when used.
(f) Carefully place the airgap cradle over the same position as previously occupied by the surface gauge. Lower the surface gauge into the recess in the cradle ensuring that the radio-active source occupies the same position as before. Care should be taken to ensure the sole-plate is free of mud and bedding sand before being placed onto the cradle.
(g) Read and record the density reading after counting has ceased. (Record in 2 of Form A10(b)T/1.)
(h) Retract the source of the gauge.

(i) Without disturbing the airgap cradle, turn the surface gauge through 180E and replace in the recess.

(j) Activate the source and read and record the density reading after counting has ceased. (Record in 2 of Form A10(b)T/1.)

3.3.3 Method C - Direct transmission (DT)

The direct transmission (DT) mode of measurement is used for determining density only. With some machines moisture count readings may be taken by backscatter simultaneously with the DT density readings. The procedure for determining the density by DT is as follows:

(a) Place the instrument over the prepared test point with the direct transmission probe directly above the hole.

(b) Lower the probe into the hole to the desired depth of density measurement.

(c) To minimize the airgap between the source and the detector, the gauge must be gently pulled to position the probe against the side of the hole.

(d) After taking density count readings, the probe must first be retracted before attempts to remove the instrument from the test point are made, in order to prevent damage to the probe.

(e) A second density count reading may be taken (by turning the gauge through 180 E and carrying out the procedure (a)- (d)

4. CALCULATIONS

4.1 For Method A - Flush backscatter (FBS)

4.1.1 Wet density: Calculate the average of the flush backscatter density counts for each test point. Read off the corresponding wet density in kg/m³ from the backscatter density calibration curve or tables. The wet density should be read off to the nearest 5 kg/m³.

4.1.2 Moisture content (m/v): Calculate the average of the moisture counts for each test point. Read off the corresponding moisture content in kg/m³ from the relevant moisture calibration curve or tables. The wet density should be read off to the nearest 5 kg/m³.

4.2 For Method B - Airgap count ratio (ACR)

4.2.1 Wet density:

(a) Calculate the average of the flush backscatter density counts and the average of the airgap density counts.

(b) Divide the average airgap density count by the average backscatter density count to determine the airgap count ratio (ACR). The division shall be carried out to the third decimal place.

(c) Read off the corresponding wet density from the ACR density curve. The wet density shall be read off to the nearest 5 kg/m³.

4.2.2 Moisture content (m/v): Calculate the average of the moisture counts. Read off the corresponding moisture content in kg/m³ from the moisture curve. The moisture content shall be read off to the nearest kg/m³.

4.3 For Method C - Direct transmission (DT)

4.3.1 Wet density: Calculate the average of the direct transmission density counts for each test point. Read off the wet density in kg/m³ from the calibrated DT density curve. The wet density shall be read off to the nearest 5 kg/m³.

4.3.2 Moisture content (m/v): Calculate the average of the moisture counts. Read off the corresponding moisture content in kg/m³ from the moisture curve. The moisture content shall be read off to the nearest kg/m³.

4.3.3 Dry density: Calculate the dry density by subtracting the moisture content from the wet density. Round off the result to the nearest 5 kg/m³.

4.4 Reporting of results

4.4.1 The results should be reported to the nearest 10 kg/m³.

5. NOTES

5.1 The basic count/moisture and count/density backscatter curves and the air-gap count ratio/density curve are supplied by the manufacturer.

5.2 Material type effect

The basic calibration curve of some instruments may require adjustment due to the effect of change in chemical composition of a material as described in 5.3 for the density, and in 5.4 for the moisture calibration curves for all instruments. Techniques such as the airgap count ratio (ACR) method can be employed to compensate for this effect.

5.3 Compensation of back scatter density curve

5.3.1 Carry out ACR wet density measurements as in Method B at six different test points.

(a) Calculate the average FBS density count for each test point.

(b) Calculate the average air-gap density backscatter count for each test Point.

(c) Determine the air-gap count ratio for each test point.

(d) Determine the wet density for each test point from the ACR curve.

5.3.2 Plot the average of these wet densities against the average of the corresponding six flush back scatter count averages on copies of the basic back scatter graph supplied with the equipment.

5.3.3 Through this point plot a line parallel to the basic backscatter curve. This is then the compensated density backscatter for the particular material.

5.4 Compensation of basic moisture curve

5.4.1 Investigations have shown that where moisture measurements are carried out on ferruginous materials (laterite, iron-stone, ferricrete) or on materials containing chemically bound water (such as clay or soil having a high organic matter content), it is necessary to compensate the basic moisture curve supplied with the instrument. The appropriate moisture calibration curve for those materials can be established by means of comparative gravimetrical moisture determinations. The calibrated curve is generally offset by a constant factor from the basic curve. The following procedure should be followed to establish the correct curve:

5.4.2 Determine nuclear moisture and wet density counts at five different test points using Method B.

5.4.3 Immediately after each test, take a sample (approximately 2 kg) at the same test point to a depth of 75 mm. Determine the moisture content (m/m basis) by oven drying.

5.4.4 Determine the wet densities from the basic ACR curve.

5.4.5 Convert the moisture content (mass per mass) to a mass per volume basis by means of the following formula:

$$\text{Moisture content (m/v) in kg/m}^3 = \frac{M \times Dw}{M+100}$$

where

Dw = wet density in kg/m³

M = moisture content (m/m) (per cent)

5.4.6 Establish the correct calibration curve by drawing a line parallel to the basic curve through a plot of the average of the five mean moisture counts against the average of the five moisture contents (m/v) in kg/m³.

SUGGESTED OVEN-DRY METHOD FOR DETERMINATION OF MOISTURE CONTENT

1. A representative sample of between 500g and 1000g is taken from the material where the nuclear gauge was placed and transferred to a suitable air tight container.
2. The more coarsely graded the material, the larger the sample.
3. The moist sample is kept contained in the air tight container until the laboratory is reached.
4. It is weighed immediately, accurate to the nearest 0.1gram and dried to constant mass in an oven at 105 to 110 ºC.
5. The moisture content is determined to the nearest 0,1 per cent as follows:

$$\text{Moisture content (\%)} = \frac{(Mw - Md) \times 100}{Md}$$

where

Mw = Wet materials sampled on site

Md = Oven dried material

6. The results are recorded on the appropriate recording form.

REQUIREMENTS OF THE DEPARTMENT OF HEALTH

Abstracts from "ANNEXURE TO AUTHORITIES": ADDITIONAL CONDITIONS

1. No activity may take place in the absence of the appointment of a radiation protection officer.
2. The authority holder must ensure that the appointment radiation protection officer and/or the acting radiation protection officer are replaced by suitable nominees before the former person (s) have terminated their service (s). Form RN785 must be used for this purpose.
3. The authority holder must, prior to engaging in any action with regard to this authority, compile internal rules pertaining to the specific circumstances in his undertaking.
4. Controlled areas must be:
   - 4.1 Physically marked off or demarcated;
   - 4.2 placed under entrance control; and
   - 4.3 furnished with a radiation warning sign.
5. A stock record must be opened for each group IV hazardous substance.
6. Each group IV hazardous substance must be stored in a storage place when not in use.
7. The authority holder must calibrate any radiation monitor being used to monitor radiation levels and contamination:
   - 7.1 directly after the procurement thereof from the supplier; and
   - 7.2 before it is put into use after any repair; and
   - 7.3 at least once every 14 months, except industrial radiography; or
   - 7.4 at least once every 7 months for industrial radiography monitors.
8. A blood sample must be drawn from all people possibly exposed to more than 50 mSv during a single TLD wearing period and be sent to the iThemba Labs (previously known as the National Accelerator Centre) at Faure for biological dosimetry within 30 days of being notified by the SABS. The contact person at iThemba Labs (NAC) is Dr Kobus Slabbert, Tel. (021) 843-1000.
9. The importation and use of previously owned equipment containing radio-nuclides in terms of which this authority is issued may not be delivered to the end-user until the following requirements have been met:
   - 9.1 The item(s) in question must be subjected to quality control tests based on the protocols stipulated by the original manufacturer.
   - 9.2 The tests stipulated in 8 must be carried out by either:
   - 9.2.1 The South African Nuclear Energy Co-operation, or
   - 9.2.2 Any other company approved by the manufacturer of the equipment.
   - 9.3 The results of these tests must be attached to page 4 of the application form RN787 completed by the end user.

9.4 Items for permanent export must be dealt with in the same manner, i.e. the aforementioned results must accompany the application for authority to export the particular item(s).

10. No item(s) listed on this authority may be transferred to another authority holder before the item(s) are registered on their authority.

11. The Director-General must forthwith be notified following any group IV hazardous substance being:

11.1 lost, stolen or missing;

11.2 released into the atmosphere as a gas, aerosol, or otherwise; or

11.3 dumped or released in such a way that could have caused contamination.

12.

12.1 The authority holder must within 14 days after the end of December of each year take stock, or cause stock to be taken, of all sealed sources in his possession or under his control;

12.2 A copy of the December stocktaking must be submitted not later than the end of January of each year;

12.3 The radiation protection officer must indicate discrepancies between the stocktaking and this authority.

13. Gauges containing a gaseous source (e.g. Kr-85 or H-3) need not be tested for leakage (contamination).

14. A record must be kept of the leak test results.

15. Leak tests must be performed annually on gauges containing a movable probe, and every 24 months on those with permanently built-in sources only.

16. The item(s) listed on the authority may not be hired or loaned to any party unless prior written authority has been obtained.

17. Persons operating Nuclear gauges model 4640 and 2376 respectively must wear personal dosimeters TLD's).

18. A red flag must be mounted on a yellow and black striped pole so as to be clearly visible to all operators of vehicles or earth moving equipment. The pole must be placed adjacent to the instrument while in use.

GUIDE TO PREVENTIVE AND SAFETY MEASURES

1. Safety or preventive measures:
   a. Make sure that when the nuclear gauge is loaded on the vehicle, it is secured with the chain and the lock.
   b. Make sure that radioactive stickers are on the vehicle at all times when the nuclear gauge is in use.
   c. Never leave the nuclear gauge un-attended at any time. When not in use it must be stored in a box in a safe place. (Preferably in the locked vehicle or the laboratory store).
2. Guidelines in case of an incident:
   a. If there is an accident where the nuclear gauge is involved, the safety officer must be notified immediately, so that the necessary arrangements can be made.
   b. The first step that you thereafter take is to clear the area and cordon off at least 30m radius.
   c. When the health Inspector comes out and give us the OK, then only will the affected area be opened.

REFERENCES AND ACKNOWLEDGEMENTS

1. The photographs were taken by Mr Sunil Dewnath of MTTC (Pty) Ltd on 30 September 2004.
2. The persons photographed were Mr Willem R Nkuna and Mr Adriaan Vorster from the SANAS accredited civil engineering laboratory, Matrolab Group (Pty) Ltd, Pretoria Branch.
3. The apparatus photographed were provided by Matrolab Group (Pty) Ltd, Pretoria Branch.
4. "TMH1 Method A10(b): Tentative method for determining the in-place density and moisture content of soils and gravels by nuclear methods" was obtained in pdf format from the CSIR website, www.csir.co.za in May 2004.
5. The Department of Health requirements were obtained from the Annexure to Authority 0261/1/03/0923 Additional Conditions by Dr T C Kotze, dated 19 September 2003.
6. The preventive and safety measures are guides only and were based on experiences by Matrolab Group (Pty) Ltd, Pretoria Branch.
7. Any contributions to the further development of these notes will be welcomed.
8. Although every effort was made to present the latest technology as accurately as possible in these notes, MTTC (Pty) Ltd will not be responsible for any omissions, errors or outdated technology contained herein and will not be liable for any action or outcome that may arise as a result of interpretations and/or conclusions made from these notes.

APPENDIX

FORMS

Form A10(b)/1: Recording sheet for the determination of the in-place density of soils and gravels by nuclear methods.

Form 10(b)/2: Monthly count rate record on reference unit.

Form 10(b)/3: Long-term count rate performance record.

Form 10(d)/4: Count rate on reference unit record.