TVET CERTIFICATE V IN ROAD CONSTRUCTION

IN SITU DENSITY TEST

RCTSD501

Perform in situ density test

Competence

Credits: 3

Learning hours: 30

Sector: Construction and building services

Sub-sector: Road construction

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Purpose statement

This module describes the skills and knowledge required to perform in situ density test in road construction. Choose and use the appropriate materials, tools and equipment while performing in situ density test.

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I. Learning Unit 1 – Prepare for works.

LO 1.1 – Prepare tools, equipment and material

Introduction

In-situ density is widely used to control the field compaction of earthworks and pavement layers. There are a number of methods available for measuring in-situ density but only the two common methods are considered here. These are the core cutter method and the sand replacement method.

- Topic 1 Tools used for density in situ

Suitable tools for excavating holes in compacted soil (bent spoon, scraper tool, hammers, chisels and paint brush)

- ✓ **Scraper:** a hand scraper is a single-edged tool used to scrap metal from a surface. This may be required where a surface needs to be trued, corrected for fit to a mating part, needs to retain oil (usually on a freshly ground surface), or to give a decorative finish.
- ✓ **Trowel:** any of various hand tools used to apply, spread, shape, or smooth loose or plastic material; also: a scoop-shaped, tool to make a level surface.
- ✓ **Dibber or elongated trowel:** for digging and excavating material
- ✓ **Hammer**
- ✓ **Specimen**
- ✓ **Cleaning tool**

- Topic 2 Types of equipment used for density in situ

Equipment used for density in situ

a. **Sand pouring cylinder** of 3 litre/16.5 litre capacity mounted above a pouring come and separated by a shutter cover plate.
b. Cylindrical calibrating container with an internal diameter of 100 mm/200 mm and an internal depth of 150 mm/250 mm fitted with a flange 50 mm/75 mm wide and about 5 mm surrounding the open end.
c. **Balance** to weigh unto an accuracy of 1g.
d. Metal containers to collect excavated soil.
e. Metal tray with 300 mm/450 mm square and 40 mm/50 mm deep with a 100 mm/200 mm diameter hole in the centre. Glass plate about 450 mm/600 mm square and 10mm thick.
f. Clean, uniformly graded natural sand passing through 1.00 mm
g. I.S. sieve and retained on the 600micron I.S. sieve. It shall be free from organic matter and shall have been oven dried and exposed to atmospheric humidity.
h. Suitable non-corrodible airtight containers.

i. Thermostatically controlled oven with interior on non-corroding material to maintain the temperature between 105 ^{0}C to 110 ^{0}C.
j. A desiccator with any desiccating agent other than sulphuric acid.
k. Membrane densitometer
l. Sand densitometer
m. Personal protective equipment

- Topic3 Materials used for density in situ

A. **Ottawa sand**: sand that can be used in Sand Cone Method for determining in situ soil density

Properties of Sand Used in Sand Cone Method

According to ASTM (1989) properties and requirements of sand that can be used in Sand Cone Method for determining in situ soil density are described below:

1. Sand should be clean, dry, uniform uncemented, durable and free flowing.
2. Any gradation may be used that has uniformity coefficient ($C = D_{60} / D_{10}$) less than 2, a maximum particle size less than 2.00 mm (No. 10 sieve) and less than 3% by weight passing 250 tm (No. 60 sieve)
3. Uniform sand is needed to prevent segregation during handling, storage and use. Sand free of fines and fine sand particles is needed to prevent significant bulk density changes with normal daily changes in atmospheric humidity.
4. Sand comprised of durable, natural surrounded or rounded particles is desirable. Crushed sand or sand having angular particles may not be free flowing, a condition than can cause bridging resulting in inaccurate determinations
5. In selecting sand from a potential source, five separate bulk density determinations shall be made on each container or bag of sand. To be acceptable sand, the variation between any determination and average shall not be greater than 1% of the average.
6. Before using sand in density determinations it shall be dried. Then allowed to reach an air dried state in the general location where it is to be used.
7. Sand shall not be reused without removing any contaminating soil, checking the gradation and drying.
8. Bulk density tests shall be made at intervals not exceeding 14 days, always after any significant changes in atmospheric humidity, before reusing and before using a new batch from a previously approved supplier.

B. **In situ Soil/compacted**: All of the soil excavated from every hole to be tested .As you are digging the hole put the retrieved soil into the plastic bag in order that the soil does not lose moisture.

LO 1.2 – Identify test procedures

- Topic 1 In situ density methods

There are a number of methods for the determination of in place density of soil.
Following methods are widely used.

A. **Sand cone method**: The sand replacement method is the most widely used in-situ density test. Although the test takes slightly longer to perform than some other in-situ density tests, the test may be carried out on most type of materials.
B. **Core cutter method:** This method is only used on fine-grained cohesive soils which do not contain stones. It is, therefore, very useful for control of earthworks and subgrade materials but is not suitable for coarse grained pavement materials.
C. **Rubber balloon method:** The same as the sand cone, except a rubber balloon is used to determine the volume of the hole
D. **Water displacement method:**

- Topic 2 Test procedures

1. Hole excavation: Dig up a 10 to 15 cm deep hole.
2. Measuring of excavated soil weight
3. Measuring of excavated soil volume
4. Measuring of excavated soil moisture content
5. Calculate Dry density

LO 1.3 – Prepare test point

- Topic 1 Test point preparation procedures

A. Leveling
B. Swiping
C. Placing plate

Procedures

1. Expose an area of about 450mm square on the surface of the soil mass. Trim the surface down to a level surface using a scrapper tool.

2. Place the metal tray on the leveled surface.

3. Excavate the soil though the central hole of the tray, using the hole in the tray as a pattern. The depth of the excavated hole should be about 150mm.

4. Collect all the excavated soil in a metal container, and determine the mass of the soil (M).

5. Remove the metal tray from the excavated hole.

6. Fill the sand pouring cylinder within 10mm of its top.

Determine its mass (M).

7. Place the cylinder directly over the excavated hole. Allow the sand to run out the cylinder by opening the shutter. Close the shutter when the hole is completely filled and no further movement of sand is observed.

8. Remove the cylinder from the filled hole. Determine the mass of the cylinder (M).

9. Take a representative sample of the excavated soil.

Learning Unit 2 – EXECUTE TEST PROCEDURES

LO 2.1 – Localize the trial point

- Topic 1 Methods of point selection

    1. Randomly
    2. Systematically

2.1.1. Systematic Sampling

Systematic sampling is simple rand more straightforward than random sampling.

It can also be more conducive to covering a wide study area. On the other hand, systematic sampling introduces certain arbitrary parameter sin the data. This can cause over-or under representation of particular patterns.

Systematic sampling is popular with researchers because of its simplicity.

Researchers generally assume the results are representative of most normal populations, unless a random characteristic disproportionately exists with every "nth" data sample (which is unlikely). To begin, a researcher selects a starting integer on which to base the system. This number needs to be smaller than the population as a whole (e.g., they don't pick every 500th yard to sample for a100-yard football field). After a number has been selected, there searcher picks the interval, or spaces between samples in the population.

Systematic Sampling Example

In a systematic sample, chosen data is evenly distributed. For example, in road construction you are given a compacted road to test in situ density, the road measures ten kilometre (10Km) and you are asked to take sample systematically in three parallel points every fifty metre (50m), one point in the middle another point at the right side and other one at left side of the road.

Advantages of Systematic Sampling

The pros of systematic sampling include:

Easy to Execute and Understand

Systematic samples are relatively easy to construct, execute, compare, and understand. This is particularly important for studies or surveys that operate with tight budget constraints.

Control and Sense of Process

A systematic method also provides researchers and statisticians with a degree of control and sense of process. This might be particularly beneficial for studies with strict parameters or a narrowly formed hypothesis, assuming the sampling is reasonably constructed to fit certain parameters.

Clustered Selection Eliminated

Clustered selection, a phenomenon in which randomly chosen samples are uncommonly close together in a population, is eliminated in systematic sampling. Random samples can only deal with this by increasing the number of samples or running more than one survey. These can be expensive alternatives.

Low Risk Factor

Perhaps the greatest strength of a systematic approach is its low risk factor. The primary potential disadvantages of the system carry a distinctly low probability of contaminating the data.

Disadvantages of Systematic Sampling

There are also drawbacks to this research method:

Assumes Size of Population can be Determined

The systematic method assumes the size of the population is available or can be reasonably approximated. For instance, suppose researchers want to study the size of rats in a given area. If they don't have any idea how many rats there are, they cannot systematically select a starting point or interval size.

Need for Natural Degree of Randomness

A population needs to exhibit a natural degree of randomness along the chosen metric. If the population has a type of standardized pattern, the risk of accidentally choosing very common cases is more apparent.

For a simple hypothetical situation, consider a list of favorite dog breeds where (intentionally or by accident) every evenly numbered dog on the list was small and every odd dog was large. If the systematic sampler began with the fourth dog and chose an interval of six, the survey would skip the large dogs.

Greater Risk of Data Manipulation

There is a greater risk of data manipulation with systematic sampling because researchers might be able to construct their systems to increase the likelihood of achieving a targeted outcome rather than letting the random data produce a representative answer. Any resulting statistics could not be trusted.

2.1.2. Random Sampling:

A simple random sample is used by technicians themselves they select points to be tested. For example, in road construction you are given a compacted road to test in situ density, the road measures ten kilometre (10Km), then technician will locate points to be tested by him/ herself.

Simple Random Sample:

These disadvantages include the time needed to gather the full list of a specific population, the capital necessary to retrieve and contact that list, and the bias that could occur when the sample set is not large enough to adequately represent the full population.

Advantages of a Simple Random Sample

Random sampling offers two primary advantages.

Lack of Bias

Because individuals who make up the subset of the larger group are chosen at random, each individual in the large population set has the same probability of being selected. This creates, in most cases, a balanced subset that carries the greatest potential for representing the larger group as a whole.

Simplicity

As its name implies, producing a simple random sample is much less complicated than other methods, such as stratified random sampling. As mentioned, individuals in the subset are selected randomly and there are no additional steps.

Important: To ensure bias does not occur, researchers must acquire responses from an adequate number of respondents, which may not be possible due to time or budget constraints.

Disadvantages of a Simple Random Sample

The drawbacks of this research method include:

Difficulty Accessing Lists of the Full Population

In simple random sampling, an accurate statistical measure of a large population can only be obtained when a full list of the entire population to be studied is available. In some instances, details on a population of students at a university or a group of employees at a specific company are accessible through the organization that connects each population.

However, gaining access to the whole list can present challenges. Some universities or colleges are not willing to provide a complete list of students or faculty for research. Similarly, specific companies may not be willing or able to hand over information about employee groups due to privacy policies.

Time Consuming

When a full list of a larger population is not available, individuals attempting to conduct simple random sampling must gather information from other sources. If publicly available, smaller subset lists can be used to recreate a full list of a larger population, but this strategy takes time to complete. Organizations that keep data on students, employees, and individual consumers often impose lengthy retrieval processes that can stall a researcher's ability to obtain the most accurate information on the entire population set.

Costs

In addition to the time it takes to gather information from various sources, the process may cost a company or individual a substantial amount of capital. Retrieving a full list of a population or smaller subset lists from a third-party data provider may require payment each time data is provided. If the sample is not large enough to represent the views of the entire population during the first round of simple random sampling, purchasing additional lists or databases to avoid a sampling error can be prohibitive.

Sample Selection Bias

Although simple random sampling is intended to be an unbiased approach to surveying, sample selection bias can occur. When a sample set of the larger population is not inclusive enough, representation of the full population is skewed and requires additional sampling techniques.

- Topic 2 The types of materials by layers

1. **Platform**: is the layer directly in contact with traffic loads and generally contains superior quality materials. They are usually constructed with dense graded asphalt concrete (AC). The functions and requirements of this layer are: It provides characteristics such as friction, smoothness, drainage, etc. Also it will prevent the entrance of excessive quantities of surface water into the underlying base, sub-base and sub-grade, it must be tough to resist the distortion under traffic and provide a smooth and skid- resistant riding surface, it must be water proof to protect the entire base and sub-grade from the weakening effect of water.
2. **Foundation:** The pavement foundations generally consist of two layers: the sub-base and the base course

   These layers must perform the following functions:

- ✓ Provide a level surface with a good bearing capacity and act as a satisfactory temporary wearing course during works.
- ✓ Once pavement construction is complete, provide the roadbed with thermal protection and give the pavement sufficient strength to withstand the vertical loads generated by traffic.

3. **Mar rum** (well graded lateritic soil): Murrum is widely used material for the construction of pavement shoulders. Sometimes the available murrum may not satisfy the requirement of CBR and hence need to be modified. The locally available granular material like sand and/ or the crusher dust may be mixed to the soil to obtain the desired characteristics.
4. **Base course:** The base course is the layer of material immediately beneath the surface of binder course and it provides additional load distribution and contributes to the sub-surface drainage it may be composed of crushed stone, crushed slag, and other untreated or stabilized materials.

- Topic3 Status of ground:

1. Ground clearing

Clearing and grubbing involves the removal of trees and brush on a piece of land. Depending on the size, location, and purpose of the land, the excavation may require professional land clearing equipment.

Pushover, cut, grind and burning are three of the most used land clearing methods.

- ✓ The pushover method of land clearing often involves the use of major construction equipment. The trees are pushed over and hauled off the land with the roots intact. Once the trees are moved to a central location, they are often processed for sale or ground for use as a mulching material.
- ✓ The second method is cut and grind. This method begins with cutting down the trees on the piece of land. These trees are often moved to a processing location, but the stumps are left in the ground. These stumps can be ground into mulching material or pulled out of the ground using a large piece of construction machinery.
- ✓ A third method involves using a controlled burn for land clearing, it can be one of the most dangerous methods. Burning involves starting a controlled fire and maintaining

that fire until all trees and brush are burned to the ground. After the fires are extinguished, the land can be cleared using a bull dozer or other piece of construction equipment.

2. Ground levelling

Ground levelling is the process of clearing debris from worksites, and creating an even surface. It's a key function at constructions sites, for road building.

Construction sites

Ground levelling is one of the most important tasks on a construction site. It provides a level, well-compacted, and stable surface on which to build sturdy foundations.

Once the site is perfectly even, and the foundations are laid, grading is required to adjust the slope and elevation of the site so that water flows away from the foundations.

Grading is also the technique used to create landscaping features on a property. Properly graded slopes prevent water from pooling, and eroding driveways and paths, damaging plants and shrubs, and attracting mosquitos.

Road building sites

During road construction, one of the first steps is to level the ground to create an even surface on which to build a solid base.

LO 2.2 – Dig and handle the sample

- Topic 1 Sampling process:

1. Surface cleaning: Expose a flat area, approximately 600mm square (approximately 450mm square for the small cylinder method) of the soil to be tested and trim it down to a level surface. Brush away any loose material which is not part of that being tested. The surface should be as level as possible in order to reproduce the laboratory calibration conditions.

2. Setting of densitometer: place the metal tray and fasten the 4 screws. Lay the metal tray on the prepared surface with the hole over the portion of the soil to be tested. Run a trowel or other sharp tool around the outside of the tray, marking square on the surface of the soil being tested. This will help to position the pouring cylinder

during the later stages of the test. It is often helpful for the tray to be nailed to the ground to stop it moving during the excavation of the test hole

3. Excavation (digging): Dig up a 10 to 15 cm deep hole. Using the hole in the metal tray as a pattern, excavated a round hole, approximately 200 mm in diameter (100 mm for the small cylinder method) and the depth of the layer to be tested up to a maximum of 250 mm deep (150 mm for the small cylinder method). Do not leave loose material in the hole and do not distort the immediate surround to the hole. Carefully collect all the excavated soil from the hole and determine its mass, mw to the nearest 10g (1 g for the small cylinder method). Remove the metal tray before placing the pouring cylinder in position over the excavated hole.

Note. Take care in excavating the hole to see that the hole is not enlarged by levering the excavating tool against the side of the hole, as this will result in lower densities being recorded.

As you are digging the hole put the retrieved soil into the plastic bag in order that the soil <u>does not lose</u> moisture. <u>All of the soil including the soft soil</u> at the bottom of the hole is poured into the bag as well.

4. Measurement of the hole:

After flow of sand stops <u>close the valve</u> and pick the assembly up, the sand in the cone will be

poured into the tray. This sand will be left there in the field. (Notice, unlike this picture, the plastic bag should be kept closed while transferring to the lab to avoid moisture loss and consequently weight of the soil)

Measurement of the material: Measure the weight of plastic Gallon+Cone+Sand,

LO 2.3 – Determine Moisture content

- Topic 1 **Moisture content determination procedures**
  - Sample weight
  - Specimen weight
  - Specimen weight with wet materials
  - Specimen weight with dry materials

Water is present in most naturally occurring soils and has a profound effect in soil behaviour. A knowledge of the moisture content is used as a guide to the classification. It is also used as a subsidiary to almost all other field and laboratory tests of soil.

The oven-drying method is the definitive method of measuring the moisture contents of soils. The sand-bath method is used, where oven drying is not possible, mainly on site

Moisture content, $W = \frac{\mathrm{Mw}}{\mathrm{Md}}\ X100(\%)$

Where, *Md* = mass of water

Md = dry mass of sample

Sample mass. The mass required for the test depends on the grading of the soil, as follows;

a) Fine-grained soils*, not less than 30 grams

b) Medium-grained soils*, not less than 300 grams

c) Coarse-grained soils*, not less than 3 kg

Soils group

i) Fine-grained soils: Soils containing not more than 10% retained on a 2 mm test sieve.

ii) Medium-grained soils: Soils containing more than 10% retained on a 2 mm test sieve but not more than 10% retained on a 20 mm test sieve.

iii) Coarse-grained soils: Soils containing more than 10% retained on a 20 mm test sieve but not more than 10% retained on a 37.5 mm test sieve.

Accuracy of weighing. The accuracy of weighing required for test samples is as follows;

a) Fine-grained soils: within 0.01 g.

b) Medium-grained soils: within 0.1 g.

c) Coarse-grained soils: within 1g.

Safety aspects

a) Heat-resistant gloves and / or suitable tongs should be used to avoid personal injury and possible damage to samples.

b) If glass weighing bottles are used they should be placed on a high shelf away from heating elements.

c) A heat-insulated pad should always be used to place hot glassware of any description.

- Topic 2 **Calculate wet and dry density**

Density determination

- Weight of sand pouring in cylinder and sand filled up to 10mm from top edge
- Weight of sand in the cone, mean value
- Weight of cylinder and the sand after pouring into the calibration container and cone
- Weight of cylinder and sand after pouring into the excavated hole and cone
- Volume of excavating container
- Weight of the materials from the excavated hole

Method used to calculate wet and dry density

1) Sand replacement methods

➢The basic principle of sand replacement method is to measure the in situ volume from which the material was excavated from the weight of sand with known density filling in the hole.

➢The in situ density of the material is given by the weight of excavated material divided by in situ volume

Apparatus

a. Sand pouring cylinder equipment:

i. Small pouring cylinder
ii. Large pouring cylinder
iii. Medium pouring cylinder

b. Tools for leveling and excavating

i. Scraper with handle for levelling surface
ii. Dibber or elongated trowel for digging and excavating material

c. Container: metal containers of any convenient size (about 150mm diameter and

200mm depth) with removable lid for collecting the excavated material.

d. Sand: dry and clean test sand of uniform gradation, passing 1.0mm and retained in

600-micron sieve.

e. Balance: suitable balance of 15 or 30kg capacity with accuracy of 1.0 g.

The test require two stages:

i. Calibration of apparatus
ii. Measurement of field density

A. Calibration of apparatus

1. The method given below should be followed for the determination of the weight of sand in the cone of the pouring cylinder:

I. The pouring cylinder should be filled so that the level of the sand in the cylinder is within about 10mm of the top. Its total initial weight (W 1) should be maintained constant throughout the tests for which the calibration is used. A volume of sand equivalent to that of the excavated hole in the soil (or equal to that of the calibrating container) should be allowed to run out of the cylinder under gravity. The shutter of the pouring cylinder should then be closed and the cylinder placed on a plain surface, such as a glass plate.

II. The shutter of the pouring cylinder should be opened and sand allowed to run out. When no further movement of sand takes place in the cylinder, the shutter should be closed and the cylinder removed carefully.

III. The sand that had filled the cone of the pouring cylinder (that is, the sand that is left on the plain surface) should be collected and weighed to the nearest gram.

IV. These measurements should be repeated at least thrice and the mean weight (W 2) taken.

2. The method described below should be followed for the determination of the bulk density of the sand (Ys):

I. The internal volume (V) in ml of the calibrating container should be determined from the weight of water contained in the container when filled to the brim. The volume may also be calculated from the measured internal dimensions of the container.

II. The pouring cylinder should be placed concentrically on the top of the calibrating container after being filled to the constant weight (W 1). The shutter of the pouring cylinder should be closed during the operation. The shutter should be opened and sand allowed to run out. When no further movement of sand takes place in the cylinder, the shutter should be closed. The pouring cylinder should be removed and weighed to the nearest gram.

III. These measurements should be repeated at least thrice and the mean weight (W 3) taken.

B. Measurement of soil density

The following method should be followed for the measurement of soil density:

I. A flat area, approximately 450sq.mm of the soil to be tested should be exposed and trimmed down to a level surface, preferably with the aid of the scraper tool.

II. The metal tray with a central hole should be laid on the prepared surface of the soil with the hole over the portion of the soil to be tested. The hole in the soil should then be excavated using the hole in the tray as a pattern, to the depth of the layer to be tested up to a maximum of 150mm. The excavated soil should be carefully collected, leaving no loose material in the hole and weighed to the nearest gram (W w). The metal tray should be removed before the pouring cylinder is placed in position over the excavated hole.

III. The water content (w) of the excavated soil should be determined as discussed in earlier posts. Alternatively, the whole of the excavated soil should be dried and weighed (W d).

IV. The pouring cylinder, filled to the constant weight (W 1) should be so placed that the base of the cylinder covers the hole concentrically. The shutter should then be opened and sand allowed to run out into the hole. The pouring cylinder and the surrounding area should not be vibrated during this period. When no further movement of sand takes place, the shutter should be closed. The cylinder should be removed and weighed to the nearest gram (W 4).

CALCULATIONS

1) Calculate the mass of sand required to fill the calibrating container, m_a (in g), from the equation:

$$m_a = m_1 - m_3 - m_2$$

where
m_1 is the mass of [cylinder and] sand before pouring in the calibrating container (in g) :
m_2 is the mean mass of sand in cone (in g);
m_3 is the mean mass of [cylinder and] sand after pouring into the calibrating container (in g).

2) Calculate the bulk density of the sand. ρ_a (in Mg/m^3), from the equation :

$$\rho_a = \frac{m_a}{V}$$

where, V is the volume of the calibrating container (in mL).

3) Calculate the mass of sand required to fill the excavated hole, m_b (in g). from the equation:

$$m_b = m_1 - m_4 - m_2$$

where,
m_1 is the mass of [cylinder and] sand before pouring in the hole (in g) :
m_2 is the mean mass of sand in the cone (in g);
m_4 is the mean mass of [cylinder and] sand after pouring into the hole (in g)

4) Calculate the bulk density of the soil. ρ (in mg/m^3). from the equation:

$$\rho = \left(\frac{m_w}{m_b}\right)\rho_a$$

where
m_w is the mass of soil excavated (in g);
m_b is the mean mass of sand required to fill the hole (in g);
ρ_a is the bulk density of the sand (in Mg/m^3).

5) Calculate the dry density, ρ_d (in Mg/m^3), from the equation:

$$\rho_d = \frac{100\rho}{100 + w}$$

where, w is the moisture content of the soil (in %).

6) Calculate the in-situ relative compaction (RC) of the tested layer from the equation :

$$RC = \frac{\rho_d}{MDD} x100\%$$

where,
MDD is the Maximum Dry Density obtained from the compaction test used as the standard for the particular layer. Note that the type of compaction test used is dependent on the type of material.

Test procedure

1- Measure the weight of Proctor mold + Base, **W1** (Go to row 1 of table)

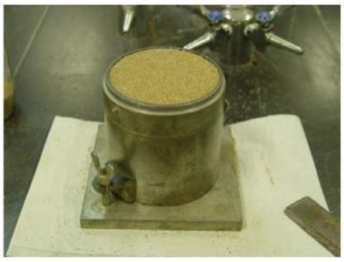
2- Fig. (a). Pour the sand into the compaction mold

Fig. (b). Level the surface (Do not disturb the mold as the sand may rearrange and get compacted)

Fig. (c). Compaction mold filled with sand

Fig. (d). Measure the weight of proctor mold+ base + Sand, **W2** (Go to row 2 of table)

(a) **(b)**



(c) **(d)**

3- Measure the weight of plastic Gallon +Cone +Sand, W3 (before use) (Go to row 5 of table)

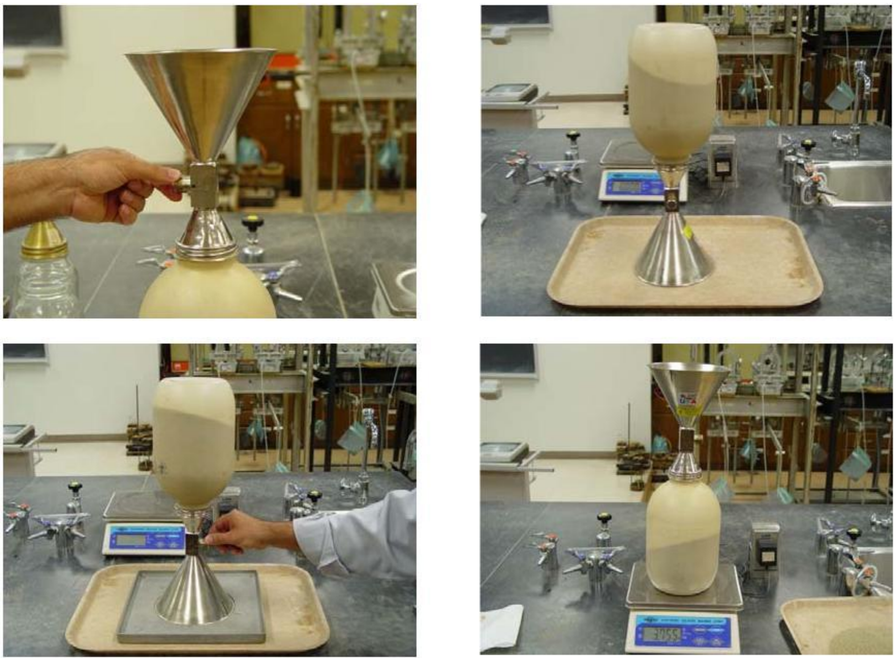
4- (a). Close the valve attached to the cone

(b).Turn the cone and gallon upside down on the tray

(c).Open the valve, sand flows from the gallon to the cone, after the flow stops close the valve and take the gallon+cone from the tray

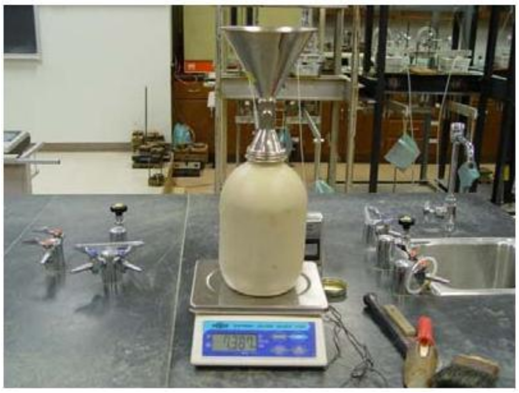
d). Measure the weight of plastic Gallon+Cone+Sand, W4 (after use) (Go to row 6 of table)

(a) **(b)**



(c) **(d)**

5- Weight of plastic Gallon+Cone+Sand, W5 (before use) (Go to row 8 of table)



Let’s go to the Field. A little time out!

6- Go to the field where the soil's unit weight is to be measured, place the metal tray and fasten the screws.

7- Dig up a 10 to 15 cm deep hole.

8- As you are digging the hole put the retrieved soil into the plastic bag in order that the soil does not lose moisture. All of the soil including the soft soil at the bottom of the hole is poured into the bag as well.

9- Having the valve closed turn the gallon+cone upside down and place the cone in the center hole of tray and open the valve so that sand flows down to the hole.

10- After flow of sand stops close the valve and pick the assembly up, the sand in the cone will be poured into the tray. This sand will be left there in the field. (Notice, Unlike this picture, the plastic bag should be kept closed while transferring to the lab to avoid moisture loss and consequently weight of the soil)

11- Measure the weight of plastic Gallon+Cone+Sand, **W6 (after use)** (Go to row 9 of table)

12- Measure the weigh the evaporating dish, **W7** (Go to row 11 of table)

13. Measure the weigh the evaporating dish + wet soil from the field, W8 (Go to row 12 of table)

14- Put the evaporating dish + wet soil in the oven and after 24hrs weigh it again**, W9** (Go to row 13 of table). *In the sample test we did for you **W9** turned out to be 2.251 Kg.*

15- Having the information you got so far in the table, Calculations can be carried out easily

2) Core cutter method

➢This method is only used on fine-grained cohesive soils which do not contain stones.

➢It is, therefore, very useful for control of earthworks and subgrade materials but is not suitable for coarse grained pavement materials.

➢The test involves jacking or hammering a steel cylinder of known mass and volume into the soil, excavating it and finding the mass of soil contained in the cylinder.

Apparatus

The following apparatus is required for the test:

a) Cylindrical steel core cutter. 130 mm long and of

100±2 mm internal diameter, with a wall thickness of

3mm beveled at one end, of the type illustrated

The cutter shall be kept lightly greased.

Note. If the average density over a smaller depth is required, then the appropriate length of cutter should be used.

b) Steel dolly, 25 mm high and of 100 mm internal diameter, with a wall thickness of 5mm, fitted with a lip to enable it to be located on top of the core cutter

c) Steel rammer.

d) Balance, readable to 1 g.

e) Palette knife, a convenient size is one having a blade approximately 200 mm long and 30 mm wide.

f) Steel rule, graduated to 0.5 mm.

g) Short-handled hoe, or spade, and pickaxe.

h) Straight edge, e.g. a steel strip about 300 mm long 25 mm wide and 3 mm thick, with one beveled edge.

i) Apparatus for moisture content determination.

j) Apparatus for extracting samples from the cutter (optional).

Care of apparatus

1. The condition of the cutting edge should be frequently checked as any damage will lead to inaccuracy in the test.
2. A badly damaged edge may be reformed on a lathe taking care to cut the new edge square to the long axis of the mould.
3. Any repair to the cutting edge will require the mould factor to be determined.

Preparation of apparatus

a) Calculate the internal volume of the core cutter in cubic centimeters from its dimensions which shall be measured to the nearest 0.5 mm (Vc)

b) Weigh the cutter to the nearest 1 g (mc).

c) Mould factor,

➢To assist in the calculation of the bulk density of the soil it can be useful to calculate a mould factor for each cutter, and to stamp or paint the value on the mould.

➢For the size of core cutter detailed above, the mould factor ratio F/H calculates as 0.979.

➢This value would be used as a multiplier for the mass of wet soil in the core cutter (in g).

Alternatively, a mould factor can be calculated

Mould Factor

$$F = \frac{p}{4} X \frac{D^2 XH}{1000^2} X 1000$$

$$F = 0.7854 \text{ x } \frac{D^2 XH}{1000^2}$$

Where,

D is the diameter of the mould in mm.

H is the height of the mould in mm.

The value obtained from this calculation is used as a divisor to the mass of wet soil in the core cutter (in g).

Procedures

1. First, leveled and remove all loose material on the area to be tested.
2. Placed lightly greased mould with driving dolly fixed, in position with the cutting edge on the prepared surface.
3. Then, drive a mould slowly into the soil by use of a jack or with a suitable rammer

✓Take care not to rock the mould and drive the cutter until only about 10 mm of the dolly remains above the surface of the soil.

✓The use of a jack is to be preferred as this causes least disturbance to the soil.

✓However, some form of reaction weight such as a vehicle is required.

✓To use a jack, a block of wood is first placed on the top of the dolly and a hydraulic or screw jack is then placed between the wood block and the underside or the reaction weight (normally a jeep).

4. Then, extended jack so that the mould is driven squarely into the ground until only about 10mm of dolly is remaining above the surface.

5. Continue driving until the soil completely fills the mould. If the soil fills in the dolly, there is a danger of compressing the soil in the mould, thus giving incorrect results.

5. Dug out the mould, dolly and soil from the ground using a spade. The soil in the mould should not be disturbed during this operation.

6. Then, remove the driving dolly from the mould and the soil protruding from each end of the mould trimmed off using a straight edge.

7. Weigh the mould and soil, ms.

8. Then, remove the soil in the mould, crumble (crush) and representative samples taken for moisture content.

Calculation and expression of results from core cutter methods

- In principle, the bulk density of the soil. *r* (in Mg / m3) , is calculated from the equation :

$$\rho = \frac{m_s - m_c}{V_c}$$

where,

ms is the mass of soil and core cutter (in g);

mc is the mass of core cutter (in g);

Vc is the internal volume of core cutter (in mL).

- Alternatively, using the mould factor ratio, the bulk density of the soil, $\boldsymbol{\rho}$ (in Kg / m3) , can be calculated from the equation : $\rho = m_s - m_c \text{ x } \frac{F}{H}$
- As a second alternative, using the mould factor F, the bulk density of the soil, $\boldsymbol{\rho}$ (in kg / m3) can be calculated from the equation : $\rho = \frac{m_s - m_c}{F}$
- Value in kg/m3 are converted to Mg/m3 by dividing by 1000.

$$\rho_d = \frac{100\rho}{100 + w}$$

- Where, **W** is the moisture content of the soil (in %).
- The in-situ bulk and dry densities of the soil (Mg/m3), are expressed to the nearest 0.01Mg/m^3.

Core cutter method Report

The test report shall contain the following information:

a) the method of the test used;

b) the in-situ bulk and dry densities of the soil in Mg/m3) to the nearest 0.01 Mg/m3;

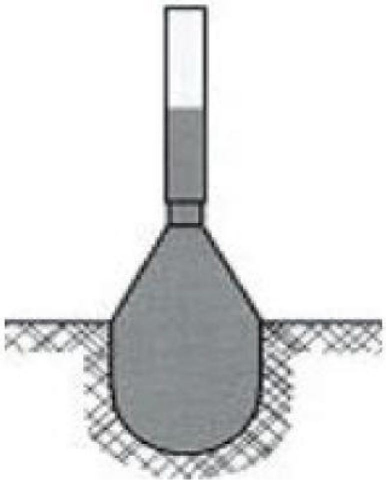
c) the moisture content, (in %), to two significant figures;

d) all other details required by the test form regarding sample origin and description etc.;

e) the operator should sign and date the test form

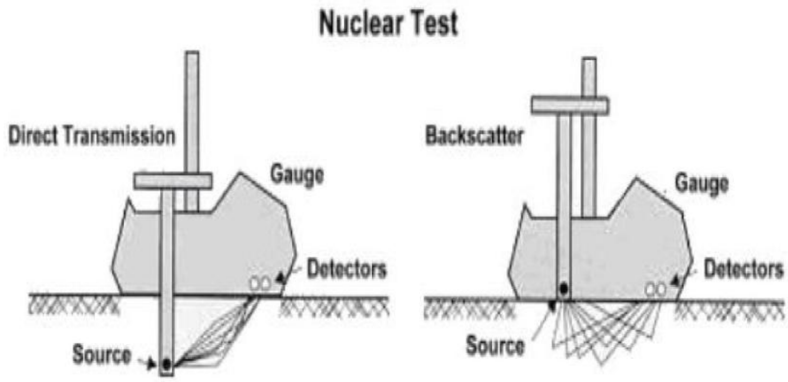
3) Rubber balloon method

The same as the sand cone, except a rubber balloon is used to determine the volume of the hole



4) Nuclear Density (ASTM D2292-91)

- ✓Nuclear Density meters are a quick and fairly accurate way of determining density and moisture content.
- ✓The meter uses a radioactive isotope source (Cesium 137) at the soil surface (backscatter) or from a probe placed into the soil (direct transmission).
- ✓The isotope source gives off photons (usually Gamma rays) which radiate back to the mater's detectors on the bottom of the unit.
- ✓Dense soil absorbs more radiation than loose soil and the readings reflect overall density.
- ✓Water content (ASTM D3017) can also be read, all within a few minutes.



- Content /Topic3 **Moisture content determination**

Oven-drying method (standard method)

Apparatus

1) Thermostatically controlled drying oven capable of operating to 105±50C.
2) Glass weighing bottles or suitable metal containers (corrosion-resistant tins or trays).
3) Balance (to the required sensitivity).
4) Desiccator containing anhydrous silica gel.
5) Scoop, other small tools as appropriate.

Optional: Test sieves - 2 mm, 20 mm, and 37.5 mm (to check classification of sample, in order to confirm required sample size).

Test procedure

a) One clean container with the lid (if fitted) is taken and the mass in grams is recorded (m1) together with container number.

Note: The container plus lid or bottle plus stopper should have the same number and be used together.

b) The sample of wet soil is crumbled and placed in the container. The container with the lid on is weighed in grams (m2).
c) The lid is removed and both lid and container are placed in the oven. The sample is then dried in a thermostatically controlled drying oven which is maintained at a temperature of 105±50C. A period of 16 to 24 hours is usually sufficient, but this varies with soil type. It will also vary if the oven contains a large number of samples or very wet samples. The soil is

considered dry when the differences in successive weightings of the cooled soil at 4 hour intervals do not exceed 0.1% of the original mass.

Note. 1) For peats and soils containing organic matter a drying temperature of 600C is to be preferred to prevent oxidation of organic matter.

2) For soils containing gypsum a maximum drying temperature of 800C is preferred. The presence of gypsum can be confirmed by heating a small quantity of soil on a metal plate. Grains of gypsum will turn white within a few minutes, but most other mineral grains will remain unaltered.

d) The container is removed from the oven. For medium and coarse-grained soils, the lid should be replaced (if fitted) and the sample allowed to cool. For fine-grained soils, the container and lid, or bottle and stopper if used, should preferably be placed in a desiccator and allowed to cool. After cooling, the lids or stoppers should be replaced and the container plus dry soil weighed in grams (m3).

Moisture content, $W = \frac{\text{Mass of moisture}}{\text{Mass of dry soil}} X100(\%)$

$$W = \frac{(\text{Mass of container} + \text{wet soil}) - (\text{Mass of container} + \text{dry soil})}{(\text{Mass of container} + \text{dry soil}) - (\text{Mass of container})} X100(\%)$$

LO 2.4 – Correct refilling of materials on the worked area according to the standard

Refill materials the extracted hole

Methods of Compaction

- Manual
- Mechanical

Factors affecting compaction

- Mix proportion
- Water content
- Size of soil particles (The type of soil being compacted).
- The amount of compactive energy used

III. Learning Unit 3 – Make report

LO 3.1 – Elaborate working sheet

- Content/Topic 1 Contents of in Situ Density test working sheets:

➢ Title ➢ Project ➢ Lab no ➢ Date ➢ Location ➢ Client ➢ Company name ➢ Responsible technician ➢ Approver ➢ Checker	➢ Test method ➢ Depth ➢ Density in% of MDD ➢ Target MDD ➢ Target OMC ➢ DD ➢ Present MC Values ➢ Mean present MC ➢ Calculation of compaction %

TEST : FIELD COMPACTION TEST BY SAND REPLACEMENT METHOD
(IS : 2720 PART - 28)

Frequency of Tests	
Embankment	**1Tests / 1000m^2**
Subgrade	
Granular Sub Base	**1Test / 500m^2**

Permissible Limits	
Embankment	**Min. 95 %**
Subgrade	**Min. 97 %**
Granular Sub Base	**Min. 98 %**

Lab Ref No :________________ Date of Sampling :___________

Type of Material :________________ Date of Testing :___________

Location :Km_____________

Determination of Weight of Sand in Cone

S.No	Test No. :		1	2	3
a	Intial weight of container and sand	(gms)			
b	Final weight of container and sand after filling cone	(gms)			
c	Weight of sand in cone = (a) - (b)	(gms)			
	Average Value	(gms)			

Note : 1. Before test, remove from initially filled container a vplume of sand approximately equal to that of the calibrating cylinder.
2. Use density plate in each test.
3. Place container with cone on level ground / glass plate.

Determination of Bulk Density of Sand :

S.No	Test No. :		1	2	3
c	Weight of sand in cone	(gms)			
d	Weight of sand before pouring	(gms)			
e	Weight of sand after pouring	(gms)			
f	Weight of sand in calibration cylinder [(d) - (c) - (e)]	(gms)			
g	Volume of calibration cylinder	(cc)			
h	Bulk density of Sand (f) / (g)	(gms/cc)			
Average Value		**(gms / cc)**			

Remarks :____

Tested by :______________________ Checked by :______________ ______________

(For Contractor) (For Contractor) (For Engineer)

- Topic 2 Situ Density test working sheets

Calibration							
Mean mass of sand in cone (of pouring cylinder) (m2)	g						
Volume of calibrating container (V)	mL						
Mass of sand (+cylinder) before pouring (m1)	g						
Mean mass of sand (+cylinder) after pouring (m3)	g						
Mass of sand to fill calibrating container (m_s = m1 - m3 - m2)	g						
Bulk density of sand $\rho_a = m_s/V$	Mg/m^3						
Test Number							
Mass of wet soil from hole (m_w)	(g)						
Mass of sand (+cylinder) before pouring (m1)	(g)						
Mass of sand (+cylinder) after pouring (m4)	(g)						
Mass of sand in hole (mb = m1 - m4 - m2)	(g)						
Ratio mw/mb							
Bulk density $\rho = (m_w/mb) \times \rho_a$	(Mg/m^3)						
Moisture content container no.							
Moisture content (w)	(%)						
Dry density $\rho d = (100\rho)/(100 + w)$	(Mg/m^3)						

Remarks:---

Tested by -------------------- (For contractor)

Checked by ------------------ (For contractor)

---------------------- (For engineer)

LO 3.2 – Identify in situ density test report elements

- Topic 1 **In situ density test elements:**

  - Types of material and sample identification
  - Reference of this procedure
  - Wet density result
  - Moisture content result
  - Dry density result
  - Percentage of compaction

LO 3.3 – Calculate wet density and Dry density

- Topic 1 Methods of calculation of Dry density

- Manual calculation
- Using excel spreadsheet

1. Manual calculation

Wet density and Dry density are calculated by hand using related formulas

2. Using excel spreadsheet

Create a Microsoft Excel spreadsheet to analyse modified proctor test data and sand cone test data.

Model your spreadsheet after the spreadsheet posted on the class web site for the lecture example.

After you finish your spreadsheet, enter the HW #4 data into it, save it, and upload it as lastname_firstname.xlsm to SkyDrive (see SkyDrive directions in class Dropbox fold).

Your spreadsheet should:

- ✓ Indicate input cells (e.g. with a yellow background)
- ✓ Describe each parameter
- ✓ Show units for all numbers when appropriate
- ✓ Use Greek letters and subscripts for variable names
- ✓ Show all formulas

Include a plot of dry density and moisture content for the proctor test results. Plot the data as points (no lines) and fit a polynomial to the data (a3 x3 + a2 x2 + a1 x + a0).

Set up your spreadsheet to calculate the optimum moisture content and the maximum dry density "automatically". Example calculations are shown below

fit polynomial to ω vs γ_d data:			$\gamma_d = a_3 * \omega^3 + a_2 * \omega^2 + a_1 * \omega + a_0$			
			a_3	a_2	a_1	a_0
coefficients from LINEST function:			43857	-27287	4827.3	-145.245325
			=LINEST(γ_d, ω^{1,2,3})			
(highlight all four cells, type formula, press CTL-SHIFT-ENTER)						
set derivative of γ_d to zero and solve for ω using quadratic formula						
$d\gamma_d / d\omega = 3 * a_3 * \omega^2 + 2 * a_2 * \omega + a_1 = 0$						
(a = $3 * a_3$, b = $2 * a_2$, c = a_1)						
Polynomial Coef.			Quadratic Eqn. Coef.			
a_3	43857					
a_2	-27287		a	131570	= $3 * a_3$	
a_1	4827.3		b	-54575	= $2 * a_2$	
a_0	-145.25		c	4827	= a_1	
ω_{opt}	12.8%		= (-b + SQRT(b^2 - 4 * a * c)) / (2 * a)			
γ_{d_max}	117.6	pcf	= $a_3 * \omega_{opt}$^3 + $a_2 * \omega_{opt}$^2 + $a_1 * \omega_{opt} + a_0$			

- Content/Topic 2 Describe the final result

The ability to investigate and evaluate the dry density of any road project leads one to determine the state of the relative compaction which ultimately specifies compaction standards.

The project study has only dealt with the evaluation of the compaction standards of the under construction road project, which has immense potentiality to judge the condition of the road.

Basing on field tests and laboratory test results, the relative compaction tests were calculated. For relative compaction of more than 95%, the road will be usable for heavy vehicle, for 90~95 % road is for all other vehicle movement. For relative compaction of less than 90%, soils may be further compacted.

The decision of test will depends of the degree of compaction obtained compared to the required for the project.

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