LFE9 - Compliance testing earthworks on landfill sites using nuclear density gauges

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Contents

Introduction

The methods in this document are based on test methods set out in BS 1377, Part 9:1990. We have developed this document to clarify and standardise the methods used to calibrate nuclear density gauges, and to test and report on earthworks on landfill sites.

Nuclear density gauges (NDGs) are increasingly being used to carry compliance testing on mineral liners. This method of testing has several advantages over alternative in-situ density measuring methods, such as those in BS 1377 (sand replacement methods or core cutting testing). The major advantage of using NDGs is that they're quick, convenient and less invasive, the results are immediately available on site. Also, any material which fails can be reworked or removed immediately allowing construction to proceed with minimal disruption.

Many test laboratories that carry out NDG testing are UKAS accredited. The methods described in this document may not be compatible with their UKAS accreditation. You should discuss any proposed deviation from these methods before proceeding.

The detail in this document supports our general approach to landfill engineering which is detailed in our policy LFE1 – Our approach to landfill engineering.

Modes of testing

NDGs can be used to measure bulk density in one of several modes. These are outlined below.

Backscatter method

The backscatter method is non-destructive and you can perform it rapidly. Both the gamma source and the detector are contained within the body of the NDG. The radioactive source is never exposed when using the backscatter method. Gamma rays enter the mineral liner and are scattered back towards the detector, those rays that reach the detector are counted. The backscatter method is generally insensitive to density changes below 9cm, this limits its use to thin lifts of material of less than 100mm. We recommend the backscatter method primarily for use on asphaltic concrete. See Figure 1 for more detail.

Direct transmission method

The direct transmission method places the radioactive gamma source directly into the material being tested. The gamma rays are transmitted from the source directly through the test material to the detector, which is located in the body of the NDG.

If the test material has low density, a large amount of gamma rays will be received by the detector. Conversely, if the test material has high density, a lower number of gamma rays will be detected during the same time period. High density materials absorb gamma radiation, acting as a shield between the gamma source and the detector. See Figure 2 for more detail.

You can set a test depth to suit the depth of the compacted material you wish to test. Normally, you should set a test depth 50mm greater than the depth of the layer you're testing.

The direct transmission method is our preferred mode of testing the density of earthworks on landfill sites.

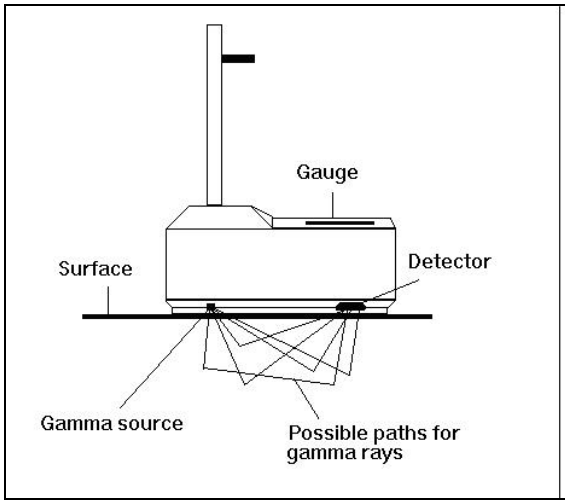

Figure 1. The backscatter method

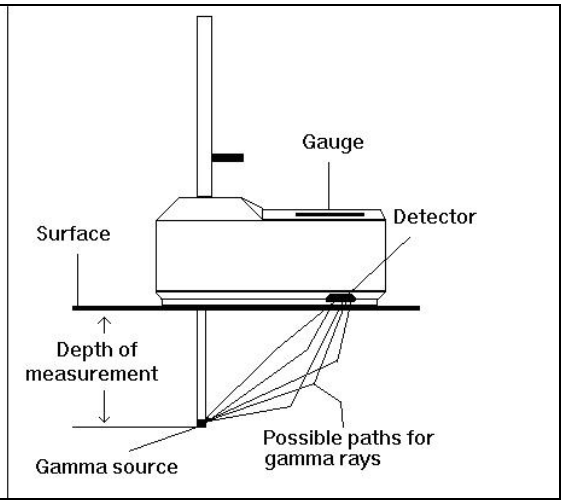

Figure 2. The direct transmission method

Moisture content measurement

The moisture measurement method is also non-destructive. The neutron source and detector are both located within the body of the NDG as in the backscatter method. Neutrons first enter the test material, thermalisation occurs after a series of collisions between neutrons and any hydrogen present in the test material. The detector in the NDG records the presence of any thermalised neutrons.

Because hydrogen can be present in earthworks in compounds other than water, it's essential you exercise caution when interpreting moisture content results. Unreliable and variable results commonly arise because of other sources of hydrogen being present in the test material. Soils containing significant amounts of organic matter, such as coal measures or colliery shales can cause erroneous moisture content readings. Unless you can express a high level of confidence in the NDG's calibration and its readings, you should send a disturbed sample from each test location to a laboratory for verification.

An uneven distribution of water throughout a test material can occur as a result of adverse weather and other factors. This uneven distribution of moisture can also cause unreliable readings from NDGs. Again, unless you're confident in the readings you should send a disturbed sample from each test location to be verified.

Calibration methods

NDGs provide convenient methods of obtaining density and moisture readings on site. However, as with other test equipment you must pay careful attention to their calibration to achieve reliable results. There are several methods of calibrating an NDG. Because the direct transmission method is preferable for landfill earthworks, only the calibration methods relevant to direct transmission NDGs are detailed below.

In-situ calibration

Carefully select a calibration area which allows a minimum of five test locations (as required in BS 1377). The calibration area you select should be representative of the site being tested. NDGs **must** be calibrated at least every three months if they're being used continuously.

There is an amount of scatter inherent with the in-situ method, therefore you must carry out a large enough number of tests to provide reliable data. Carry out the steps in the table below at each of the five (or more) test locations to complete the calibration.

Step	Action
1	Ensure each test location is level. (see Preparing the test area)
2	Prepare two holes (position 1 and 2) at each end of the NDGs levelling plate. Each hole must be the same as the actual depth to be tested. That is, the lift thickness plus 50mm.
3	Measure and record the density and moisture content at position 1.
4	Remove the gamma source from position 1. Rotate the gauge through 180˚, then insert the gamma source into position 2.
5	Measure and record the density and moisture content at position 2.
6	Calculate the average of your readings and record the result.
7	Repeat steps 2 - 6 for an additional two holes orientated at 90˚ to the first two. This allows you to verify the first reading by testing the same area using different test holes.
8	Use the results from your calibration checks to adjust the NDG as required.
9	Include the details of each calibration in your final validation report for the landfill site. You'll need to forward this report to us once construction is completed.

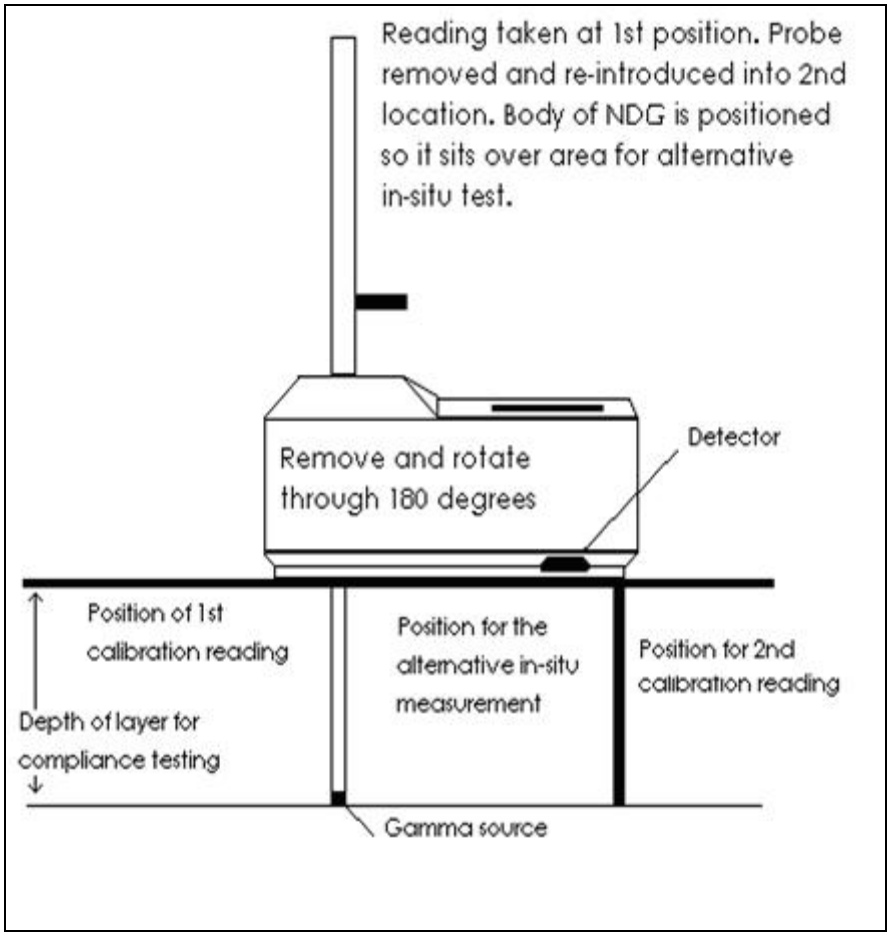

Figure 3. In-situ calibration method for NDGs

Container calibration

BS 1377 contains basic guidance on preparing a single container calibration for NDGs. Essentially, you should prepare a container at the lower compliance limit of bulk density plus or minus 2%. The material within the container must be sufficiently deep to accommodate a probe at the planned test depth. You should avoid creating a container with a density gradient, you can achieve this by frequently compact the materials in layers. Test laboratories often have an in-house method for preparing these containers, if such a method is used, you should send us a copy of the method for scrutiny.

We only expect you to state you used the container calibration method and the calibration results in your final validation report.

Site testing methods

There are several steps involved in compliance testing landfill earthworks. These are detailed below.

Preparing the test area

You must carry out all testing on a clean and level surface. This can be difficult to achieve under site conditions if a tamping roller has been used. Tamping rollers leave a pattern of indentations on the surface of the test material, you can however use a smooth roller to prepare the area for testing. The area must however be scarified once again before further material is added.

Alternatively, if a smooth roller isn't available, you can remove the surface of the test layer until you achieve a smooth level surface. Usually, contractors will scrape the area flat using a levelling plate or heavy plant equipped with blades. This is perfectly acceptable, but you must make sure that no more material is removed than needed. Removing too much material could encroach on the layers beneath the test layer.

The test area **must not** be tamped flat by repeated blows with the back of a shovel.

Preparing the spike holes

Using the NDG's levelling plate as a guide, drill a hole using a steel pin and hammer to accommodate the gamma source rod at each test location. The hole must be 50 mm deeper than the lift thickness being tested. Remove the steel pin by pulling straight up and twisting.

You **must not** release the steel pin by tapping it from side to side as this may distort the NDG's readings.

Positioning the probe

Insert the source rod into the hole to the required test depth. By gently moving the body of the NDG, position the source rod against the edge of the test hole nearest the NDG's body housing.

The NDG operator must exercise caution to always keep the NDG's body between them and the radioactive source. This will reduce the operator's exposure to ionising radiation during what is the highest-risk part of the test procedure. Anyone not directly involved in operating the NDG **must** be kept at a safe distance while testing is ongoing. The NDG's manufacturer's guidelines often offer further details on safely operating the equipment.

Taking the readings

Manufacturer's guidelines often advise a minimum test time, often it is one minute. Take at least three readings for both density and moisture at each test location. You can either arrange the three readings in a Y formation at 120˚ to each other, or at 90˚ to each other. If the three results differ by more than 5%, you should take a fourth reading at that location.

You **must** record and report all the results, not just the average value.

Confirmatory testing

NDG data is inherently liable to scattering. We've attached an example of an actual graph of test readings showing this inherent scatter as Appendix A. In Appendix A, the NDG bulk density readings are plotted against bulk density readings from an alternative core cutter test, the straight line shows the data's best-fit line.

As a result of the variability this example shows, you should carry out a confirmatory test by a means other than NDG as follows. One confirmatory test per five NDG tests, or one confirmatory test per day, whichever is greater. You confirmatory tests can take the form of a dry/bulk density and moisture content test at selected NDG test locations.

You **must** fully identify the location of both the confirmatory and NDG tests in your final validation report.

The test report

In addition to the standard information such as site name, test date, test location and so on, you must include the following additional information for NDG test reports.

Item	Detail
1	Model and serial number of NDG used.
2	Test method used – backscatter or direct transmission
3	Depth of compacted layer and test probe.
4	The in-situ bulk density of the test material, including all recorded measurements and their averages.
5	The moisture content of the test material, including all recorded measurements and their averages. Include the results of any alternative test methods you carried out.
6	The dry density of the test material
7	Details of your chosen calibration method.
8	Confirmatory testing data including reference to the NDG test locations they were carried out at.
9	Any failed test results, and details of the remedial work and retesting.

Safety

Obviously, anyone operating an NDG must be fully trained and authorised. NDGs must be stored, handled and operated in accordance with the manufacturer's instructions.

For safety reasons, NDGs must not be used during wet weather. If work has to continue, you must initiate an alternative testing method.

NDG manufacturers

There are three main manufacturers of NDGs. Their details are shown in the table below.

	Supplier	Supplier	Supplier
Contact details	Troxler NDGs Controls Testing Equipment Ltd. Control House, Icknield Way Tring Herts HP23 4JX Tel: 01442 828311 Fax: 01442 828466	CPN NDGs ELE International Ltd. Eastman Way Hemel Hempstead Herts HP2 7HB Tel: 01442 218355 Fax: 01442 252474	Humbolt NDGs Wykeham Farrance International Ltd. Weston Road Slough Berks SL1 4HW Tel: 01753 571251 Fax: 01753 811313

Appendix A – a comparison of density data gathered by NDG and the core cutter method