# NUCLEAR GAUGES & TMH1

# REPORT for RPF May 2010

**Prepared by Dave Wright and kindly presented by Tony Lewis**

# Nuclear Gauges

- **Dave Wright and Barry Dumas were asked by SANRAL as part of the TMH1 initiative to investigate the state of nuclear gauge usage and prepare a suite of test methods to provide improved control and hopefully reduced variation in test outcome.**
- **This work has included a major investigation of the performance of various makes of gauges on standard blocks and the reasons for significant differences in the use of more than one gauge.**

# Nuclear Gauges

- It was found that there are a number of calibration block sets in use and there is little or no correlation between sets across the country.
- To date calibration of gauges has been based on a limited number of counts and a tolerance of up to plus or minus 1% on each block.
- Only one organisation has insisted on an annual verification of gauges

# Nuclear Gauges

- The proposed new set of methods include:
  - correct procedures for storing, handling, usage and maintenance of gauges
  - the correlation of all calibration block sets against a set held by the CSIR
  - a tighter tolerance for the calibration of individual gauges
  - an annual certified verification procedure to ensure that a gauge remains in calibration
  - an annual maintenance check

# Nuclear Gauges

- It should be clearly understood that a nuclear gauge is not a ‘density meter’ and the results are affected by a number of factors. Thus a single ‘correct’ value at one position is not possible.
- Hopefully the new methods will reduce the variance between gauges.
- The gauge remains the most reliable density method available at this time.
- Tightened requirements for the calibration and verification of gauges will result in increased costs. These should be weighed against the reduction in disputes and delays.

# SOUTH AFRICAN NATIONAL STANDARD

## Civil engineering test method

## Part-NG1: The administration, handling, and maintenance of a nuclear density gauge

**Published by SABS Standards Division**
**1 Dr Lategan Road Groenkloof ✉ Private Bag X191 Pretoria 0001**
**Tel: +27 12 428 7911 Fax: +27 12 344 1568**
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# SOUTH AFRICAN NATIONAL STANDARD

## Civil engineering test method

## Part-NG2: The verification of standard calibration blocks for nuclear density gauges

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## Civil engineering test method

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# SOUTH AFRICAN NATIONAL STANDARD

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## Part-NG4: Verification of a nuclear density gauge

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# SOUTH AFRICAN NATIONAL STANDARD

## Civil engineering test method

## Part-NG5: The determination of in situ density using a nuclear density gauge

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# Nuclear Gauges

- The current situation with the methods is that they are in final draft.
- A correlation exercise by the Built Environment of CSIR of calibration block sets across the country is under way to establish a national standard.
- When this is complete (estimated June 2010) the suite of methods will be published in draft on the SANRAL website for use until SABS publication.
- A power presentation giving further details of the methods is available from the RPF secretariat.

# Annexure

# NUCLEAR GAUGES

## FURTHER DETAILS

## EXTRACTS FROM
## NUCLEAR GAUGE TEST METHODS

**Dave Wright** **May 2010**

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# NG1: The administration, handling, and maintenance of a nuclear density gauge

- **Introduction**
- The in situ density of road construction materials is only determined in civil engineering using indirect methods such as the nuclear density gauge and sand replacement methods. Nuclear density gauges in terms of the South African Hazardous Substances Act, 1973 are defined as Group IV hazardous substances. This standard sets out procedures that comply with the Act for administrating, handling and maintaining gauges and the requirements for verifying gauges.

# SOUTH AFRICAN NATIONAL STANDARD

## Civil engineering test method

## Part-NG2: The verification of standard calibration blocks for nuclear density gauges

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- **Introduction**

- The in situ density of road construction materials is only determined in civil engineering using indirect methods such as the nuclear density gauge and sand replacement methods. To achieve a consistent outcome from nuclear gauges it is required that they be calibrated using a set of standard calibration blocks. To ensure uniformity the calibration blocks are validated against a national reference set.

# • 5 Principles

- Verification of a set of standard blocks is carried out by comparing nuclear density gauge count and wet density readings on the set of standard calibration blocks with counts and wet density readings on a reference set of blocks held by the CSIR ranging from 1 500 kg/m3 to 2 700 kg/m3. The differences between the two sets of wet density readings are subtracted from the assigned densities for the reference set. The densest block consists of granite or aluminium, while the other composite blocks are made of alternating laminations of aluminium and polymer. The blocks are given assigned values because experience has shown that correlations based on measurements of solid material differ from those taken on voided materials (typical of materials as measured in the field).

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## Civil engineering test method

## Part-NG3: Calibration of a nuclear density gauge

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- **Introduction**

- The in situ density of road construction materials is only determined in civil engineering using indirect methods such as the nuclear density gauge and sand replacement methods. To achieve a consistent outcome from nuclear gauges it is required that they be calibrated using a set of standard calibration blocks.

- **Calibration is only required when verification as described in NG4 fails.**

NG3

- **5 Principles**

- Nuclear density gauges do not provide a direct reading of the density of a material. The gauge emits gamma radiation from a Cesium source in backscatter mode (indirect) or from a probe (direct) which passes through the material. The radiation having passed through the material is measured by detectors located in the base of the gauge and converted by a microprocessor using calibrated empirical algorithms into a wet density reading. Moisture readings are obtained by counting slowed neutrons emitted by a neutron radiation source in the gauge and measured by a detector in the base of the gauge.

The calibration process consists of taking a series of readings on the three calibration blocks. The gauge counts are translated into wet density and moisture content using empirical algorithms. The density algorithm contains three constants that can be adjusted for each gauge reading mode (backscatter, 50 mm depth and so on). The constants are calculated using a formula supplied by the gauge manufacturer, the average counts on the three calibration blocks, the standard reference block counts and the assigned wet density values for the blocks. Certain gauges contain an inbuilt adjustment for moisture and require an addition of 40 kg/m3 to the assigned value for the composite A calibration block (lowest density) and 20 kg/m3 for the composite B calibration block.

# SOUTH AFRICAN NATIONAL STANDARD

## Civil engineering test method

## Part-NG4: Verification of a nuclear density gauge

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- **Introduction**

- The in situ density of road construction materials is only determined in civil engineering using indirect methods such as the nuclear density gauge and sand replacement methods.  To achieve a consistent outcome from nuclear gauges it is required that they be calibrated using a set of standard calibration blocks.  To ensure that the nuclear gauge continues to function acceptably the gauge is verified on a regular basis against a standard set of calibration blocks.
- **The gauge is only recalibrated if it fails the verification procedure**.

- **5 Principles**

- The verification process consists of taking a series of readings in all the reading mode positions and depths on the three calibration blocks. The average wet density reading for each mode position is compared with the assigned value for the block. The outcome of the verification is determined by evaluating the important properties (*P*) obtained from the three operational modes: moisture content, backscatter and direct transmission.

- **5 Principles (continued)**

- For gauges used in road construction the backscatter, moisture content and asphalt modes are considered to be non-critical properties (see SANS 3001-NG5 section 5 Principles). As a result a gauge which indicates successful conformance in the direct probe mode but has non-conformances in the other modes may be issued with a verification certificate provided that the non-critical non-conformances are clearly noted.

NG4

- **6 Verification**

- **6.1 General**
- Gauges are **verified on an annual basis** after routine maintenance and the leak test have been carried out as described in SANS 3001-NG1, or after repairs when the performance of the gauge may have been affected. Nuclear density gauges fall in the category Group IV substances in terms of the Hazardous Substances Act. The use and handling of the gauges in the following procedure is to comply with the requirements of the Act and as described in SANS 3001-NG1.

- **7 Verification calculations**
- **Note these are quite complicated**

**7.2 Outlier check per set of readings (only one outlier per set can be rejected)**

**7.3 Assessment**

| | |
|---|---|
| **Variability** | Range of individual values |
| **Bias** | Difference from assigned block values |
| **Overall Assessment** | Gauge performance versus historical records |

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## Civil engineering test method

## Part-NG5: The determination of in situ density using a nuclear density gauge

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NG5

- **Introduction**
- The in situ density of gravels, sands and soils is only determined in civil engineering using indirect methods such as the nuclear gauge and sand replacement methods. As a result the values obtained are only approximations.
- The nuclear gauge counts gamma radiation detected at the surface where the source is either at the surface (backscatter), or at a known depth of up to 300 mm (direct transmission). The density of the material being tested is determined by comparing the radiation counts with previously established calibration data.
- A number of conditions may affect the measurements:

  a) the chemical composition of the material,

  b) in the backscatter mode the instrument is more sensitive to the density of the material close to the surface (spatial bias), and

  c) oversize rocks or voids in the source/detector path.

- **5 Principles**

- Testing on standard calibration blocks has shown that without moving the gauge, for a set of 10 by 1 min counts the resulting densities can vary over a range of up to 0,5 % of the block density. Further by switching the gauge off between sets of 10 by 1 min counts the average for each of the 10 sets can vary over a range of up to 0,4 % of the block density. As a result it is clear that an individual gauge reading can not be an exact statement of density. By using the 15 s count option on the gauge the ranges are doubled. A comparison between commonly available makes of gauges showed similar properties for each make.

- **5 Principles (continued)**

- **5.2 Field density tests**
- For all field density investigations it is recommended that the number and positioning of the tests should be based on a random sampling procedure and a minimum number of test positions depending on the size of the area to be tested. These procedures are usually described in the materials manuals of the roads authorities. It is recommended that notwithstanding the size of the area to be tested the number of tests should never be less than 4. Field density tests are only to be carried out with the probe in direct transmission mode, preferably located at a depth close to the full depth of the layer.

# 5.2 Field density tests (continued)

For compaction quality control only 1 min counts are to be taken and no 15 s counts are to be used. For more critical layer works such as base, and subbase on high volume roads, it is recommended that at each test position three 1 min counts should be taken and the average value reported as the field density.

NG5

## 5.3 Moisture contents

... recommended that moisture samples should be taken at each field density point and **gravimetric moisture contents** determined as described in SANS 3001-GR20. The gravimetric moisture contents are to be the reference method. For uniform homogeneous materials a correlation can be established between the nuclear gauge readings and the gravimetric moisture contents and where applicable a bias applied. This bias should be checked at regular intervals and may not be used for new materials until a correlation has been established..

- **5.4 Asphalt testing**
- Asphalt density tests are carried out either with thin layer gauges or conventional gauges with the probe in backscatter or AC mode (the probe located within the gauge). These readings are affected by the presence of hydrogen atoms (similar to the detection of water) and for thin layers of asphalt (50 mm or less) are influenced by the density of the underlying material. Significant variations in density can be experienced between readings taken while the asphalt is hot and when it is at ambient temperature.
- Nuclear gauge asphalt density readings should not be used for compaction quality control, which should be determined by tests on cores or blocks of compacted asphalt; and on very thin layers by indirect tests such as permeability.

# TMH1

- The first 13 methods in the new SANS 3001 format have been available since early 2009. These can be viewed on the SABS web store site.

- Currently a further 26 methods have been with SABS for anything from 6 to 23 months awaiting editing, public scrutiny, etc.

- Further funding has been made available by SANRAL to tackle approximately a further 20 methods.

# SPECIFICATIONS

Need to amend standard specifications to give precedence to SANS 3001 methods already published instead of TMH1 – superseded TMH1 Methods will have very little legal standing

For example: COLTO - Special Provisions

Section 8102 TESTING METHODS

Insert the following: "(a) South African National Standards, Series 3001 published by SABS"

Amend remaining subparagraph numbering (a) to (b), (b) to (c) and so on.

# PUBLISHED SANS 3001 Methods

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