SOME LONGSTANDING PROBLEMS IN GEOTECHNICAL LABORATORY TESTING OF PAVEMENT AND ROADBED MATERIALS

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ABSTRACT

In spite of most of our laboratory test methods having been used for over 70 years some of them remain problematic either in terms of the choice of the method and apparatus or its reproducibility, or both. Those methods discussed are road vs foundation indicators, their origin and when each should be used, the problem of accurately determining the mica and smectite contents of pavement materials, the necessity for using several test methods for aggregate durability and, in all cases, the necessity for using the same or comparable methods to those used to derive the specifications, especially for soluble salts and pH. The problem of stabilization durability is briefly discussed – is it still a problem or just the interpretation of the test results?

Keywords: Laboratory testing, Pavement, Roadbed, Materials.

1. INTRODUCTION

Some longstanding problems concerning the laboratory testing of pavement and roadbed materials are listed, briefly discussed, and possible solutions suggested.

2. INDICATOR TESTS – WHAT PI ARE YOU USING?

2.1 Problems

- Road and foundation indicator test methods differ and can yield different results (e.g. Netterberg & Van Coppenhagen, 2024).

- **Road indicators** are intended for rapid construction control of all disturbed and **reworked** soils but especially gravels and crushed stone; the following are applied:
  - therefore boiled, wet sieved and dried at 105ºC -110ºC (SANS GR1 is specified).
  - **not** just quick dry sieved (GR2).
  - TMH1 (NITRR, 1986) and SANS (SABS, 2008 onwards) LL device is **ASTM D423** type.

- **Foundation indicators** are intended to represent in-situ, undisturbed foundation and roadbed soils; the following are applied:
  - therefore air- dried at low temperature(max. 50ºC) or not at all.
  - Kantey & Brink (1952) and Van der Merwe (1964, 1976) used air drying, pulverization, dry sieving, **ASTM (**1966) D423 LL: device (unchanged between 1939 and 1968), flow curve LL, no presoaking (Netterberg, 2019).
  - Weston (1980) used air drying, pulverization, dry sieving, **BS** 1377-1975 LL device, presoaking, flow curve LL (NIRR, 1968).

- BS devices (both cup and cone) yield LLs and therefore **also** PIs 4 units higher than ASTM cup (Sampson & Netterberg, 1984).
- Poor reproducibility of tests (e.g. Sampson & Netterberg, 1985; Jacobsz & Day, 2008).

2.2 Possible Solutions

- Use test methods comparable to those used to derive the specifications!
- SANS GR5 air drying and wet preparation probably the closest to Kantey & Brink and Van der Merwe methods.
- Stott & Theron (2015, 2016) and others relooking at test methods.
- Use Cone Penetration Index (CPI) instead of PI and PL (Sampson & Netterberg, 1985) for better reproducibility.
- **State-of-the-art and TRH documents on roads on expansive clays needed**.

3. MICA – HOW TO DISTINGUISH 2% FROM 3% LIMIT?

3.1 Problems

- From Tubey (1961), Tubey & Webster (1978) and Tubey & Bulman (1984), possible limits are ≤ 10% by mass of fraction passing 420 µm (P420) and/or 3% of the whole material for untreated or cement - treated material.
- Weinert (1980) suggested as limit ≤10% coarse (>0,5 mm) **free** muscovite by volume.
- But how to determine it? As no simple and reliable test method could be found (Millard, 1993) TRL, NIRR and Zimbabwe just gave up!
- Weinert (1980) and TRH 14:1985: stated that if the mica is easily seen then related problems are likely to manifest, especially with muscovite.
- COLTO:1998 requires that there shall be **no** mica in G1 G2 and G3 materials (**and** also in asphalt aggregate).
- ASPASA (2010) EXCLUSION CLAUSES: Unrealistic; Members **shall not comply** with this.
- COTO:2020 requires ≤ 2% by mass of **free** mica in G1–G3 materials especially muscovite, when assessed by visually separating the particles, or ≤ 4% by volume when assessed by means of microscopic slides; and **no** visible free mica in other materials unless suitability confirmed by engineering tests:
  - **In whole material** (by default) or in which fraction?
  - Can't pick out **free** particles < 1 mm in diameter, **and how many particles must be picked out** (1 000 weigh < 1 g)?
  - Slide can only reliably indicate **total** mica particles seen on **area** basis, (flat or on edge); how many points to count? Probably 1 000 – 2 000!
  - Specification origin obscure, but 2% **seems** about right as **conservative** limit for C3 (Mshali & Visser, 2012, 2014), maybe also for G1–G3 materials.
  - But how to tell 2% from 3%?
  - **Sampling & Splitting** - How to make **< 1 gram** analysed representative of **tons**?
  - Powder XRD analysis uses ≤ 1 g **but** only the **upper 100 µm** or less**,** i.e. about **100 mg** is actually analysed!
  - Thin microscope section is size of small postage stamp - weighs only **50 mg**!

3.2 Possible Solutions

- Use the appropriate Rietveld quantitative XRD program for **total** mica according to rock type and stereo microscopic visual **estimation** of **free** mica in each particle size fraction:
  - However unpublished Rietveld analyses on split samples differed by several percentage points in the critical 1 - 5% range.
  - **and** difficult to distinguish illite from muscovite and muscovite from biotite at such low percentages - biotite also deleterious – several such mostly unpublished cases.
- The type of mica is best determined petrographically, although XRD and visual examination may be adequate.
- Take **many** samples, crush, split, recrush, resplit, mill, resplit, etc., **but cost?**
- Reduce PI and P075 x PI specifications by 33% when "significantly" micaceous (Mitchell et al, 1975); by 50% when "visibly" micaceous (Mitchell, 1982) as in Zimbabwe.
- Use mica content only as indicator and confirm suitability with engineering tests
- Refine specifications and methods, especially XRD and suitable engineering tests which use kilograms (kgs) not grams (gms), but which ones?
  - Measure rebound "swell**"** in compaction moulds?
  - Use K-mould for resilience, even for biotite (Paige-Green & Semmelink, 2002)
- Cement stabilize (Mitchell, 1982).
- **State- of- the- art review needed**.

4. SMECTITE – SIMILAR PROBLEMS

4.1 Problems

- 3 – 20% Smectite suggested for basic rock durability by various workers.
- COTO:2020 5% limit by spot counting &/or Rietveld XRD.
  - but cannot be quantified accurately enough (Council for Geoscience, unpublished; Leyland et al., 2014).
  - **and** additional work required to **confirm** smectite.
- Sodium hexametaphosphate dispersant coats and masks clay minerals in XRD analysis (Stephens & Dunlevy, 1990).
- Same problems of number of samples, splitting, small specimen size and cost.
- **In whole rock or in which particle size fraction?**

4.2 Possible Solutions

- Weinert (1964, 1980), COTO:2020 and others: point counting of secondary minerals
  - but can't reliably distinguish smectite (staining may help).
- Use XRD & petrography only as indicators.
- Use methods which use **kgs not gms** of sample e.g. Ten Percent Fines Value (TFV), durability mill, glycol soak.
- Methylene blue (New Zealand NZS4407) best for smectite and PI better than Rietveld XRD for total clay minerals.
- Crush and mill – how fine? – & use PI and methylene blue.
- Refinement of XRD method not feasible?
- **Smectite** is the correct term – montmorillonite is a type of smectite.
- **State-of-the-art review needed**.

5. AGGREGATE DURABILITY – AGAIN USE KILOGRAMS NOT GRAMS

5.1 Problem

- No single test adequate for all rock types.

5.2 Possible Solutions

- COTO:2020 requires **suite of tests** for basic rocks.
- Use mineralogy and petrography only as **indicators**.
- Use combination of XRD and XRF tests (Loubser & Verryn, 2018) – but cost?
- ACV (SANS AGIO) requires less material, better for higher strengths (< 30%).
- TFV (SANS AGIO) requires more material, better for lower strengths (< 100 kN) but good for all.
- Good correlation between them for dry ACV < 30% (Weinert, 1980) – don't then need to do both.
- Soaking in water or glycol may require **>** 1 day or 1 day under vacuum.
- ACV, TFV only test 9 – 13 mm fraction, i.e. **only 10% of grading.**
- Fine grinding and heating can affect clay minerals, leading to low results.
- Los Angeles test offers wider choice of gradings; use plus 2 mm as for laterite in Brazil (Paige-Green & Netterberg, 2025) with before and after PI.
- Durability Mill (SANS AG16) tests whole grading and before and after PI but lower energy.
- **State-of-the-art review needed**.

6. SOLUBLE SALTS & SULFIDE DAMAGE – ARE THEY STILL A PROBLEM?

6.1 Problems

- Over 150 cases known in southern Africa from 1957 to 2011 (Netterberg, 2011).
  - and about five in the last 10 years, including two recently.
- Such cases varied from cosmetic to court cases.

6.2 Possible Solutions

- State-of-the-art review.
- Education!

7. SALT AND SULFIDE TESTING – WHAT METHODS ARE YOU USING ?

7.1 Problems

- COLTO:1998 and TRH 13:1986 specify TMH1:1986 soil **paste** EC (A21) and pH (CA 21) for total soluble salts and pH and BS 1377 methods for water-and acid-soluble sulfates.
- **Not** SANS 6240 for EC, 5849 for total salts, 850 for sulfates and TMH1 A20 for pH.
- Such tests are extremely method-dependent – they give very different results!
- COTO:2020 **specifies** TMH 1 A21T paste EC, paste pH (but no method therefore SANS AG32 by default) and SANS 5840 for sulfates.
- **Sulfides** also a potential problem if pH < 6 and **total** sulfur > 0,1% (COTO: 2020).

7.2 Possible Solutions

- **Use the same methods used to derive the specifications**!
- As in COLTO:1998, TRH14:1985 and TRH13:1986 until new SANS methods.
- But do the new SANS methods AG30, AG31 and AG32 give the same results?
- Can only use XRD to identify solid salt (several percent usually needed).
- Use chemical analysis of saturation extract as in soil science to identify small amounts and quantify.
- **Sulfides** may be a problem regardless of pH and
  - can oxidise in pavement to cause ongoing damage for over 20 years (Netterberg, 2022a).
  - can also oxidise in sample bags in weeks to give misleading results.
  - quickest method is for total sulphur.
  - if visible then a potential problem.
  - treat with lime to pH of 10 or more.
- **State-of-the-art review needed**.

8. STABILIZATION DURABILITY

8.1 Problems

- Is it still a problem or just the interpretation of test results (eg. Netterberg, 1991)?
- Is it only carbonation?
- ICS (ICL / ICC) test – often no clear result with SANS GR 57 or other pH methods
- Only modification with too little stabilizer – not always permanent.
- Road lime may be highly plastic (Netterberg, 2004).

8.2 Possible Solutions

- Stabilization not always necessary (e.g. Netterberg & Pinard, 1991;2019; Netterberg & Elsmere 2015; Netterberg, 2022b, 2023).
- Avoid weak interlayers at all costs (Netterberg & De Beer, 2012).
- Wet / dry durability test SANS GR55 now compulsory in COTO:2020.
- Accelerated carbonated UCS / ITS & PI much quicker (De Wet & Taute, 1985).
- Add enough stabilizer but beware of cracking and pavement imbalance.
- Cure properly (Netterberg et al; 1987, Netterberg 1991; TRH13; COTO:2020).
- More correlations with durability tests and long-term performance needed.
- **ICS (ICL/ICC)** test precautions:
  - Do not oven-dry soil and use proposed, **fresh** stabilizer, **not** pure $Ca(OH)_2$.
  - Use suitable meter and spear-type high alkali electrode, not shrouded bulb-type, and **check electrode**.
  - Use pH 12 buffer not 10.
  - Check setup using saturated reagent grade $Ca(OH)_2$: e.g. pH 12,42 **at** 25ºC.
  - **Also** determine pH of neat soil, with 10% stabilizer and pure stabilizer as **controls and use stabilizer pH as desired end point**.
  - Measure pH in increasing order of stabilizer content; also at 24h, 7d, 28d (then not **I**CS but better indication of longer term requirement).
  - **Report** temperature of **paste –** depending on temperature may not even reach pH of 12.4.
  - Graph on linear not semilog scale.

  - First-class constant pH ICS test result: 3 point constant pH all ± 0,05; **and** ≥12,4 at 25ºC, **depending on stabilizer**.
  - COTO:2020 only requires that pH be constant within **0,1%**, with no minimum pH.
  - As a last resort use ASTM D6276 definition just at pH 12,4 or at lower "constant" pH, **but report it**.
  - Supplement ICS with PI afterwards.
  - **Zimbabwe STP 704 sucrose ICL test is simpler and yields a more definite answer**.
- Determine the PI of the proposed lime.
- **State-of-the-art review needed**.

9. CONCLUSIONS

- Problems with all these tests remain.
- Most can be overcome by following the correct method with additional precautions.
- However, some specifications and/ or test methods are unrealistic and better ones must be developed.
- Use petrography and mineralogy as indicators and engineering tests as definitive – but which?
- Use tests which require kilograms rather than grams or milligrams.
- State-of-the-art reviews needed on expansive clay, mica, smectite, aggregate durability, soluble salts, sulfides, and stabilization durability.

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