MICA – IS ITS PROBLEM REPUTATION DESERVED?

P PAIGE-GREEN[1] and D WESSELS[2]

[1]Dept. of Civil Engineering, Tshwane University of Technology, Pretoria, South Africa;
Tel: 082 444 1121; Email: paigegreenconsult@gmail.com
[2]RockSoil Consult (Pty) Ltd, Garsfontein, Pretoria; Tel: 082 467 0967;
Email: herman@rocksoilconsult.co.za

ABSTRACT

Mica in road building aggregates was first identified as a potential problem in the 1960s. Since then, numerous specification requirements minimising mica contents have been incorporated in aggregate specifications over the years, unfortunately becoming more severe with time. The current COTO (2020) requirements exclude many potentially useful materials, probably unnecessarily, due to an apparent misunderstanding of the mineralogical, identification and engineering properties and behaviour of micas in road layers. This paper considers the history of mica problems and specifications and makes recommendations regarding their testing and evaluation for road aggregates. A proposed test method for their assessment is suggested.

Keywords: Mica, muscovite, specification, roads.

1. INTRODUCTION

During the 1960s, potential compaction problems with materials containing significant quantities of mica were reported and researched (Tubey, 1961; Tubey and Bulman, 1964). Similar problems were suspected in South Africa (Weinert, 1980) which led to specific clauses relating to handling mica in local documentation and specifications. TRH 14 (1985) identified mica ("especially muscovite") as a deleterious material and this was carried through various local specifications and their updates.

The result has been that almost any material that is seen or suspected to contain "mica" is viewed as potentially problematic and unsuitable for use in roads. Much of this distrust can be traced to the few articles on micaceous soils that appeared in the literature (McCarthy and Leonard, 1963).

Work by a number of researchers in Sweden also assessed mica problems, mostly related to excessive water retention and frost damage (Kondelchuk, 2008; Kondelchuk and Miskovsky, 2009; Lagerblad, 2005; Loorents et al., 2007). This work did not differentiate between muscovite and biotite and made no mention of compaction difficulties.

This paper reviews the background and attempts to provide balance in addressing the "mica compaction problem".

2. TYPES OF MICA

Various types of mica occur in many rock types in South Africa. These are all phyllosilicates (flaky) and range from muscovite, biotite, phlogopite and lepidolite down to the finer clay-like hydromicas, sericites and illites, derived during chemical decomposition

of parent rocks. Only muscovite and biotite occur in sufficient quantities in most unweathered aggregate and muscovite in residual gravels to require special attention.

2.1 Muscovite

Muscovite (often referred to as white mica) is the most commonly found mica occurring in igneous rocks such as granite and pegmatite, metamorphic rocks such as schists and gneisses and sedimentary rocks such as sandstone and shale (more often as the fine grained variety sericite). It is essentially a hydrous potassium aluminium silicate. Large flat and shiny flakes may be found in coarse grained granites and particularly pegmatites, often greater than 25 mm. Muscovite is one of the most resistant minerals to weathering and alteration after quartz) and thus is common in weathered gravels and residual soils.

2.2 Biotite

Biotite is a much darker mica, but seldom occurs as crystals as large as muscovite. It contains more iron and magnesium than muscovite, but has a similar flaky nature. It occurs mostly in unweathered igneous and metamorphic rocks. It is less resistant to weathering and alteration than muscovite and is thus less common in residual gravels and soils, where it usually occurs as very fine particles.

2.3 Other Micas

Micas such as lepidolite (lithium rich) and phlogopite (magnesium with little or no iron) are generally less common than the previous two minerals but can also occur in large flakes and note should be taken of these when observed on site.

2.4 Hydro-Micas

There is still some debate regarding the identification and properties of these micas but essentially they are very fine grained muscovite like minerals occurring mostly in shales and residual and transported soils. Typically the potassium content is reduced compared with muscovite and the particle size is much smaller.

2.5 General

It is difficult to differentiate between any of the micas using traditional X-ray diffraction (XRD) methods, especially when interpretation is carried out using the Rietveld method. All of the micas and hydro-micas have a dominant XRD peak at about 10Å which is not affected by the normal XRD differentiation treatments (heat, glycolation, etc.). Close evaluation of the XRD outputs by experienced analysts can assist in separating the “hydro-micas” from the other mica types based on the intensity and shape of the XRD peaks, which is not generally considered in the Rietveld analysis software.

The following materials must always be checked for their muscovite contents (Weinert, 1980):

- Acid crystalline rocks: Weathered paragneiss, orthogneiss, granite, pegmatite.
- Arenaceous rocks: Weathered mica schist, micaceous sandstone.
- Argillaceous rocks: Weathered sericite schist, phyllite.
- Transported soils: Muscovite may occur in any of them.

3. ROAD BUILDING PROPERTIES OF MICA

Excessive mica in road materials may cause problems with compaction resulting in densities often less than 1 770 kg/m^3 (Weinert 1980). The flaky, soft but strong, elastic, resilient nature of the mica particles are thought to act as small leaf springs during compaction, bending around quartz or other solid soil particles, rather than breaking, and then springing back to their original shape once the compacting force is removed, resulting in a loss of density. In a compacted layer, This may be sufficiently rapid to be reflected as an inability to achieve compaction or may manifest itself later during service, causing rutting. The flat shape of larger flakes could also tend to increase the air voids content and affect close packing of particles (Clayton et al., 2004). The undesirable effects are aggravated by the tendency of the muscovite plates to arrange their longer crystal axes, i.e. those defining the prominent crystal planes, perpendicularly to the direction of effort (Weinert, 1980). This means that they all attain an approximately horizontal position in the compacted layer.

Other deleterious effects reported to be imparted by mica are that it:

- Reduces the apparent plasticity (i.e. that which is measured by the Atterberg limits), but increases the effective plasticity making materials weaker and more difficult to compact.
- Increases the Plastic Limit (PL) more rapidly than the Liquid Limit (LL) so that a negative Plasticity Index (PI) might be obtained at high mica contents. The linear shrinkage gives more consistent results and provides a convenient check on the properties of the soil fines, in conjunction with the plastic and liquid limit tests (Tubey and Bulman, 1964).
- Reduces the California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS).
- Increases the Optimum Moisture Content (OMC).
- Causes large density gradients in the CBR mould.
- Can cause surfacing failure due to “sponging” of the base.
- Can cause the maximum CBR to not coincide with the optimum moisture content or maximum dry density.

Work was carried out in Sweden on crushed granitic isotropic rocks (rocks with no plane of preferred fracture) and anisotropic rocks (those rocks displaying compositional layering (cleavage or foliation) that controls the aggregate breakage) (Loorents et al. 2007). They concluded that in isotropic rocks, “there is a general trend towards the enrichment of mica in the finer fraction of the fine grained rocks while for medium and coarse grained rocks, the amount of free mica generally peaks within the fraction 0,125-0., mm range. Work on the enrichment of free mica in anisotropic crushed rock aggregate supported these trends (Lagerblad, 2005).

This would indicate that crushing of most fresh rock types will produce fine mica particles, which should not give compaction problems. However, similar work should be carried out in South Africa, as the majority of micas in the Swedish samples were identified as biotite.

4. SPECIFICATION AND REQUIREMENTS

Tubey (1961) stated that weathered rock or soil which contains more than 10% mica, especially muscovite, and particularly if it is coarse, (>0,5 mm) should be avoided for use in any layer of a pavement. He also indicated that there was *no easy and satisfactory* method for the determination of the percentage of mica in soil and methods which produce

reasonable approximations are rather involved. He suggested the following rule of thumb: if mica can be detected at a glance in an engineering soil, the quantity of mica is likely to cause problems, especially if the mica is muscovite.

Weinert (1980) quoted Tubey (1961) with respect to limiting the mica content to a maximum of 10%, particularly if particles are >0,5 mm. Mitchell et al (1975) suggested that if materials are judged to be "very micaceous", the acceptable plasticity limits (?) should be reduced by 33%, besides meeting the strength specifications. No indication of the type of mica is provided.

Based on early recommendations by Weinert (1980), requirements related to mica were loosely introduced (CSRA, 1987; COLTO, 1997) in local specifications. A general statement for crushed stone (Clause 3602(a) in COLTO 1997) stated that aggregate "*shall not contain* any deleterious material such as weathered rock, clay, shale or *mica*". This statement would eliminate a large percentage of rock materials commonly used in South Africa.

The revised standard specification in South Africa (COTO, 2020) was considerably more detailed including under "definitions of deleterious materials" in Section A4.1.2 that:

"Mica, of which the most striking features are its platy structure and elasticity. In this respect muscovite, the "light" or "white" mica, is the most troublesome. The deleterious properties of mica only manifest themselves when the minerals are separated from the rock, that is when it occurs in a loose state in weathered rock, gravel or soil (also known as free mica). The springy action of free mica, especially muscovite, affects the compaction so that low densities and strengths are achieved. The mica plates may also prevent filling the voids in the material, resulting in a high void ratio and a high water demand. Biotite, the "dark" or "black" mica is not as elastic as muscovite and tends to break more easily into smaller pieces during construction. Fewer problems are experienced with biotite. Material derived from granite, gneiss, mica schist, phyllite and some sandstones usually contain mica."

As indicated, biotite is often included in deleterious micas, but has not been reported to give problems (Weinert, 1980). One case of biotite giving compaction problems has been reported (Paige-Green and Semmelink, 2002). Even in this case, the biotite, although visually resembling fresh biotite, had been weathered and altered and in fact was predominantly smectite (when X-rayed) and the particles were acting as compressible "balls".

COTO (2020) Section A4.1.5.17 (Deleterious minerals) also states in part (c) that:

"Crushed stone base aggregates shall not contain more than 2% by mass of free mica, especially muscovite, when assessed by visually separating the particles, or more than 4% by volume when assessed by means of microscopic slides. Other road pavement material that contains free mica that can be detected with the naked eye shall not be used, unless its durability (density reduction, CBR and/or ITS strengths and wet-dry durability) has been evaluated and the material has been recommended fit for use by an experienced engineering geologist or road materials specialist."

There is no simple test to determine mica content. A good rule of thumb is – if the mica can readily be seen with the naked eye (platy, shiny particles within the soil mass) then it is most likely to behave as described above. Work in Sweden used point counting of separated fractions between 0,125 and 1,0 mm and stereoscopic point counting of

mounted thin sections of various fractions finer than 1,0 mm down to 24μm (Loorents et al, 2007). This is, however, tedious and difficult work requiring significant equipment and experience.

5. DISCUSSION

Rocks containing mica make up a large proportion of exposed (and mined when mine waste is considered for use) material in South Africa. Generally, the current specification requirement is very stringent and will result in the unnecessary rejection of many materials.

It is very difficult (almost impossible) to visually separate 2% of free mica by mass and even identify the type of mica, bearing in mind that biotite is generally non-deleterious as stated in the COTO definition. Although this allows an opinion of an "experienced engineering geologist", there are very few engineering geologists in South Africa with adequate experience of this particular situation in road materials.

The requirement of not more than 4% mica by volume when assessed in microscope slides is equally difficult. Firstly it is assumed that most of this mica may be released during processing and service, which is usually unlikely. Secondly, assessment in a microscope slide is by area and not volume (the slide is only 30μm thick), which, depending on the way the slide is prepared could differ significantly.

More quantitative approaches may be adopted for detecting and measuring mica content. They include macroscopic examination to determine the lithology and X-Ray Diffraction analysis to determine the quantity of mica present in the different fractions of the sample.

A simple laboratory test that can be used is to compact the material into CBR moulds at the maximum dry density (or the proposed field density) and determine the density using the standard SANS 3001 methods. Without soaking the sample, the “CBR” swell characteristics are measured immediately after trimming the sample and then the “rebound” as regularly as possible over a 24 hour period and extended to 4-days. If mica affects the material there will be a rapid increase in volume and the potential for compaction problems exists. An increase in more than 1% over the first 24 hours is tentatively proposed as a maximum limit (there may also be some stress relief and natural rebound swell which should be considered). If the swell exceeds 1% the material should be avoided or corrective measures taken as discussed below.

Other methods for dealing with micaceous soils include:

- Avoid or remove the micaceous soil layer to below the material depth in the subgrade.
- Stabilise the micaceous soil with lime or cement with the qualification that, as a precaution, should mica be readily visible, then the soil should preferably not be stabilised (Ballantine and Rossouw, 1989; DoT, 1993). However, Weinert (1980) states that “it is always advisable to stabilize micaceous soils even if the spring action of muscovite platelets cannot be halted entirely. Cement will be used in most cases to increase strength sufficiently fast to reduce this spring action to some degree. In micaceous clays, lime should of course be used to reduce plasticity, although, because of the slower gain of strength, the density of the layer concerned may decrease slightly.” Tubey and Bulman (1964) found that satisfactory subbases may be obtained with small proportions of cement or lime and that certain micaceous soils may even be used for the bases of lightly trafficked roads.

- Tubey and Webster (1978) investigated micaceous China clay sands and noted that the quantity of mica normally present in such sands is not deleterious and suggests that many problems attributed in the past to mica are quite likely to have resulted from other causes, such as the overall particle-size distribution.

It has been established (Kondelchuk and Miskovsky, 2009) that the sand equivalent and Methylene blue adsorption tests were the most sensitive to mica presence. “Both methods showed susceptibility to mica content and gave strong correlation in terms of mica content”. These should perhaps be comprehensively researched in South Africa as possible methods for assessing and quantifying the presence of mica in aggregates and gravels.

Ballantine and Rossouw (1989) indicate that, if mica can be easily seen in a sample, it is likely to cause problems and should be stabilised. Mshali and Visser (2012) carried out an investigation into the effects on the unconfined compressive strength (UCS) of added mica (muscovite) to a weathered granite gravel. They concluded that an increased mica content steadily decreased the UCS. Less than 2% added muscovite had no. negative impact on the strength. Adequate UCS (>3 MPa) with less than 5% mica could be obtained with at least 4% cement. However, when the mica content exceeded 5%, the UCS decreased.

They also concluded that a UCS >1,5 MPa could be achieved with up to 10% mica with at least 4% cement. When the mica content exceeded 10%, even 6% cement could not produce adequate UCS values.

Mshali and Visser (2014) also noted:

An increase in mica content was also seen to decrease the compacted density (Mshali and Visser, 2014) with difficulty in achieving high compactions. They noted a steady trend of 0.5% decrease in compacted Mod AASHTO density for every 1% increase in free mica content. Similarly, an increase in mica content resulted in an increase in water absorption, which steadily increased with an increase in mica content. More than 10% mica content resulted in an increase in water absorption of the gravel material from 3% to greater than 10% by mass.

6. CONCLUSIONS

Based on the literature and local experience, the mica compaction problem is probably over-emphasised in South Africa, but should always be considered critically. It appears, however, that the current specifications are too strict and will eliminate many potentially useful materials that will not release sufficient muscovite of the necessary size to cause compaction problems, during crushing. There is also some debate over whether cement stabilisation is an effective solution or not.

A simple swell test after laboratory compaction is suggested to assess whether there is any compaction “rebound” due to excessive muscovite. The recommendation that micaceous soils can be improved with cement stabilisation appears to not always be successful, or economically viable.

It does appear that more research is required to actually define appropriate test methods and specifications for use in South Africa.

7. REFERENCES

Ballantine, RW & Rossouw, AJ. 1989. Stabilization of soils. PPC Lime Ltd.

Clayton, CD, Theron, M & Vermeulen, NJ. 2004. The effect of particle shape on the behaviour of gold tailings. *Proc Advances in Geotechnical Engineering*, 1:393-404.

Committee of Land Transportation Officials (COLTO).1997. Standard Specifications for Road and Bridge Works for State Road Authorities. SAICE, Johannesburg.

Committee of State Road Authorities. 1987. Standard specifications for road and bridge works. CSRA, Pretoria.

Committee of Transport Officials (COTO). 2020. Standard Specifications for Road and Bridge Works for South African Road Authorities. COTO, Pretoria.

Department of Transport. 1993. *Towards appropriate standards for rural roads – Discussion Document*- RR92/466/1, Department of Transport, Pretoria.

Kondelchuk, D. 2008. Studies of the free mica properties and its influence on the quality of road constructions. Licentiate Thesis, Luleå University of Technology, Sweden.

Kondelchuk. D & Miskovsky, K. 2009. Determination of the test methods sensitive to free mica content in aggregate fine fractions. *Journal of Materials Engineering and Performance,* 18(3):282-286. Doi: 10.1007/s11665-008-9293-6

Lagerblad, B. 2005. Krossat berg som ballast till Betong, Slutrapport. MinBas projekt nr 2,2 Framtida betong – Delprojekt 2,23 Utnyttjande av alternativa typer av ballast i betong. MinBas Område 2 Rapport 2:19, Stockholm, in Swedish.

Loorents, K-J, Johansson, E & Arvidsson, H. 2007. Free mica grains in crushed rock aggregates. Bulletin of Engineering Geology and the Environment. Online publication.

McCarthy, D & Leonard, RJ. 1963. Compaction and compression characteristics of micaceous fine sands and silts. Highway Research Record, 22, Highway Research Board, Washington, DC, pp 23-37. Available at:
https://onlinepubs.trb.org/Onlinepubs/hrr/1963/22/22-003.pdf

Mitchell, RL, van der Merwe, CP & Geel, HK. 1975. Standardised flexible pavement design for rural roads with light to medium traffic. Special Report, Salisbury (Harare), Rhodesia (Zimbabwe). Rhodesian Government Central Laboratory, Harare.

Mshali, MR & Visser, AT. 2012. Influence of mica on unconfined compressive strength of a cement treated weathered granite gravel, *Journal of the SAICE*, 54(2):71-77.

Mshali, MR & Visser, AT. 2014. Influence of mica on compactability and moisture content of cement–treated weathered granite gravel, Proceedings 33rd Southern African Transport Conference (SATC), Pretoria, pp 546-555.

Paige-Green, P & Semmelink, CJ. 2002. Road compaction problems related to the presence of biotite. Proceedings of 9th Cong. Int. Assoc. Engng Geol. Environ., Durban, pp. 2605-2610.

Technical Recommendations for Highways (TRH14). 1985. TRH14: Guidelines for road construction materials. Department of Transport, Pretoria.

Tubey, LW. 1961. A laboratory investigation to determine the effect of mica on the properties of soils and stabilized soils. RRL Research Note 4077, Road Research Laboratory (RRL). Crowthorne.

Tubey, LW & Bulman, JN. 1964. Micaceous soils: Methods of determining mica content and the use of routine tests in the evaluation of such soils. Australian Road Research Board Proceedings, Vol. 2, pp. 880-901

Tubey, LW & Webster, DC. 1978. The effects of mica on the roadmaking properties of materials. TRL Supp. Rpt. 408, Transport and Road Research Laboratory (TRRL), Wokingham, United Kingdom.

Weinert, H. 1980. The natural road construction materials of southern Africa. *H&R Academica*, 52-54:239-242.