INFLUENCE OF MICA ON COMPACTABILITY AND MOISTURE CONTENT OF CEMENT–TREATED WEATHERED GRANITE GRAVEL

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ABSTRACT

The occurrence of mica in soils is reported to significantly affect the engineering properties of materials including plasticity index and compacted density. The objective of this paper is to present the results of an investigation into the influence of mica on the compactability and moisture content of a cement treated weathered gravel material. Free mica (muscovite) was added in predetermined percentages by mass to neat granitic gravel (G5) and specimens subjected to a series of standard laboratory tests. The results show a steady decrease in compacted density and increase in water absorption of the cement treated gravel with increase in mica content greater than 2% mica content.

Key words; *mica, muscovite, compacted density, moisture content, cement treated gravel.*
*This paper is based on the first author's MSc research submitted to the University of Pretoria.

1 BACKGROUND

The road construction industry faces a shortage of naturally occurring gravel materials that meet the requirements of specified pavement layer quality. Utilisation of locally available pavement building materials of marginal quality by stabilisation to improve the engineering properties is in most cases supported from construction economics, social and environmental point of view. However, suitability of soil for stabilisation depends on factors such as grading characteristics, chemical and mineralogical composition as well as conditions under which they occur on site. Occurrence of free mica in gravel has been reported by several authors to influence the engineering properties.

Natural gravel materials vary in nature, composition and properties depending on their geological formation and weathering environment. The content of free mica minerals in gravel, particularly muscovite, is reported to significantly affect such engineering properties as plasticity index, compacted density and strength (Tubey and Bulman 1964; Stewart *et al* 1971; Weinert 1980; Balogun 1984, Gogo 1984 and Clayton *et al* 2004). This problem has been reported in several countries in Africa for example; Ghana, Nigeria (Gogo 1984; Gidigasu and Mate-korley 1980), Zimbabwe (Mitchell *et al* 1975), South Africa (Paige-Green and Semmelink 2002) where road projects traversed micaceous soils.

Mica is a phyllosilicate mineral with a common basic crystal structure, platy morphology and perfect basal cleavage (Fleet 2003). Micas are broadly classified as true micas that include minerals such as muscovite and brittle micas that include biotite. True micas are platy and highly elastic minerals that have been reported to influence the Atterberg limits, density and compactability of road building soils whereas biotite is known to have less effect on engineering properties of the soil (Weinert 1980). Micas occur in igneous rocks such as granite (contain 2-5%), sedimentary rocks and certain metamorphic rocks such as mica schist, gneisses and sandstones (Harvey 1982 and Dapples 1959).

2 AIM AND SCOPE OF THE PAPER

The objective of this paper is to present the results of an investigation into the compactability and moisture content of a cement treated weathered granite gravel material. After a literature review, the laboratory study on a single material with added mica is described and results presented. Finally the conclusions are presented.

3 INFLUENCE OF MICA ON SOIL PROPERTIES

Casagrande (1947) pointed out that micaceous soils have substantially greater liquid limit than a similar soil without the mica. Mitchell *et al* (1975) also reported that presence of mica reduced the apparent plasticity as measured in the Atterberg tests but increased the effective plasticity making the material weaker and difficult to compact. Weinert (1980) notes that mica affects soil properties such as liquid limits, plastic limits, density and compactability.

In a study on the influence of decomposed mica schist on compaction and strength of major soil groups in Ghana, Gogo (1984) found that presence of mica at about 13.5% contributed to the relatively low compaction densities and the high sensitivity to moisture changes.

Ballantine and Rossouw (1989) state that compaction problems associated with micaceous soils are due to the springy action and high water demand of the mica mineral. Tubey and Webster (1978) concluded, from their investigation on the effects of mica on physical properties of china clay sand as a road-making material, that the resilience of mica plates reduces the degree of compaction (compacted density) achievable for a given compaction effort by about 0.007 mg/m^3 and 0.12 mg/m^3 per one per cent of fine (<0.425 mm) and coarse mica, respectively.

A study of micaceous sandy silts by Tubey and Bulman (1964) showed that the relation between soil strength in terms of California Bearing Ratio (CBR) and equilibrium moisture content was relatively poor. CBR values of the micaceous soils at the same compaction effort but from different climatic environments affected the established correlation between CBR and pavement thickness. The soils are noted to be permeable and their field strength rapidly reduces by entry of water. Gogo (1984) notes that predicting CBR strengths of soil with mica content greater than 13% and at moisture contents greater than 15% could be quite difficult.

These findings have been incorporated into road building materials guidelines and specifications by percentage occurrence of free mica in parent gravel materials. For example, SANRAL (2004) recommends that crushed stone base aggregates containing mica, such as granite, mica schist, pegmatite and sandstone 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. Ballantine and Rossouw (1989), TRH 14, TRH13, and DoT (1993) state that if mica can be easily seen, the quantity of mica is likely to cause problems and the soil should preferably not be stabilised. Weinert (1980) suggests that soils containing more than 10% of mica, especially muscovite, should be avoided for use in pavement layers

Reports are available (Netterberg et al, 2011) that link failure of road and airport pavements to occurrence of mica but limited information exist that relate percentage by mass of mica cement content and field performance levels. A recent study by Mshali and Visser (2012) showed that free mica content in excess of 5% results in steady decrease in unconfined compressive strength of weathered granite gravel with further increase in mica content.

4 MATERIALS AND METHODS

This study used dry ground muscovite sourced from Phalaborwa mines, G5 weathered granite gravel (potentially problematic with less than 0.5% free mica content) from Midrand quarry, fresh CEM II/B-V 32.5R Portland fly ash cement from Pretoria Portland Cement (PPC) Ltd and tap water.

UCS is the main criterion for assessing suitability of the treated gravel material for use in base and subbase layers (TRH 14, 1986). Thus, two variables (mica and cement content) were considered to influence the engineering properties of the treated gravel and hence the use of a factorial design for the experiment was adopted.

Free mica was added to G5 gravel material in predetermined percentages of 0, 2, 5, 10 and 15% by mass so that subtle trends in effects of the mica content on the compactability and moisture content (absorption and retention) could be investigated. Figure 1 shows particle size distribution of free mica, neat gravel and the prepared specimens. Based on the Initial Consumption of Cement (ICC, 2% after one hour) of the gravel material 2, 4, 6 and 8% cement was added and then each specimen compacted to 100% Mod AASHTO density. Specimen preparation and testing were conducted in accordance with the standard methods of testing road constructions materials (TMH1, 1986).

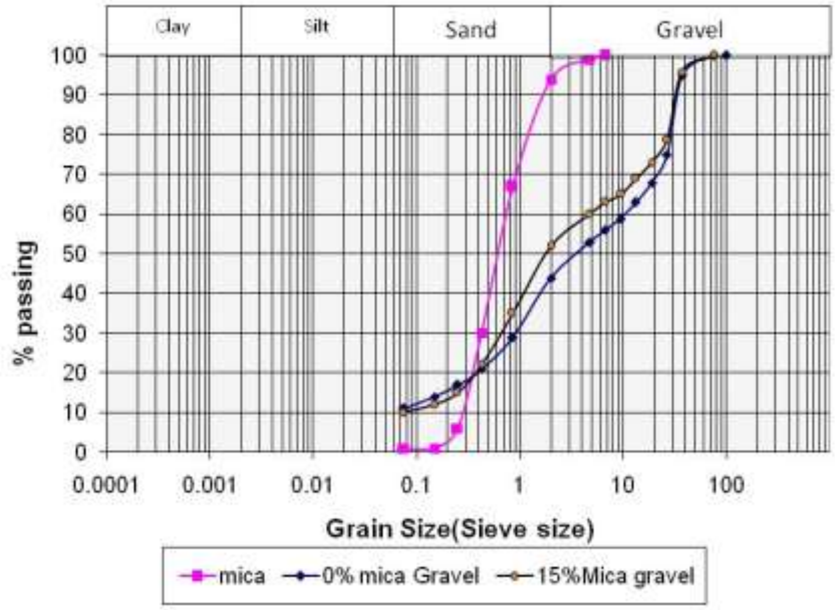

Figure 1 Particle size distribution of original samples and prepared specimens.

Table 1 shows the Atterberg limits and linear shrinkage for 0, 2 and 5% mica content gravel. Difficulties in determining reliable Atterberg limits for 10% and 15% mixes were noted and hence not recorded. Similar difficulties in replication of Atterberg limits results were also reported by Tubey and Bulman (1964) and Ruddock (1967).

Table 1 Atterberg limits and soil classification of prepared specimens

Specimen	Liquid limit	PI	Linear shrinkage	AASHTO classification
0% Mica - gravel	22	7	2.0	A-2-4
2% Mica-gravel	22	NP	2.5	A-2-4
5% Mica-gravel	22	NP	2.5	A-2-4

5 RESULTS AND DISCUSSIONS

Figure 2 gives selected Scanning Electron Microscope (SEM) images of gravel and mica samples. Gravel particles are noted to be cubical and with rough faces whereas mica particles are noted to be platy and with very smooth faces. Figures 3 and 4 show a SEM image of a compacted sample with high (15%) mica content and schematic presentations of the gravel particles and mica plates during compaction process. It is postulated in these figures that the platy mica particles restrain smaller gravel particles from filling the voids in the coarse gravel particle fabric. This could be one of the reasons for the difficulties reported by many in compacting high mica content gravels.

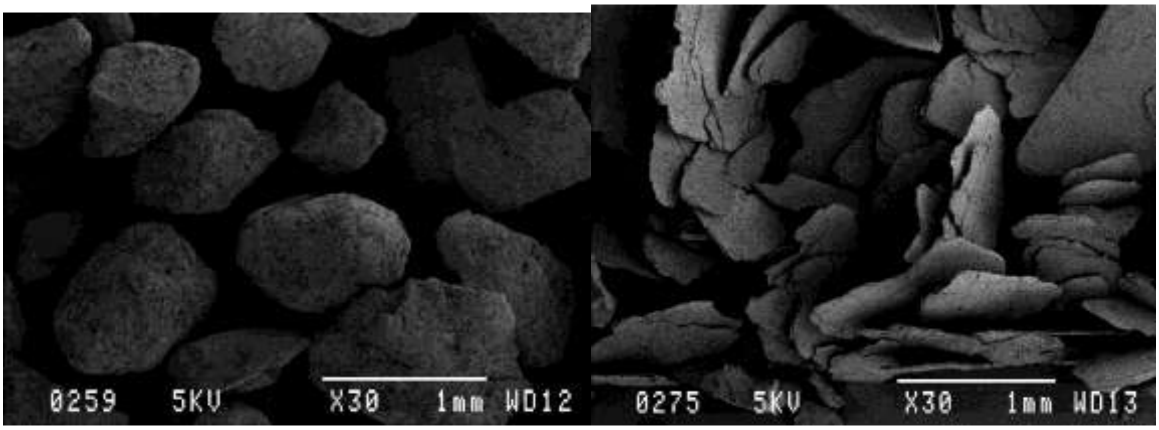

Figure 2 Scanning Electron Microscope images of + 0.425 mm and -2 mm neat gravel soil particles (left) and mica (Muscovite) particles (right).

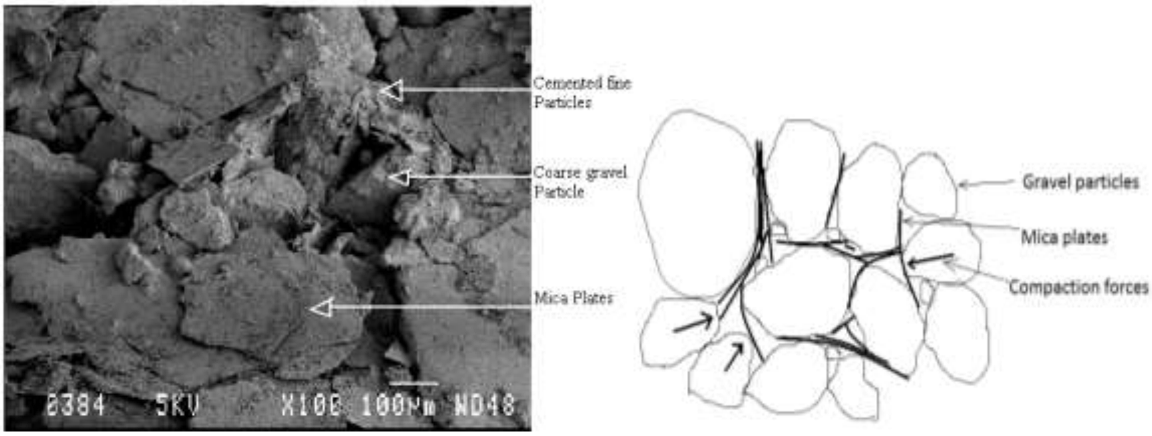

Figure 3 SEM image of 15% mica-gravel treated with 2 % cement and schematic figure of mica plates restraining soil grains from filling voids during compaction

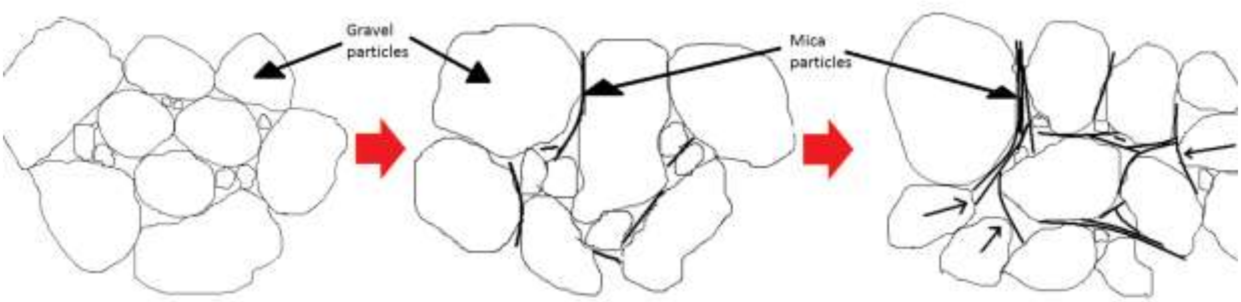

Figure 4 Schematic diagram of gravel soil structure with increase in mica content.

5.1 Relation between mica content and compacted density

Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were determined as 2154 kg/m^3 and 6.2% respectively. All compaction specimens were prepared using minus 19 mm gravel with greater gravel particles crushed and mixed in and compacted using Mod AASHTO compaction effort. Figure 5 shows that addition of 10% mica reduces compacted density by almost 5% from 2154 kg/m^3 to 2069kg/m^3 and increases OMC from 6.2% to 8.3%.

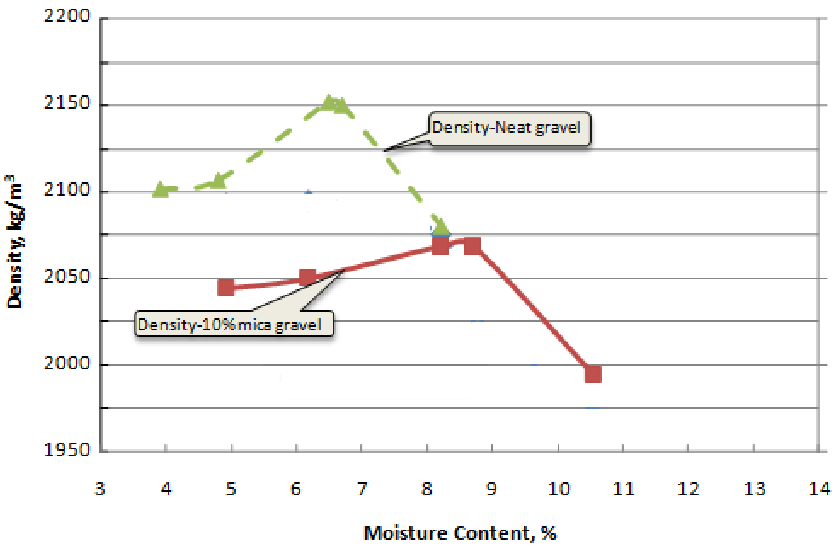

Figure 5 Density versus moisture content graphs for neat and 10% Mica gravel.

It is evident from Figure 6 that an increase in mica content results in a decrease in compaction percentage and density. It is interesting to note that the specific gravity of mica plates is about 2.8 and yet the compacted specimen show steady decrease in density with increase in mica content. The density of individual mica particles is compromised by the high void ratio in the compacted specimen and exacerbated by the difficulty to compact the material due to springy nature of the mica particles as mica content increases. The figure also shows that there is an average trend of 0.5% drop in compaction density for every 1% increase in free mica content. It can be argued therefore that this decrease in compaction density could be a contributing factor to poor soil strengths reported in high mica content soils.

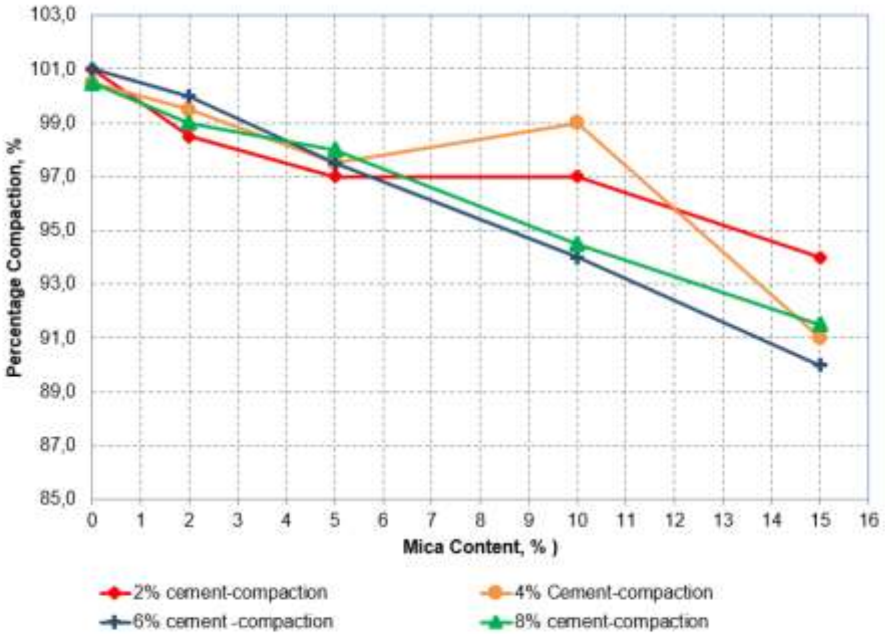

Figure 6 Relation between mica content and compaction percentage

5.2 Relation between mica content and water absorption percentage

Figure 7 shows the relation between mica content and water absorption percentage by mass of cement treated granite gravel specimens that were cured for 28 days and then soaked for 4 hours. Indications are that there is a steady increase in water absorption with increase in mica content. The figure indicates a trend of approximately 0.6% increase in absorption percentage for every 1% increase in free mica content.

As evident from SEM for specimen with more than 5% mica content by mass, free mica particles do not stack in flat face to flat face but rather randomly crisscross in the voids and between the larger granite soil particles. The flat surfaces of mica plates together with the crisscrossing packing in the gravel particles fabric results in increased void ratio and ability of the soil to absorb more water and reduce gravel particle interlocking and friction force at contact points. This explains to some extent why micaceous gravel materials retain high moisture contents and are susceptible to failure in wet conditions.

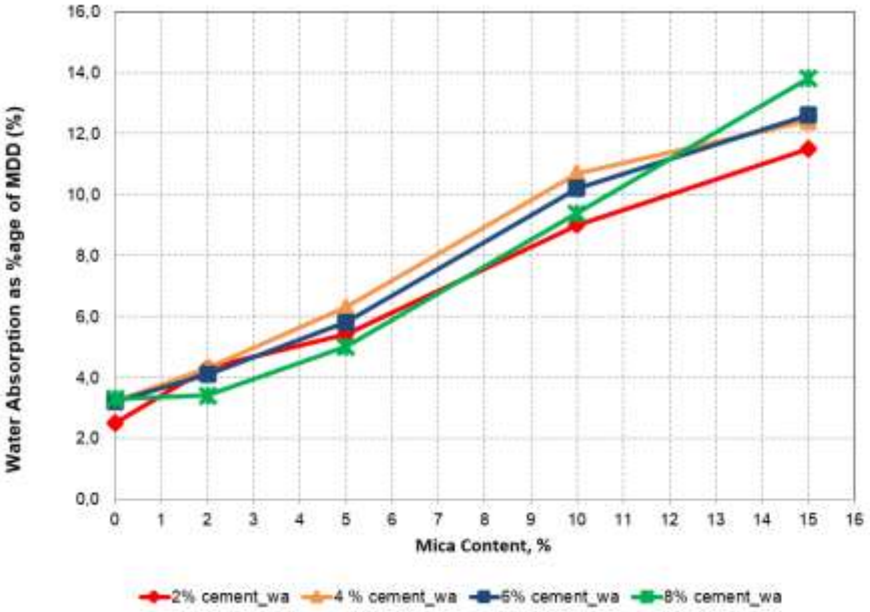

Figure 7 Mica content and water absorption percentage relation

6 CONCLUSIONS

The results and the discussions in this paper are limited to laboratory tests performed on the weathered granite gravel and added free mica. From the results, limited to the materials used, the following is concluded:

☐ An increase in mica content results in a decrease in compacted density

Difficulty in achieving high compaction was observed with an increase in mica content. A steady trend of 0.5% decrease in compacted Mod AASHTO density is noted for every 1% increase in free mica content.

☐ An increase in mica content results in an increase in water absorption

Water absorption steadily increases with an increase in mica content regardless of cement stabilization. More than 10% mica content results in an increase in water absorption of the gravel material from 3% to greater than 10% by mass.

These results show that great care needs to be taken when using gravel containing mica. The higher the mica content the poorer the material quality. Current guidelines such as SANRAL (2004), Ballantine and Rossouw (1989), TRH 14, TRH13, and DoT (1993) thus appear to be reasonable to prevent unexpected failures of cement stabilised gravel containing mica.

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REFERENCES

Ballantine, R.W. and Rossouw, A.J. 1989. Stabilization of soils, PPC Lime Ltd, Pretoria, pp. 25-27, pp. 42-51.

Balogun, L.A. 1984. Influence of geological origin on the geotechnical properties of lime-stabilized laterates. Soil Mechanics & Foundation Engineering Eighth Regional Conference for Africa Vol. 1, A.A. Balkema public, Netherlands.

Casagrande, A. 1947. Classification and identification of soils, Proceedings of American Society of Civil Engineers, pp. 783-810.

Clayton, C.R.I., Theron, M. and Vermeulen, N.J., 2004. The effect of particle shape on the behaviour of gold tailings. Proc. 'Advances in Geotechnical Engineering - The Skempton Memorial Conference' (ed. Jardine, R.J., Potts, D.M. and Higgins, K.G.), 1, 393-404.

Dapples, E.C. 1959. Basic geology for science and engineering, New York, John Wiley & sons Inc. Pp. 52-62.

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

Fleet, M.E. 2003. Rock-Forming Minerals Volume 3A; Micas, The Geological Society, 2nd Edition. pp. 1-40, 178-180, 512-515.

Gidigasu, M.D. and Mate-korley, E.N. 1980. Highway geotechnical characterisation of residual micaceous soils over granite. 7th Regional Conference for Africa on Soil Mechanics and Foundation Engineering; Accra, pp. 831-844.

Gogo, J.O. 1984. Compaction and strength characteristics of decomposed mica schist. Proceedings of Eighth Regional conference for Africa on Soil Mechanics and Foundation Engineering, Harare.

Harvey, J.C. 1982. Geology for Geotechnical Engineers. Cambridge University Press, pp. 19-21.

Mitchell, R.L., Van der Merwe, C.P. and Geel, H.K. 1975. Standardised flexible pavement design for rural roads with light to medium traffic. Special Report – Rhod. Govt Central Laboratory, Salisbury.

Mshali, M.R. and Visser, A.T. 2012. Influence of mica on unconfined compressive strength of a cement treated weathered granite gravel, Journal of the SAICE, Volume 54 No 2, pp. 71-77.

Netterberg, F. Hefer, A.W. and Du Preez, H. 2011. Cracking and staining of an airport. Proc 10th Conf. on Asphalt Pavements for Southern Africa, Drakensberg, paper 1037.

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

Ruddock, E.C. 1967. Residual soils of the Kumasi district in Ghana soils. British Road Research Laboratory (UK), Overseas Bulletin No.8, pp. 24.

SANRAL. 2004. Project specifications, SANRAL Version 2004/2005, Pretoria.

Stewart, R.L., Fletcher, O.S. and Chu, T.Y. 1971. Stabilization of Piedmont (Micaceous) soils for use as base material on secondary road projects. Highway Research Record, No. 351, pp. 21-34.

Technical Methods of Highways (TMH1). 1986. Standard methods of testing Road Construction Materials, NITRR-CSIR, Pretoria

Technical Recommendations for Highways (TRH13). 1986. TRH13: Cementitious stabilizers in road construction. NITRR, Pretoria.

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

Tubey, L.W. and Bulman, J.N. 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, L.W. and Webster, D.C. 1978. The effects of mica on the roadmaking properties of materials. Transp. Road Res. Lab. Suppl. Rep 408, Crowthorne, pp. 22.

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