Lime: A convenient chemical material utilised for more than one purpose

P.H. Bhengu[1], D. Allopi[2]*

Dept. of Civil Engineering, Durban University of Technology[1,2]

P.O Box, 1334, Durban 4000 South Africa

Author 1-Tel: 031 819 9333; Email: bhenguph@yahoo.com.sg

Author 2-Tel: 031-373 2310; Email: allopid@dut.ac.za

Abstract: Lime is a chemical stabilisation agent utilised widely for soils stabilisation particularly for roads construction throughout the world. It has other relevant uses such as that relating to environmental and steel manufacturing to mention a few, hence qualifying it to be perceived as a convenient material. The paper summarises available pure literature and information pertaining to lime, as one of the most preferred chemical agent for diverse uses. The paper sets out and illustrate the relevant literatures of previous and recent works relating to the usage of lime. The literature review presented here is taken from the existing knowledge base, and includes substantive findings as well as theoretical and methodological contributions made relating to this subject. It is literature from a number of scientific and engineering fields, including soils mechanics, geology, mineralogy, soils physics, soils chemistry etc., with presentation of it published and translated in English language. It is hoped that this literature review will serve both to guide and to stimulate further investigations relating to the concept of lime usage in general.

Key Words: Lime, soil stabilisation.

Introduction

Literature Review

Lime is a material that is reactive in the presence of moisture and is created from limestone. Lime, as referred to in this paper, comes in many configurations and different authors define it in different ways depending on the requirements and intended final use (Addy, Green and Herron, 2004; National Lime Association, 2004; Thompson, 2005; Orts *et al.*, 2007; Schwab, Murdock and Ditsch, 2007; Akbulut and Arasan, 2010; Hall, Najim and Dehdezi, 2012; US Department of the interior: Geological survey, 2012; Roohbakhshan and Kalantari, 2014).

Corresponding Author: Mr P.H Bhengu, Department of Civil Engineering & Surveying, Durban University of Technology, Durban
P.O Box, 1334, Durban 4000 South Africa, Cell: 0793410391, E-mail address: bhengupk@gmail.com

The derivation of many final forms of lime is very complex and requires that high purity limestone be used during the production of lime for different uses. Processes such as mining, crushing, screening, burning, and milling of rocks (limestone), have relevance to lime production operations with the common final product(s) emanating from the production process being mainly lime, either in a form of hydrated lime, quicklime or lime slurry (calcium hydroxide), slaked/high calcium/putty/air/fat or non-hydraulic lime. This lime is produced by slaking fresh quicklime in an excess of water, hydrated or bag lime, natural hydraulic lime (NHL), hydraulic lime (HL), formulated lime (FL), natural/roman cement, pozzolans as aforementioned.

The composition of the rocks (limestone) mentioned above entail approximately fifty percent of carbonate minerals, with calcite or dolomite (calcium-magnesium carbonate - $CaMg(CO3)2$- being the general minerals. During the transforming process of limestone to lime follows a carefully planned and well controlled process which follows four basic sub minimum processes, namely quarrying and mining, stone preparation, calcining and hydration (Little, 1995). During the manufacturing process heating limestone at elevated temperatures produces quicklime. The latter is illustrated by the below chemical equation (Eq. 1) specifying that, limestone is heated to produce quicklime with carbon dioxide produced as a by-product (Canada, 2004; International finance Corporation, 2007; Kuenen, 2009; European commission: Directorate-general joint research centre, 2010; Stork *et al.*, 2014).

$CaCO_3 + Heat \rightarrow CaO + CO_2$ 1

Milburn and Parsons (2004) states that the formation follows a hydration process which transforms quicklime to hydrated lime. The above indicates when water is added to quicklime, hydrated lime is produced with the creation of heat as a by-product (Eq. 2).

$CaO + H_2O \rightarrow Ca(OH)_2 + Heat$ 2

Various forms of lime are used in environmental, metallurgical, construction, and chemical/industrial applications, and more. The continuous growing utilisation of lime places it as a chemical material useful for more than one purpose. The latter is explained and justified in detail in the following subsections having relevance to lime as a reliable/time tested material, present soil stabilising material, adaptable material, construction soil stabilizing material, affordable material, an easy accessible material.

Corresponding Author: Mr P.H Bhengu, Department of Civil Engineering & Surveying, Durban University of Technology, Durban
P.O Box, 1334, Durban 4000 South Africa, Cell: 0793410391, E-mail address: bhengupk@gmail.com

Lime: A reliable and time tested material

Lime is a reliable and time tested material. It has been utilised in the ancient Egypt, Greek & Roman, with first experimental work on sand/clay achieved in the United States of America around 1906. In the 20th century, lime for soil stabilisation was adopted in Europe. It is now spread across the globe with lime-soil stabilization relevant to road construction and dominant in South Africa. The concept of soils stabilization dates back 5000 years ago. McDowell (1959) reported that stabilized earth roads were utilised in ancient Mesopotamia and Egypt, and that the Greek and the Romans utilised lime-soils mixtures to improve the strength of soils (Liu, Pemberton and Indraratna, 2010). Kézdi (1979) mentioned that the first experiments on soils stabilization were achieved in the United States of America (USA) with sand/clay mixtures around 1906 being the material under review. In the 20th century, especially in the thirties, soils stabilization relevant to road construction was applied in Europe. In Germany, it has been reported that the utilisation of lime or cement for the stabilization of pavement bases was investigated and developed into practical construction procedures (Otoko, 2014). In South Africa, Douglas (1969) states that the history of lime industry was largely that of many uses, with the then main applications being on of gold , uranium, iron, steel , ferrochrome, water treatment, agriculture and building to mention a few.

In Southern African context-Phil Paige-Green and other, authors have published extensively about lime, particularly for lime-soil stabilisation, relevant to Southern African lime stabilization context, these include the following but not limited to; Durability of stabilised materials (P. Paige-Green, 2008); Stabilisation problems (Netterberg and Green, 1984; Bagoniza *et al.*, 1987; Green, Netterberg and Sampson, 1990; Gourley and Greening, 1999a; Gourley and Greening, 1999b; Green, 2008; Jawad *et al.*, 2014).

Lime: A present soil stabilising material

Majority of projects, particularly (road pavements) are still utilising lime to strengthen soil properties. The soil related in this document defines the material consisting of rock particles, sand, silt and clay and is formed by the gradual disintegration or decomposition of rocks due to natural process.

Corresponding Author: Mr P.H Bhengu, Department of Civil Engineering & Surveying, Durban University of Technology, Durban
P.O Box, 1334, Durban 4000 South Africa, Cell: 0793410391, E-mail address: bhengupk@gmail.com

With traffic and heavy-duty transport loads increasing in many parts of the country due to increases in population, road pavement layers are having difficulty in coping with increasingly heavy tonnages and most now exhibit damage in their lower layers, hence the necessity of improving the soil properties arises, with onus being primarily on relevant road authorities such as the South African National Roads Agency's (SANRAL).

The South African National Roads Agency's (SANRAL) prime mandate is to finance, improve, manage and maintain the national road networks, with other roads maintained and managed by provincial or local authorities. From an engineering standpoint, it is desirable to build upon a foundation of ideal and consistent density (the measure of weight by volume of a material (Vitton, 2006) soils, soils with improved engineering properties (i.e. soil stabilisation), hence the soil binders particularly lime takes a central part in archiving the above mentioned.

Lime: An adaptable material

Lime has to be adaptable to cope with different ability levels. Cambridge Dictionary (2017) defines the word adaptable as an act of being able to change easily from one activity to another or able to be used for many different purposes. Lime is no exception to the aforementioned. Over time, it has been documented and proven that lime is an adaptable mineral with various forms of it used in environmental, metallurgical, construction, chemical/industrial applications and more (Addy, Green and Herron, 2004; Thompson, 2005; Orts *et al.*, 2007; Akbulut and Arasan, 2010; US Department of the interior: Geological survey, 2012; Roohbakhshan and Kalantari, 2014). The usage of lime to address environmental problems is one among other and the fastest growing market with key uses in areas of pollution prevention and abatement, including treatment of air emissions, treatment of both drinking water and wastewaters and remediation of hazardous waste to mention a few.

In metallurgical processes relating to the treatment of aqueous solutions containing heavy metals such as lead, cadmium, zinc, copper etc, the usage of lime plays a crucial role in the sequence of metallurgical reactions. Construction wise, lime is perceived as an aid in the modification and stabilization of soil beneath road surface and similar construction projects with effective utilization of it aimed at substantially enhancing the stability, impermeability, and load-bearing capacity.

Corresponding Author: Mr P.H Bhengu, Department of Civil Engineering & Surveying, Durban University of Technology, Durban
P.O Box, 1334, Durban 4000 South Africa, Cell: 0793410391, E-mail address: bhengupk@gmail.com

Lime: A construction soil stabilizing material

Properties (physical and chemical) of soil need to be improved, particularly the physical properties. According to Ogundalu and Oyekan (2014), the physical properties (also known as geotechnical properties of soil) may range from index properties (Atterberg limits) to strength properties. The aforementioned properties need to be improved or modified in order to enable them to withstand standard and severe loading imposed in the short and long run through the usage of necessary binders such as lime.

In South Africa, the stabilisation of highways and other pavement layers using lime on natural occurring soils is very widely an adopted process. It is used extensively for road pavement layers (base course) and building platforms with diverse recommendations and standards for highway series particularly as per TRH13: Cementitious Stabilisers in Road Construction (Department of Transport: TRH13, 1986), the TRH14: Guidelines for Road Construction Materials (Department of Transport:TRH14, 1996), with its application of them in the catalogue designs listed in the TRH4: Structural Design of flexible Pavements for interurban and Rural Roads and other. This improves the long term performance of any pavement structure, as it can significantly be impacted on by the underlying soil layers if not properly strengthened. The impact emanate from the underlying layers of the soil alone not being able to support the required to achieve the acceptable performance due to a number of impacts, ranging from expansiveness of the soil, rainfall effects to lower carrying capacity (Krishna, Padmavathi and Kumar, 2013).

Lime: An economical material

Lime is one material which makes in-place material usable, thus eliminating the costs to remove and dispose. South Africa is particularly fortunate to be naturally endowed with significant reserves of limestone that are ideal for the production of high quality industrial lime. With access to superior lime raw material across the country, South Africa is able to produce, market and deliver high quality industrial lime products at affordable prices, country-wide.

Lime: An easy accessible material

In a comprehensive market report by Group (2016) which provides the in-depth assessment and outlook for world market of lime, particularly quicklime, slacked lime

Corresponding Author: Mr P.H Bhengu, Department of Civil Engineering & Surveying, Durban University of Technology, Durban
P.O Box, 1334, Durban 4000 South Africa, Cell: 0793410391, E-mail address: bhengupk@gmail.com

and hydrated lime, the accessibility of lime is being observed. The report was developed through an extensive set of interviews with key industry stakeholders in main markets (including United States of America, Mexico, Brazil, Europe, Africa, India, Russia, China, Australia, Middle East) and companies (including major global lime manufacturers, equipment suppliers, traders, analysts, production engineers, industrial lime users and association members) with major world lime manufacturers such as Carmeuse, Graymont, Grupo Calidra, Fels Werke, Lhoist, Nordkalk, Shandong CITIC, ShreeRam Lime and United States Minerals. Additionally, local champions are highlighted in each study of the major markets, including Australia (Adelaide Brighton), Brazil (ICAL), Germany (Schaefer Kalk), India (Tata Steel), Italy (Unicalce, Saced), Japan (Ashidachi Lime), Russia (Novolipetsk Steel, Bashkir Soda), South Korea (Jeongseon Lime), South Africa (PPC Lime, Idwala), Turkey (NUR Kireç, KIMTAS), UAE (Al Noora, Emirates Lime Factory), US (Mississippi Lime, US Mississippi Lime).

Larfage Industries South Africa (2012) states various innovative 'green' soil stabilization products in relation to lime to have been formulated, particularly for soil stabilization of road pavement layers and other. According to this report, these products have environmentally friendly formulations that utilise less none renewable materials, create less greenhouse gas in their process of manufacture and reduce landfill sites.

Conclusion

Literature review on lime-soil stabilization has been explored. The paper summarises available literature and information pertaining to the lime, as one of the most preferred chemical agent for diverse uses. The paper further sets out and illustrate the relevant literatures of previous and recent works relating to the usage of lime. it can therefore be concluded from the literature review that lime is a an all-time chemical material, with its relevancy primarily and largely related on lime being a time tested material, a modern soil stabilising material, a versatile material, a construction soil stabilizing material, an affordable material and an easy available material. It can therefore be concluded from the literature review that lime is suitable, agreeable to the needs or purpose it is intended for, well-suited with respect to ease in use, favourable, easy, and comfortable for use.

Corresponding Author: Mr P.H Bhengu, Department of Civil Engineering & Surveying, Durban University of Technology, Durban
P.O Box, 1334, Durban 4000 South Africa, Cell: 0793410391, E-mail address: bhengupk@gmail.com

However, it therefore remains to be seen through future studies about further developments of lime in relation to the ever changing global and local societal demands in general.

Reference

Addy, K., Green, L. and Herron, E. 2004. *pH and Alkalinity*. Island: University of Rhode Island.

Akbulut, S. and Arasan, S. 2010. The variations of cation exchange capacity, ph, and zeta potential in expansive soils treated by additives. *International journal of civil and structural engineering* 1(2): 139-154.

Bagoniza, S., Peete, J. M., Freer-Hewish, R. and Newill, D. 1987. *Carbonation of stabilised mixtures*. United Kinkdom Overseas centre; Transport research laboratory, Crowthorme Berkshire.

Cambridge Dictionary. 2017.

Canada, G. G. D. E. 2004. *Lime production: Guidance manual for estimating greenhouse gas emissions*. Canada: Greenhouse Gas Division :Environment Canada.

Department of Transport: TRH13. 1986. *TRH13: Cementitious stabilizers in road construction*. Pretoria, South Africa Department of Transport, .

Department of Transport:TRH14. 1996. *TRH14: Guidelines for road conctruction materials* Pretoria, South Africa Department of Transport, South Africa

Douglas, J. K. E. 1969. Lime in South Africa *Journal of the South African Institute of Mining and Metallurgy*: 13.

European commission: Directorate-general joint research centre. 2010. *Integrated pollution prevention and control: Reference document on best available techniques in the cement, lime and magnesium oxide manufacturing industries*. Sevilla – Spain: European commission: Directorate-general joint research centre.

Gourley, C. and Greening, P. 1999a. *Performance of chemically stabilised roadbases: Results and recommendations from studies in Southern Africa*. Department for International Development

Gourley, C. S. and Greening, P. A. K. 1999b. *Reformance of chemically stabilised roadbases: Results and recommendations from studies in Southern Africa*. Transport research laboratory, Crowthorne, Berkhire, United Kingdom

Corresponding Author: Mr P.H Bhengu, Department of Civil Engineering & Surveying, Durban University of Technology, Durban
P.O Box, 1334, Durban 4000 South Africa, Cell: 0793410391, E-mail address: bhengupk@gmail.com

Green, P. 2008. A reassessment of some raod material stabilisation problems. Paper presented at the *South African Transport Conference (SATC)*. Pretoria, South Africa 1-10.

Green, P., Netterberg, F. and Sampson, L. 1990. *The carbonation of chemically stabilised road construction materials: Guide to its identification and treatment*. Pretoria, South Africa Division of Roads and Transport Technology: CSIR.

Group, C. 2016. *Global quicklime, slacked lime and hydraulic lime market report*

Hall, M. R., Najim, K. B. and Dehdezi, P. K. 2012. Soil stabilization and earth construction: Materials, properties and techniques, . University of Nottingham. United Kingdom (UK).

International finance Corporation. 2007. *Environmental, health, and safety guidelines for cement and lime manufacturing*. International finance corporation.

Jawad, I. T., Taha, M. R., Majeed, Z. H. and Khan, T. A. 2014. Soil stabilization using lime: Advantages, disadvantages and proposing a potential alternative, . *Research Journal of Applied Sciences, Engineering and Technology*, 8 (4): 510-520.

Krishna, Y. S. S. G., Padmavathi, S. M. and Kumar, K. S. P. 2013. Stabilization of Black Cotton Soil Treated with Fly ash and Zycosoil. *International Journal of Civil Engineering and Building Materials*, 3 (3): 133-144.

Kuenen, J. 2009. *Lime production: Manufacture of cement, lime and plaster.*

Larfage Industries South Africa. 2012. *Meeting the needs of road construction industry: Soil stabilization,* . South Africa Larfarge

Little, D. N. 1995. *Handbook for stabilisation of pavement sugrades and base course with lime*. United States of America Lime association of Texas.

Liu, M. D., Pemberton, S. and Indraratna, B. 2010. *A study of the strength of lime treated soft clays,* .

Milburn, J. P. and Parsons, R. L. 2004. *Performance of soil stabilization agents,* . Topeka, Kansas: Kansas department of transportation:Bureau of materials and research, research unit,.

National Lime Association. 2004. *Lime stabilisation & lime modification,* .

Netterberg, F. and Green, P. 1984. *Carbonation of lime cement stbilized layers in road construction*. Pretoria, South Africa National Institute for Transport and Road Research: CSIR.

Corresponding Author: Mr P.H Bhengu, Department of Civil Engineering & Surveying, Durban University of Technology, Durban
P.O Box, 1334, Durban 4000 South Africa, Cell: 0793410391, E-mail address: bhengupk@gmail.com

Ogundalu, A. O. and Oyekan, G. L. 2014. Mineralogical and Geotechnical Characterization of Maiduguri Black Cotton Soil by X-Ray Diffraction (XRD), X-Ray Photoelectron (XPS) And Scanning Electron Spectroscopy (SEM), . *International Journal of Engineering and Technology Volume*, 4 (6): 345-353.

Orts, W. J., Espinosa, A. R., Sojka, R. E., Glenn, G. M., Imam, S. H., Erlacher, K. and Pedersen, J. S. 2007. Use of synthetic polymers and biopolymers for soil stabilization in agricultural, construction, and military applications. *Journal of materials in civil engineering*: 58-66.

Otoko, G. R. 2014. A review of the stabilization of problematic soils, . *International Journal of Engineering and Technology Research*, 2 (5): 1-6.

Roohbakhshan, A. and Kalantari, B. 2014. Effect of lime andwaste stone powdervariation on the ph values, moisture content and dry density of clayey soil. *International Journal of Advances in Applied Sciences (IJAAS)*, 3 (1): 41-46.

Schwab, G. J., Murdock, L. W. and Ditsch, D. 2007. *Agricultural lime recommendations based on lime quality*. United States of America University of Kentucky-College of agriculture

Stork, M., Meindertsma, W., Overgaag, M. and Neelis, M. 2014. *A competitive and efficient lime industry: Conerstone for a sustainable europe*.

Thompson, M. R. 2005. *Admixture stabilization: (Lime Treatment of Subgrades)* Illinois: University of Illinois, Dept of Civil & Environmental Engineering

US Department of the interior: Geological survey. 2012. *Limestone: A Crucial and Versatile Industrial Mineral Commodity,* .

Vitton, S. 2006. *Introduction to soil stabilization,* . Michigan Technological University.

Corresponding Author: Mr P.H Bhengu, Department of Civil Engineering & Surveying, Durban University of Technology, Durban
P.O Box, 1334, Durban 4000 South Africa, Cell: 0793410391, E-mail address: bhengupk@gmail.com