Transportation Geotechnics 4 (2015) 28–37

Contents lists available at ScienceDirect

Transportation Geotechnics

journal homepage: www.elsevier.com/locate/trgeo

Review on the effect of gypsum content on soil behavior

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ARTICLE INFO

Article history:
Received 9 June 2014
Revised 18 June 2015
Accepted 19 June 2015
Available online 27 June 2015

Keywords:
Gypsum
Sulfate bearing soil
Subgrade soil
Problematic soil
Soil improvement and treatment

ABSTRACT

Increasing the utilization of urban soil usage brings along very important problems to be addressed at the international level regarding the use of sulfate bearing soils as construction materials.

After briefly exploring current research perspective, this paper captures the current state of the art in the field of sulfate bearing soils used as construction materials through a detailed discussion of different studies that pave the way to the possible treatment of such soils to be used in road construction.

Additionally, the purpose of this paper is to acquaint geotechnical and pavement engineers with the present state of the art of the physical and chemical properties of gypsum and hence its effect on the subgrade soil performance. On the other hand, this paper discussed an opposite action in which some researchers have mixed recycled waste gypsum components with soil in order to stabilize it.

In other words, a number of open research issues are highlighted with the intension of inspiring new conditions and developments in stabilizing problematic gypsiferous soil as well as adding gypsum to stabilize non gypsiferous soils of weak performance.

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http://dx.doi.org/10.1016/j.trgeo.2015.06.003
2214-3912/

Notations

CP	collapse potential
CaO	calcium oxide
$CaSO_4$	anhydrite
$CaSO_4{\cdot}2H_2O$	gypsum
$CaSO_4{\cdot}½H_2O$	bassanite (hemihydrate)
CBR	California bearing ratio
C_c	compression index
FGD	Flue gas desulfurization
HCl	hydrochloric acid
HNO_3	nitric acid
K	dissolution rate constant
ML	sandy silt low plasticity soil
Ø	the angle of internal friction
OMC	optimum moisture content
SM	silty sand soil
SO_3	sulfur trioxide
TxDOT	Texas Department of Transportation
γ_{dmax}	the maximum dry unit weight

Introduction

It is very common that the soil at a site to be developed is not ideal from the viewpoint of geotechnical engineering. An attractive approach which is usually used to avoid many of the settlement and stability problems associated with soft foundation soils is soil improvement and treatment.

In its broadest sense, soil improvement is the alteration of any property of a soil to enhance its engineering performance (Sherard et al., 1963; Chen, 2000).

Since pavements are designed to distribute stresses imposed by traffic to the subgrade, the subgrade conditions have a significant influence on the choice and thickness of pavement structure and the way it is designed. Depending on the existing soils and project design, the properties of the subgrade may need to be improved, either mechanically, chemically, or both, to provide a platform for the construction of subsequent layers and to provide adequate support for the pavement over its design life (Jones et al., 2010).

In most regions of the world, especially in the Middle East, natural soils and aggregates contain varying quantities of soluble salts (Blight, 1976; Fookes, 1976, 1978; Fookes and French, 1977; Tomlinson, 1978). Gypsum is one of the soluble salts that can have a detrimental effect on subgrade soils, buildings and earth structures if it is presented in high quantities in the soil (Subhi, 1987; Obika et al., 1989; Razouki et al., 1994; Razouki and Kuttah, 2004, 2006).

According to Klein and Hurlbut (1985), gypsum ($CaSO_4{\cdot}2H_2O$) contains 32.6% calcium oxide (CaO), 46.5% sulfur trioxide (SO_3) and 20.9% combined water (H_2O). As a result of dehydration of gypsum, the first 1½ molecules of (H_2O) in gypsum are lost relatively continuously between 0 °C and about 65 °C, perhaps with only slight changes in the gypsum structure, leading to bassanite ($CaSO_4{\cdot}½H_2O$). At about 70 °C, the remaining (½H_2O) molecule in bassanite (hemihydrate) is still retained relatively strongly but at about 95 °C it is lost and the structure transforms to that of anhydrite ($CaSO_4$).

Both, anhydrite and hemihydrate have several different forms with different properties, but in general, if anhydrite or hemihydrate are mixed with water, they will hydrate to gypsum (Claisse and Ganjian, 2006).

The presence of gypsum in subgrade soil could be naturally or artificially added gypsum as follows:

1. Naturally occurring gypsum, in which hydrate and anhydrate gypsum are considered as part of the soil components. Soil science has paid little attention to gypsiferous soils, and this limited knowledge is reflected in the direct loan of customary terms of soil science that can lead to misconceptions on the composition and behavior of soils with large proportions of gypsum. Both geological and climatic reasons cause gypsum-rich soils to occur in dry lands (Herrero and Porta, 2000). Such soil can be found in the Middle East (especially in Iraq, Syria & Iran), Europe especially in Spain, former USSR (Siberia, Georgia, Transcaucasia, Azerbaidzhan), north Africa (Algeria, Tunisia), south east of Somalia, southern central Australia and in former inland lakes in western USA (Van Alphen and Romero, 1971). Soils containing gypsum in Cardiff area of Wales in the United Kingdom were reported by Hawkins and Pinches (1987). The presence of natural occurring gypsum in subgrade soil usually found in high quantities and therefore using such soils as subgrade materials may lead to detrimental effects of roads structures as reported by many authors (Razouki et al., 2011, 2012a,b). The problems in using naturally occurring gypsiferous soil as road construction materials are usually faced when these soils subjected to long term soaking and leaching (Razouki and Kuttah, 2006; Razouki et al., 2011; Aldaood et al., 2014) as well as cyclic drying and wetting as studied by Razouki and Salem (2014).
2. Artificially added gypsum, when gypsum and/or bassanite (virgin or recycled) are added to non-gypsiferous subgrade soil in control quantities to improve the mechanical properties of the subgrade soil (due to the cementation action of gypsum) and/or to minimize the landfilling of waste products involve gypsum, since the use of secondary (recycled) instead of primary (virgin) materials in roads construction helps easing landfill pressures and reducing demand of extraction (Huang et al., 2007). During the three stages of production, construction and demolition of plasterboards, approximately 15 million tons of gypsum waste plasterboard is generated annually in the world (Ahmed et al., 2011). Production of Flue gas