Abstract

The fact that expansive soils are a major engineering problem makes their study an important research aspect due to the accruing cost involved in terms of economic loss when construction is undertaken without due consideration to the probability of their presence. Though there are several methods that have been used to recognise their presence a need of a fast and relatively cheaper methods continues to be a necessary undertaking. In this thesis new methods are explored where the various aspects of swelling soil properties are investigated consisting of engineering, geophysical, reflectance spectroscopy and remote sensing where data from two study areas one in central Kenya and the other in southern Spain were used.

The study relied on the establishment of indicator spectral parameters as to the presence of three clay minerals commonly used in soil classification to swelling potential classes namely; mectites, illites and kaolinites. This was through several reflectance spectra analysis techniques among which are; absorption feature mapping, derivative analysis, optical density and band normalised with centre. This was followed by the establishment of correlations between these parameters and the commonly used physicochemical indices of Atterberg limits, Cation Exchange Capacity (CEC), Saturated Paste (SP), and Coefficient of Linear Extensibility (COLE) tests. In this, their widely accepted thresholds within which soils are assigned to a swelling potential class and provisionally to a dominant clay mineral were used. This was followed by analysis of airborne hyperspectral data, in the Spain case and Landsat Thematic Mapper (TM) image data for the Kenyan study area to establish similar compositional differences. In both cases the lower spectral information content was taken into consideration where not only the spectral characteristics were used but also the surface expression of the soil compositional differences in the Kenyan area in the form of gilgai microrelief. This information was integrated with field based data consisting of topography, drainage and vegetation differences and correlations with field based soil classification maps to establish the potential of remote sensing in the mapping of swelling potential. Finally a prove of concept as to the potential discrimination of swelling soils under buried non-swelling soils was also explored where two geophysical methods consisting of Induced Polarisation (IP) and Nuclear Magnetic Resonance (NMR)

known to give indication as to the CEC, moisture and clay mineralogy differences were used at a laboratory scale with the aim of identifying the problems to be overcome for such methods to be applicable in a field setting where they would provide faster ways of establishing the swelling potential characteristics based on the fact that these soil properties are the key to their swelling behaviour. From the engineering methods, three of the indices were established to best represent the potential volume change and consisted of those directly related to the clay mineralogy type i.e. CEC and the Atterberg limits of liquid limit and plastic index. This was interpreted to show them as most suited from an engineering perspective in the identification of swelling soils and as best suited at the exploration as to other methods capability at identifying these soils. The absorption feature mapping technique established several feature parameters to be diagnostic as to the dominance of these minerals in soils where significant presence of kaolinite enhanced the hydroxyl features whereas substantial amounts of smectite enhanced molecular water features. Manipulations of the spectral curves in the form of first and second derivatives were also observed to give similar information whereas other manipulations such as the optical density and the band normalised with centre were not as promising. The potential of spectral data to discriminate the soils based on the clay mineralogy differences was thus concluded to show spectroscopy to have a potential at mapping swelling soils an assumption that was finally confirmed through correlations between the spectral parameters and the established swelling potential indices. This was also confirmed based on spectral information from the hyperspectral image data where derivatives established several wavelength positions to give strong indications of such a potential. Landsat image data on the other hand added a new dimension to the potential identification and mapping of swelling soils other than the spectral differences in the form of recognition of gilgai topography pattern exclusively present in these soils. This provides a possibility of carrying out more detailed analysis of the potential differences among the swelling soils where spatial analysis of the gilgai patterns in the form of parameters such as homogeneity index can be used to relate soils in different regions based on the similarity of such indices and their association to environmental factors. This when coupled with spectral differences in the form of such indices as the soil brightness index were established capable in assigning soils in the Kenyan study area to swell potential categories upon integration with other field based information such as topography and drainage patterns coupled with land cover differences. The geophysical methods (IP and NMR) though laboratory based were also established as potentially

useful in the study of these soils and could be useful in their recognition in places where they could be buried based on good correlations obtained between the normalized IP and the CEC on the one hand and moisture and grain size distributions and the NMR parameters on the other. However, for the two methods to become operational there are some factors that require to be addressed one of which is the influence of salinity on the obtained IP and a proper calibration of the NMR to measure the various properties on which it has a potential to give information on. Reflectance spectroscopy was therefore concluded to have a potential application in swelling soil identification and to offer a fast non-destructive method based on diagnostic spectral features. Low spectral but high spatial resolution images were found useful in the recognition of these soils and to offer a potentially important tool for the comparison of the soils over wide areas through the established gilgai pattern analysis based on their expression of underlying forces resulting from differential swelling. Geophysical methods of NMR and IP were also established to have a potential to non-intrusive identification of these soils if some influencing factors could be overcome. Conclusions were therefore drawn that though soil swelling is a complex phenomenon involving several underlying factors i.e. compositional differences, structure and moisture regime etc, clay mineralogy plays a central role in determining it and thus has an overall controlling influence to most of the soil properties making their use in its estimation possible. The research however established that there are still more handles to be overcome as to the full operation of these new techniques.