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Identification and mapping of expansive soils: Effectiveness of field spectrometry and hyperspectral imagery

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Abstract (552 words):

Swelling soils are a major geologic hazard, and expansive clays and clay-shales cause extensive damage world-wide every year. One of the worst cases of swelling clay damage is illustrated with the current situation in the Front Range Urban Corridor in Colorado. Our study investigates the spectral properties of swelling soils and their detectability by hyperspectral imagery. After establishing in the field and laboratory the spectral properties of swelling soils linked to their swelling potential, we investigate the possibilities of hy-tech remote sensing sensors (AVIRIS, HyMap) in tackling a difficult operational problem of identification and mapping of expansive clays. 35% of all construction in the Front Range swelling soil corridor is affected and the remediation costs are enormous.

Current engineering and geologic practice for characterization of expansive clays involves time-consuming and expensive standard engineering tests for determination of swelling potential, and x-ray diffraction (XRD) analyses for mineralogical identification. Reflectance spectrometry has the potentiality of rapid identification of minerals in soils. One of the worst swelling soils damage regions in the United States occurs along the 300 km long Front Range Urban Corridor in Colorado which is underlain by Cretaceous clay-shales, including the Pierre Shale. The sedimentary bedrock strata are generally flat-lying, except near the foothills of the Rocky Mountains where they have been uplifted into steeply-dipping strata. Expansive clays in the Pierre Shale and adjacent formations along the Front Range are responsible for the damage. The hazard is most severe in areas where these units dip steeply because of differential movement of adjacent beds (cm-m) which has been attributed to the abundance and composition of swelling clays (Gill et al., 1996). The three most important groups of clay minerals are smectite, illite and kaolinite. Smectite (including montmorillonite, the best-known member of the smectite group) has the greatest swelling potential and is responsible for most swelling soil damage in Colorado.

Different types of clays can be identified spectroscopically thanks to their characteristic absorption bands around 2.2 ?m. Near-infrared (NIR) reflectance spectroscopy of swelling soil field samples shows that it is possible to discriminate among pure smectite and mixed smectite/illite layers samples. The absorption band at 2.35 ?m provides a measure of the illite content. The higher the amount of smectite (the less illite), the higher the swelling potential. Spectroscopic identifications are well correlated with mineralogical x-ray diffraction analyses and geotechnical engineering tests.

Airborne Visible/Infrared Imaging Spectrometer (AVIRIS: pixel=18m, 224 10nm-wide spectral channels) and Airborne Hyperspectral Scanners (HyMap: pixel=4m, 126 ~15nm-wide spectral channels) data were acquired over specific areas in late summer 1999, when the vegetation cover is at its minimum. The problem is that the outcrops are sparse and small, and most of the time more or less covered with vegetation, plus they are of variable mineralogy at a small scale (<1m). Then the remote sensing challenge is not an easy one. The analysis of the hyperspectral images shows that, using a matched filtering algorithm, exposures of expansive clays can be detected among the other components in the images, and in the presence of significant vegetation cover. A map of exposed clay material is produced and among those exposures, spectral discrimination, and identification of variable clay mineralogy (kaolinite, smectite/illite, smectite) related to variable swelling potential is possible. Field check has shown that the maps of clay type derived from the imagery are accurate.