

Non-invasive moisture monitoring

An early warning of slope failure

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The moisture content of soil controls both its density and strength, making it the key property when considering the stability of embankments containing soils. Earthworks are used for embankments and cuttings carrying road and rail links and for dams, particularly overseas. Increased water content increases the likelihood of a sliding failure because soils are heavier, their inherent resistance to shearing is reduced, and confining stresses reduce as pore pressures increase.

Non-invasive geophysical methods have the potential to monitor moisture content. Electrical resistivity, for example, is sensitive to the moisture within a soil, specifically, the total amount, degree of saturation and the dissolved salts. In the field, this method uses arrays of simple metal stakes as electrodes that enable the resistivity of the sub-surface to be estimated in two and three dimensions. Such surveys do

not require the use of boreholes, which may disturb the moisture distribution. Moisture content is the only seasonal control of resistivity, so monitoring changes in electrical resistivity enables subtle changes in moisture to be extracted from complex background values. Consequently, this method can be used as early warning of anomalous build up of moisture (e.g. heavy rains) once the seasonal cycle has been monitored and new earthworks stabilised. This technique is applicable to landslides in the UK (e.g. South Wales Coalfield) and earthworks in general.

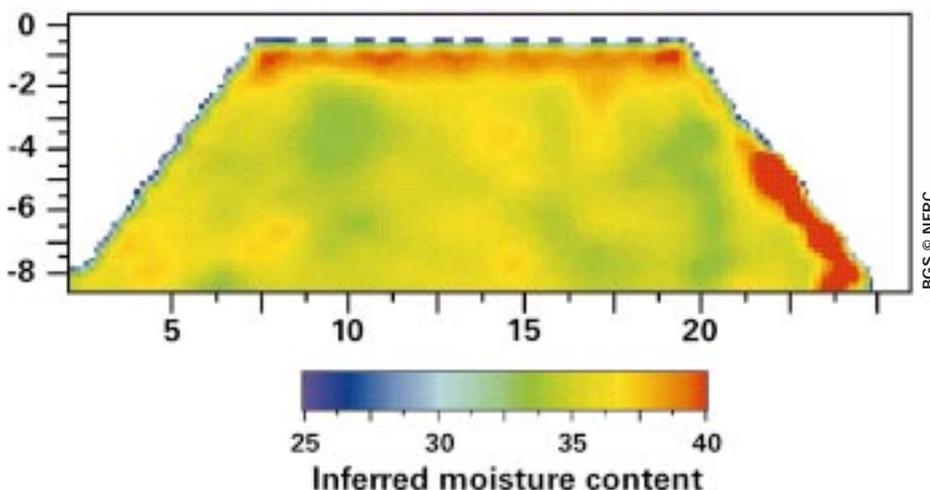
The figure, below, shows slope failure within a road embankment in Kenya constructed from tropical red clay soil, formed from the weathering of local volcanic rocks. As moisture content during compaction controls the geotechnical behaviour of such embankments, and severe cracking in response to seasonal changes in moisture is

common, resistivity monitoring was carried out over 18 months across a section of embankment. The BGS study was funded by the DFID in collaboration with the Materials Testing and Research Department (MTRD) of the Kenyan Ministry of Public Works and Housing. Cable electrodes were buried in a shallow trench prior to laying the asphalt road surface; stake electrodes may be used where trenching through existing pavement is not feasible. Samples of the clay soil were used in laboratory experiments that determined the relationship between resistivity and moisture content for this embankment.

An understanding of how moisture moves through engineered soils allows us to design systems to give early warning of moisture build up and to assess the 'homogeneity' assumption of standard construction methods.



Philip Meldrum, BGS © NERC



Earth slip in a study embankment near Molo, Kenya due to excess moisture seepage, nine months after construction.

Slope failure within a road embankment in Kenya. The high moisture content (red) adjacent to the top surface occurred early during the winter rains (December) and appeared to be 'trapped' once asphalt had been laid, gradually disappearing over the following eight months. The very high values on the bottom right only became apparent following a second survey during the 'December rains' at a location where a slip occurred some days later. The slope was stabilised using additional drainage trenches that discharged into a nearby stream.