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Non-invasive portable geophysical tool to monitor water content in earthen long linear infrastructures

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Abstract

The use of electrical conductivity measurements from a non-invasive hand held electromagnetic probe is showcased to monitor the water content of earthen embankments at routine inspections. A methodology to convert the electrical conductivity measurements from the electromagnetic device into water content values is illustrated. The methodology is based on measuring the soil electrical conductivity variation with respect to a baseline reference condition and calibrating a water content – electrical conductivity relationship by comparing electrical conductivity readings from the electromagnetic probes with water content readings taken from geotechnical probes installed in a few sections of the embankment.
The values of water content converted from the conductivity measurements according to the proposed procedure were found to be in very good agreement with independent measures of water content taken at times well beyond the calibration period.

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Keywords: geophysics; health monitoring; electrical conductivity; water content; deterioration; electromagnetic portable device.

Introduction

Earthen embankments are built for a variety of purposes the main ones being transportation, e.g. road and railway embankments, and to act as flood barriers. Usually flood defence embankments are made of lower quality materials than transportation embankments [1]. With regard to the latter, the increased focus on sustainability in the

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engineering sector brings renewed attention to health monitoring in the long term; while with regard to the former, they are subject to significant deterioration due to aging [2] so increasingly large resources are dedicated to their health monitoring.

Monitoring and condition assessment of embankments worldwide are mainly carried out by visual inspections at set intervals [3-5]. Purely visual inspections present several shortcomings, namely inconsistencies due to different levels of training and experience of the inspectors and providing qualitative measurements of deterioration rather than quantitative ones with failures often occurring without any visible warning signs of deterioration being detected. Therefore, experts agree on the fact that although visual inspection provides extremely valuable information, inspections alone cannot be relied upon to assess the fitness of earthen embankments [3, 6].

Here, the use of non-invasive electromagnetic geophysical probes is advocated for the long term monitoring of the water content in embankments made of cohesive soils. The probe employed in the study is a hand held devise that can be easily operated by untrained personnel and that could be added to the standard inspector kit. Potentially it could also be used to monitor material deterioration occurring over long time spans. In the following it will be shown how periodic measurements of electrical conductivity taken by a portable electromagnetic devise can be converted into water content. A methodology to calibrate the electrical conductivity – water content relationship was first proposed in [7]. In this paper a new simplified methodology is proposed with the aim of extending the application of the method to cases of embankments where less data are available, e.g. absence of weather stations and few geotechnical probes.

Nomenclature

A_{CMD}	portion of embankment cross-section where the induced electric field is non-zero.
m	inclination of slope in Figure 3
q	intercept of slope in Figure 3
x	horizontal coordinate in the embankment cross-section
y	vertical coordinate in the embankment cross-section, positive downwards
s	coordinate along the longitudinal axis of the embankment
$w(x,s,z,t)$	water content
$w_{i;k}=w\left(x,s=s_i,z,t=t_k\right)$	water content at cross section i measured at time t_k
$\bar{w}(s,t)$	cross-sectional average water content
$\bar{\bar{w}}(t)$	water content averaged over the entire embankment
$\bar{w}_0(s,t)$	normalised cross-sectional average water content
$\underline{\bar{w}}_0(s)$	time average of the normalised cross-sectional average water content
$\gamma_i(s)$	weight functions
$\sigma(x,s,z,t)$	electrical conductivity
$\bar{\sigma}(s,t)$	cross-sectional average electrical conductivity
$\bar{\sigma}_k(s)=\bar{\sigma}(s,t=t_k)$	cross-sectional average electrical conductivity measured at time t_k
$\bar{\bar{\sigma}}(t)$	electrical conductivity averaged over the entire embankment
$\bar{\sigma}_0(s,t)$	normalised cross-sectional average electrical conductivity
$\underline{\bar{\sigma}}_0(s)$	time average of the normalised cross-sectional average electrical conductivity
T	temperature
T_{ref}	reference baseline temperature to account for temperature effects on electrical conductivity

2. Measurements