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Investigation of deformation coordination between optical fibre and borehole sand backfill

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Land subsidence has threatened the safety of municipal infrastructures and even that of inhabitants. As one of the deformation monitoring methods, distributed optical fibre sensing (DOFS) technology has been developed for the investigation of land subsidence. The deformation coordination between the optical fibre and soil ($DC_{f\text{-}s}$) under different conditions is critical for land subsidence monitoring with DOFS. In this paper, a medium-sized triaxial apparatus was modified for testing the $DC_{f\text{-}s}$. Consolidated drained triaxial tests were conducted to investigate the effect of sand types on the $DC_{f\text{-}s}$. By linearly fitting the deformation of the sensing cable with that of the triaxial specimen, the other factors that affect the $DC_{f\text{-}s}$, such as the confining pressure, dry or wet state of the soil and cyclic variation of the loads, can be discussed. The experiments reveal that better $DC_{f\text{-}s}$ comes with a larger particle size, poor gradation of sand and larger confining pressure. The $DC_{f\text{-}s}$ of wet sand is better than that of dry sand. The $DC_{f\text{-}s}$ coefficient tends to be stable with an increase of loading cycles. The $DC_{f\text{-}s}$ obtained and its dependence on influencing factors can be used to modify the measured cable strain in practical land subsidence monitoring with DOFS.

Keywords: deformation coordination/laboratory tests/optical fibre/sands/subsidence

Notation

C_T	temperature coefficient
C_ε	strain coefficient
C_c	coefficient of curvature
C_u	coefficient of uniformity
$DC_{f\text{-}s}$	deformation coordination between optical fibre and soil
D_r	relative density
d	sampling interval of optical frequency domain reflectometer
d_f	deformation integrated by strains of optical fibre
d_s	axial deformation of specimen obtained by linear variable differential transducer
E_c	Young's modulus of the fibre coating
E_g	Young's modulus of the fibre core
e_{max}	maximum void ratio
e_{min}	minimum void ratio
G_s	specific gravity
K_0	coefficient of lateral earth pressure
L	half of the specimen height
l_c	critical adherence length
r_c	radius of the fibre coating
r_g	radius of the fibre core
r_m	radius of the soil mass
α	fibre–soil strain transfer rate
Δv_R	spectral shift
ΔT	fibre temperature change
ε	fibre strain
$\bar{\varepsilon_f}$	average fibre strain
$\varepsilon(i)$	strain of the specimen measured by the optical sensing cable
η	strain ratio of the sensing cable and specimen
μ	Poisson's ratio of the fibre core

1. Introduction

Land subsidence (LS) is an environmental geological phenomenon that is defined as the gentle or rapid sinking of the ground surface (Galloway and Burbey, 2011; Wu *et al.*, 2008). It is caused by natural processes of the vertical motion of land (tectonics, glacial isostatic, sediment compaction, etc.) and anthropogenic processes (fluid extraction, construction of underground structures, etc.); LS is therefore a global threat (Shirzaei *et al.*, 2021; Xu *et al.*, 2012). More than 95 cities in China and 45 states in the USA suffer from LS and LS-induced geohazards (Bagheri-Gavkosh *et al.*, 2021; Wu *et al.*, 2008), leaving cities' pipelines and other underground