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DISTRIBUTED FIBER-OPTIC SENSING OF GROUND DEFORMATION: AN EMPHASIS ON THE ROLE OF CABLE–SOIL INTERFACE[†]

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1 RESEARCH AIMS

The distributed fiber-optic sensing (DFOS)-based geotechnical monitoring is presently attracting immense research interest on the global level. Over the past decade, researchers have attempted to detect ground deformation (e.g., landslides and land subsidence; **Figure 1**) by directly embedding FO strain-sensing cables (**Figure 2**) into soil masses. However, the reliability of FO strain measurements remains unclear due to the imperfect attachment of FO cables to soil masses. Our goal here is to elucidate the interaction mechanism between cables and soil masses toward a better interpretation of FO strain data.

2 EXPERIMENTAL SETUP

An aluminium tank is constructed to perform displacement-controlled pull-out tests on FO cables (**Figure 3**). The FO cables used here are Nanzee cables specially designed for strain measurement of geologic materials (**Figure 2**). The soil used here is pooly graded sand (SP). During pullout, optical measurements are carried out using a Neubrex BOTDA analyzer with a spatial resolution of 50 mm and a sampling interval of 10 mm.

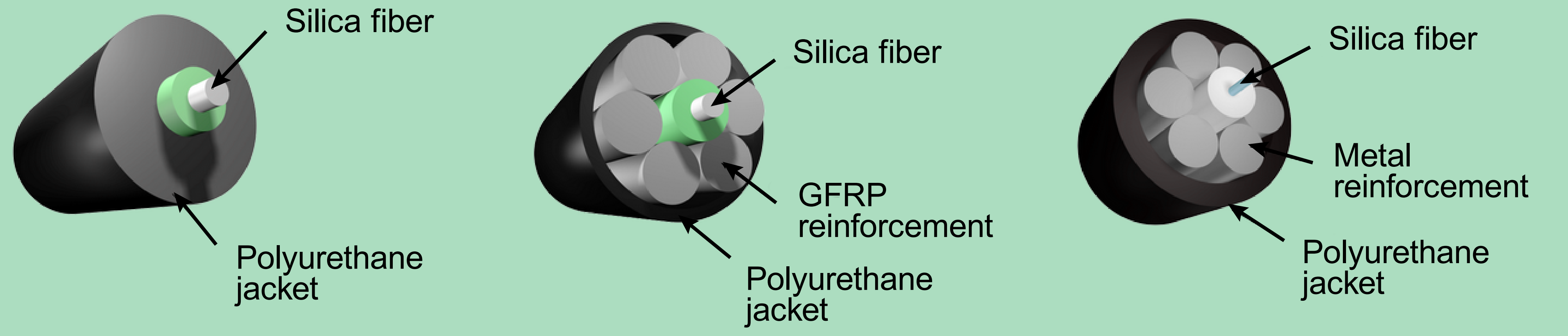

Figure 2 | Three specially designed FO cables for strain measurement of geologic materials. From left to right: tight-buffed polyurethane-coated cable, glass fiber reinforced polymer-reinforced cable, and metal-reinforced cable

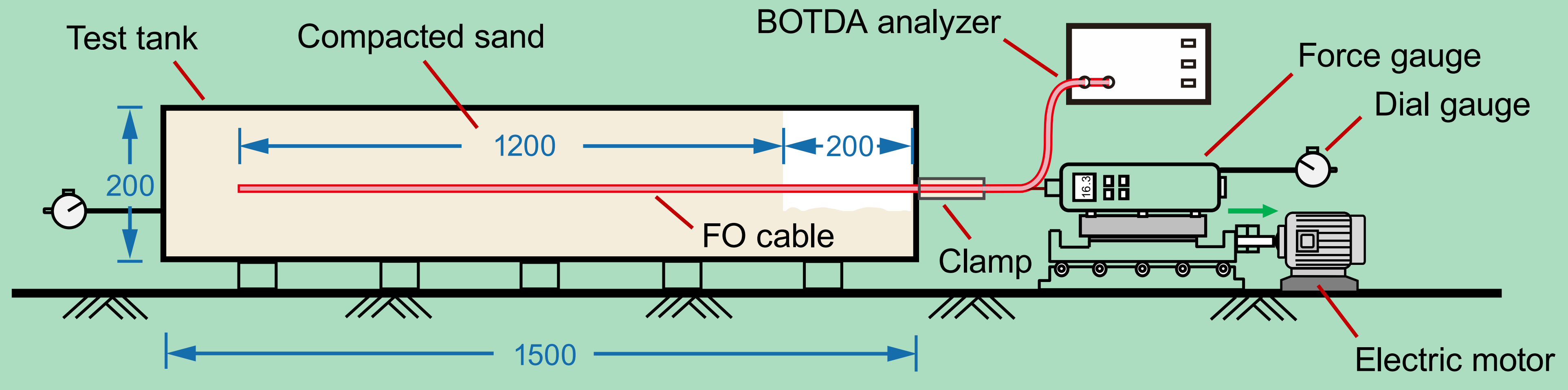

Figure 3 | The pullout apparatus to investigate the FO cable–soil interaction (unit:mm)

4 CABLE–SOIL INTERACTION MODEL

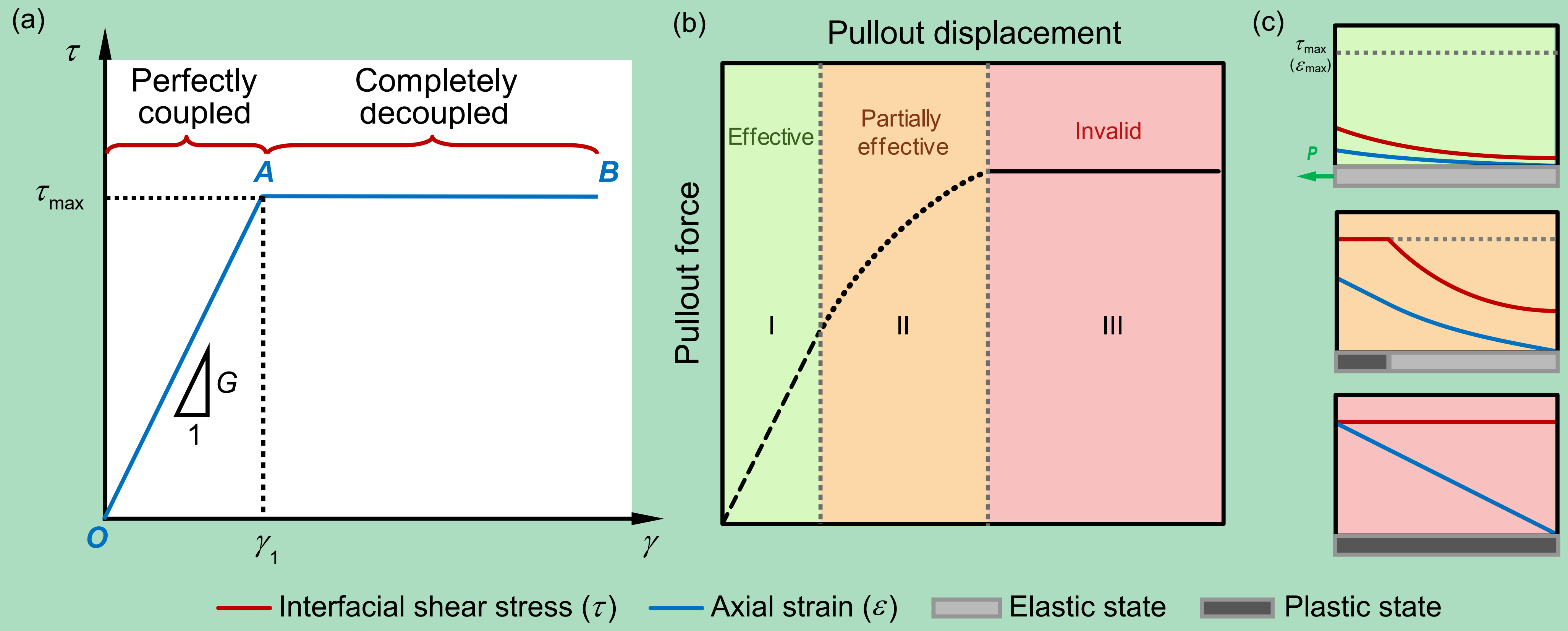

Figure 5 | A simplified model proposed to describe the FO cable–soil interfacial behavior during progressive failure process

A simplified model (**Figure 5**) is proposed to describe the cable–soil interfacial behavior during the progressive failure process (**Figure 4**).

- The cable–soil interface follows an elasto–plastic shear stress–strain constitutive relation
- Analytical solutions for the distribution of axial strain and interfacial shear stress and the relationship between pullout force and pullout displacement are derived for each of three pullout phases

Three working states of a FO sensing cable are identified during the course of cable–soil interface failure, and a simple criterion to determine the reliability of measured strain data can be proposed based on this model.

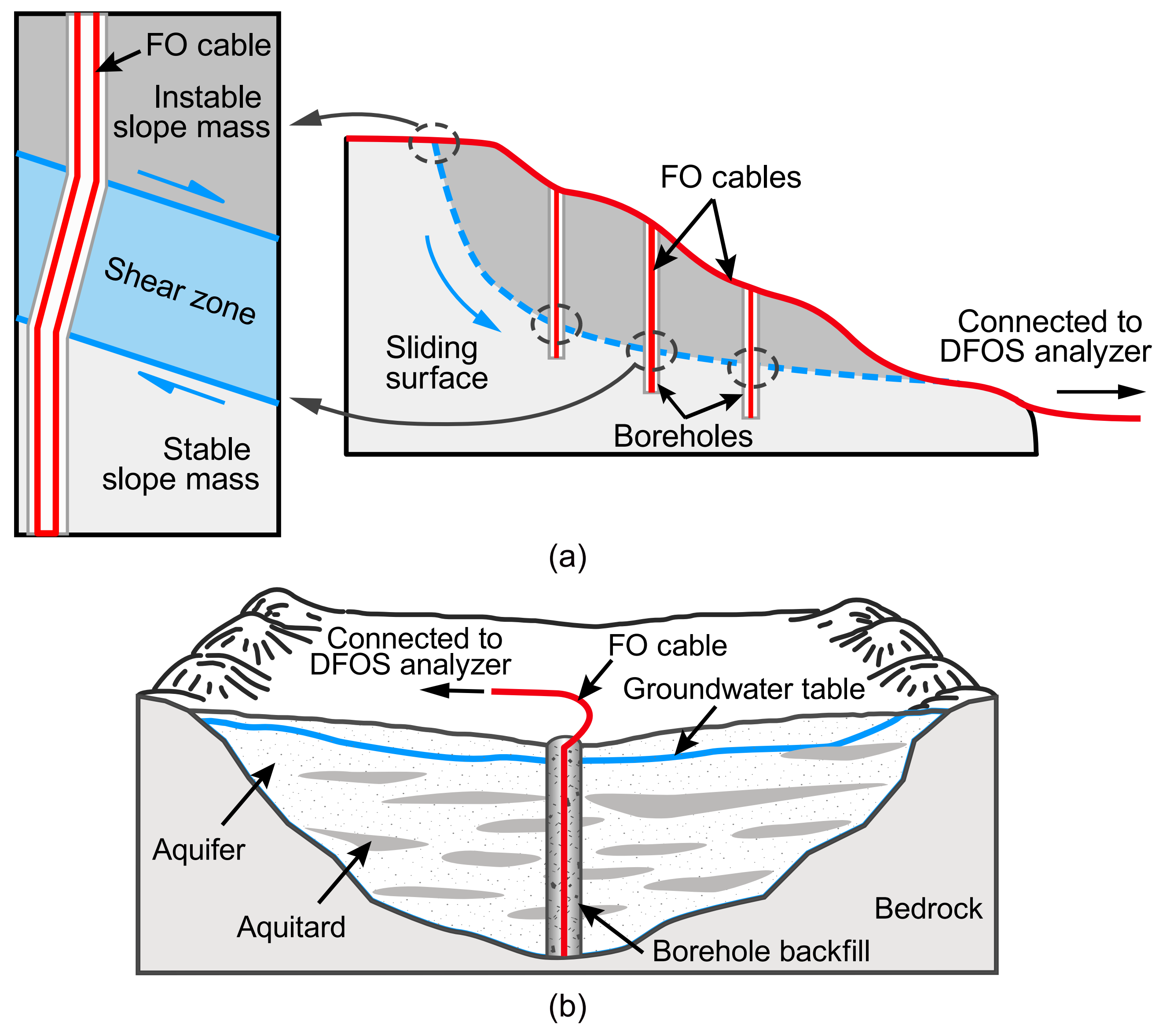

Figure 1 | Schematic of distributed fiber-optic sensing of ground deformation: (a) landslide and (b) land subsidence

EXPERIMENTAL RESULTS 3

Results of the 2-mm diameter tight-buffed polyurethane-coated cable are shown here. Twelve sets of strain data are obtained (**Figure 4**). The high-resolution strain distribution allow cable–soil interaction to be studied in unprecedented detail.

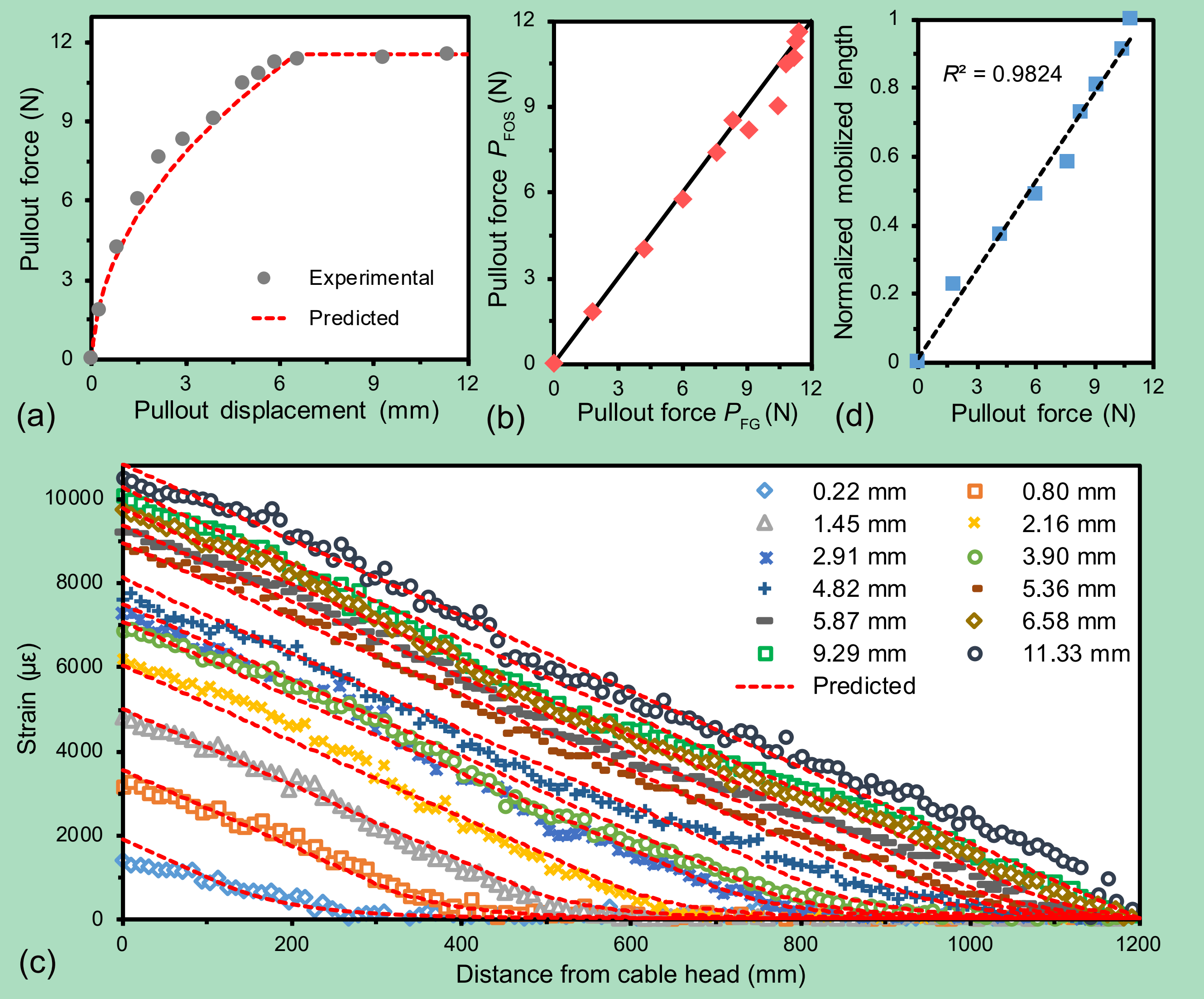

Figure 4 | Evolution of strain distribution along FO cable during progressive cable–soil interface failure

IMPLICATIONS 5

These findings may not only shed light on the cable–soil interfacial behavior, but also have important implications for interpreting FO strain data and deploying reliable DFOS-based geotechnical instrumentaion. In particular, we suggest using anchors to enhance the cable–soil interfacial coupling for near-surface applications where the CP is low, or the soil is loose/highly saturated.

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Reference: 1. Zhang, C.-C. et al. (2016) doi: 10.1038/srep36469. 2. Zhang, C.-C. et al. (2018) doi: 10.1016/j.enggeo.2018.01.002.