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Research paper

Genetic programming for soil-fiber composite assessment

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ABSTRACT

Unconfined compressive strength (UCS) of soil is one of the basic index parameters for representing the compressive bearing strength of soil. Fiber reinforced soil is one of the most popular and practical ground improvement approaches used in geotechnical infrastructures. Analytical models for estimating UCS of soil-fiber composites have been developed in the literature. However, these models rarely incorporate the combined effects of dynamic field parameters such as fiber content, soil moisture, and density. These effects can be studied by the development of a holistic model based on a dimensionless strength improvement factor (SIF), which is defined as the ratio of UCS of reinforced soil to the unreinforced UCS. The current model estimating SIF indicates the improvement expected in UCS of soil-PP fiber composite based on the three design conditions such as fiber content, soil density, and moisture content. For this purpose, a series of 108 laboratory tests were first conducted to measure UCS of both fiber-reinforced soil and unreinforced soil under different fiber contents, soil density, and soil moisture content. Clayey silt soil and commercially used polypropylene (PP) fibers were selected in this study as soil and fiber material respectively. Genetic programming (GP) approach was then used to formulate models based on the measured data. The hidden non-linear relationships between SIF and the three inputs were determined by sensitivity and parametric analysis of the GP model. It was found that the moisture content in the soil has the highest influence on the strength factor that accounts for the change in strength. Coupled effects of soil parameters (soil moisture, soil density) and fiber content have been studied using parametric analysis which includes different possible field conditions (parameters). The results have been discussed along with the reinforcement mechanism of PP fiber for different soil conditions. It is believed that the robust GP model developed will be useful to determine optimum input values for designing safe bearing foundation soils which are reinforced with PP fibers.

1. Introduction

Soil reinforcement is essential to improve engineering properties (such as shear strength, compressibility, hydraulic conductivity); thereby increasing the bearing capacity, ductility and decreasing the soil settlement [1]. A large array of synthetic tensile inclusions ranging from high tensile strength metallic sheets to low-modulus polymeric materials has been integrated into soil reinforcement applications [2]. Additionally, unconventional and eco-friendly reinforcing measures have also been investigated in the recent past [3–7]. In the past, researchers have used natural and synthetic fibers for reinforcing soil in geotechnical applications [8–11]. These soil reinforcement measures using fibers have in general been discussed as randomly distributed fiber reinforced soil (RDFS). RDFS has gained traction as it enhances soil performance which includes improvement in soil ductility, increase in shear strength and reduction of the drop in post-peak strength [12]. Figure 1(a-e) showcase the various mechanisms involved in fiber reinforcement by an individual fiber. The inclusion of these fibers in soil enhances the load-deformation response of the soil-fiber composite by interacting with the soil particles mechanically via surface friction and interlocking. The interlock leads to a stress transfer mechanism, whereby the stresses induced in the soil on loading are transmitted to the discrete fibers by mobilizing the tensile strength of the fiber. It is evident that this surface friction and interlocking forces developed on

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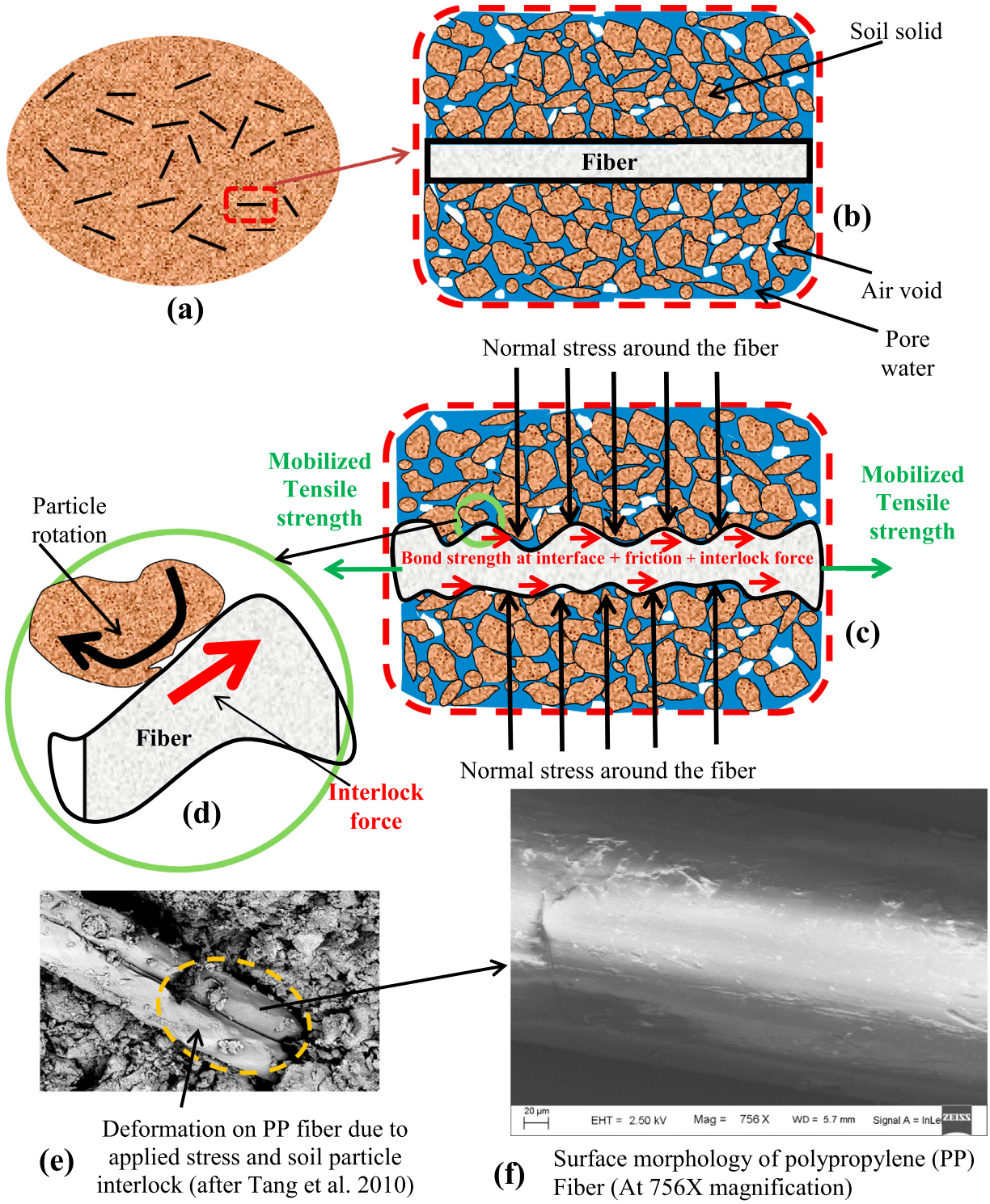

Fig. 1. Schematic representation of (a-e) fiber reinforcement mechanism and (f) surface morphology of PP fiber used.

an individual fiber will be highly dependent on the surface roughness of the fiber, soil type, soil-fiber composite density and also the moisture content in the soil [5,12–13]. Among the synthetic fibers, polypropylene fiber (PP) is one of the most popular fibers used in soil reinforcement due to high tensile strength and resistance to biodegradation [12–14]. Unconfined compressive strength (UCS) is a quick and reliable mechanical parameter that is used to judge the representative strength of soil for the initial design and analysis of various geotechnical infrastructures [15–17]. UCS of reinforced soil is known to be influenced by fiber content, fiber type as well as soil parameters such as soil moisture content and soil density [8–10, 13, 15–19]. Variations in UCS due to change in these parameters influence the stability of various field applications [20]. Hence, it is imperative to know the variability expected in strength improvement by the inclusion of fibers considering other parameters mentioned previously.

The use of soft computing approaches to formulating models for estimation, prediction and assessment of soil properties is gaining popularity owing to its robustness [21–27]. Numerous models have been

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