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Effect of particle size of sand and surface asperities of reinforcement on their interface shear behaviour

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ABSTRACT

This paper investigates the effect of particle size of sand and the surface asperities of reinforcing material on their interlocking mechanism and its influence on the interfacial shear strength under direct sliding condition. Three sands of different sizes with similar morphological characteristics and four different types of reinforcing materials with different surface features were used in this study. Interface direct shear tests on these materials were performed in a specially developed symmetric loading interface direct shear test setup. Morphological characteristics of sand particles were determined from digital image analysis and the surface roughness of the reinforcing materials was measured using an analytical expression developed for this purpose. Interface direct shear tests at three different normal stresses were carried out by shearing the sand on the reinforcing material fixed to a smooth surface. Test results revealed that the peak interfacial friction and dilation angles are hugely dependent upon the interlocking between the sand particles and the asperities of reinforcing material, which in turn depends on the relative size of sand particles and asperities. Asperity ratio (AS/D_{50}) of interlocking materials, which is defined as the ratio of asperity spacing of the reinforcing material and the mean particle size of sand was found to govern the interfacial shear strength with highest interfacial strength measured when the asperity ratio was equal to one, which represents the closest fitting of sand particles into the asperities. It was also understood that the surface roughness of the reinforcing material influences the shear strength to an extent, the influence being more pronounced in coarser particles. Shear bands in the interface shear tests were analysed through image segmentation technique and it was observed that the ratio of shear band thickness (t) to the median particle size (D_{50}) was maximum when the AS/D_{50} was equal to one.

1. Introduction/

In a soil structure reinforced by planar layers of reinforcement, the weakest zones are the soil-reinforcement interfaces and the overall strength and internal stability of the structure is governed by the stresses and strains developed and transferred at the interfaces. Therefore a clear understanding and more accurate determination of the interfacial friction characteristics could provide great help for the design of optimized and safe reinforced soil structures (Palmeira, 2009). Interfacial shear strength of sand and reinforcing materials largely depends upon the interlocking mechanism developed between them while shearing. Further, the interlocking between these materials depends upon the particle size and morphology of sands and relative surface asperities/roughness of the reinforcing material (Jewell et al., 1984; Giroud et al., 1985; Palmeira and Milligan, 1989; Jewell, 1990, 1996; Lopes and Lopes, 1999; Latha and Murthy, 2007; Tang et al., 2010; Palmeira, 2009). Several researchers demonstrated the importance of understanding morphological characteristics and grain size of sand on its shear behaviour (Rouse et al., 2008; Göktepe and Sezer, 2010). Also, the advent of numerous geosynthetics with different textures and patterns for soil reinforcement necessitated the studies which investigate the effect of surface features of geosynthetics on the interface shear behaviour. Very few studies in this direction are available in literature (Swan, 1987; Lopes et al., 2001; Subaida et al., 2008; Rawal and Saraswat, 2011; Fuggle and Frost, 2010; Frost and Karademir, 2015). Accurate estimation of interfacial shear strength through laboratory studies has not been given enough importance in literature. Many existing designs and numerical models follow approximate and empirical correlations for

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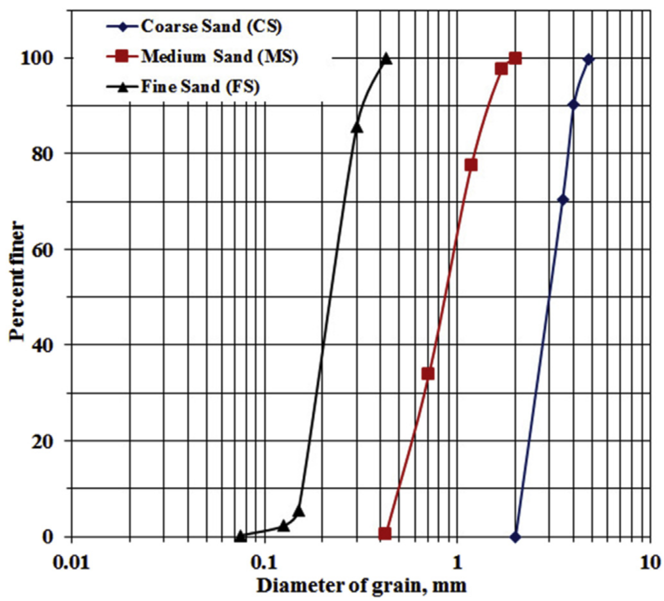

Fig. 1. Grain size distribution of sands used in this study.

the estimation of these parameters, compromising on the accuracy (Moradi, 2014).

The objective of this study is to investigate the mechanism of interlocking between the sand particles of different sizes and reinforcing materials with different surface asperities and its effect on their interfacial friction and dilation angles. Several symmetric loading interface shear tests were performed on sands of different particle sizes with similar morphological characteristics, interfacing with planar reinforcing materials with different surface features. Advanced digital imaging techniques were adopted for material characterization and experimental interpretations to enhance the clarity and accuracy of testing.

2. Materials used

Three sands of different particle sizes with similar morphological characteristics were used in this study. These sands were obtained by scalping specific size fractions from river sand of the same origin. They are coarse sand (CS: particle size 4.75 mm–2 mm), medium sand (MS: particle size 2 mm–0.425 mm) and fine sand (FS: particle size 0.425 mm–0.075 mm), classified as poorly graded sands (SP) as per Unified Soil Classification System. Grain size distribution curves for these sands are presented in Fig. 1. Fig. 2 shows the photographs and Scanning Electron Microscopic (SEM) images for understanding

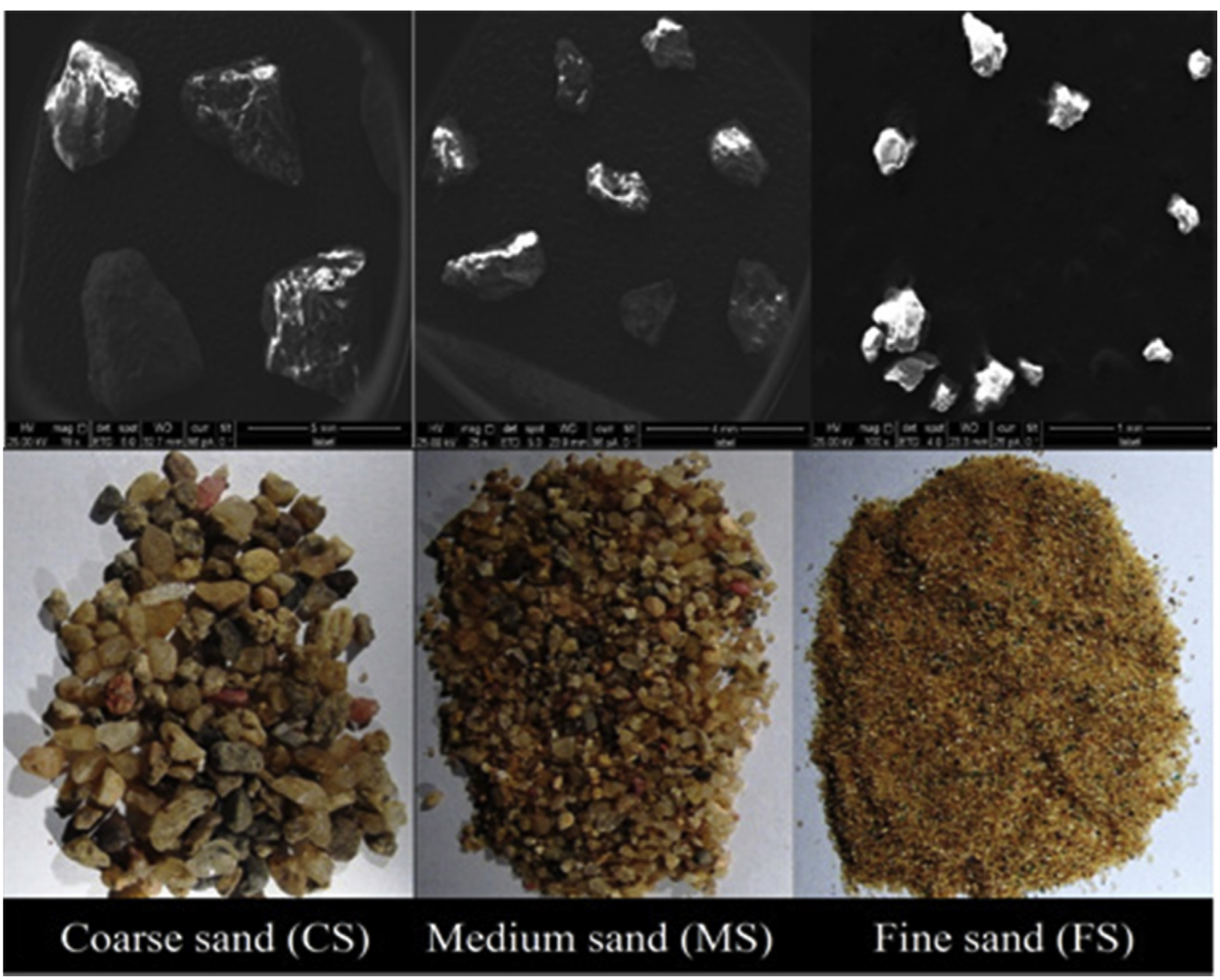

Fig. 2. Photographs and Scanning Electron Microscopic (SEM) images of sand.