

論文の内容の要旨

論文題目 Pre-failure Multiple Yield Characteristics of
Lightly Cemented Geo-materials
(弱固結土の多段階降伏特性)

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Cementation is the chemical bonding between particles by carbonates, silica, alumina, iron oxides and organic compounds. In soils, this can take place artificially and/or naturally. The Japan Cement Association (2008) observes that, 6million tons of cement or associated products are used annually for soil treatment. Cement or its derivatives have been widely accepted as a material of choice to improve the strength and performance of geomaterials. This is based on numerous studies that have confirmed the benefits of cementation on the overall increase in strength and in the liquefaction resistance of geomaterials. The effect of cementation on the overall increase in strength directly informs on the effect of cementation on the traditional definition of yielding- the transition of stress strain behaviour from elastic to plastic behaviour- with the existence of only one boundary which can be defined as the failure point. But, it is a well understood fact that this is not the general behaviour of geomaterials. The stress-strain behaviour of geomaterial: will have multiple transitions before failure (shift to plastic behaviour), consists of a very small elastic region and with the pre-dominant stress-strain behaviour being elasto-plastic.

For typical geotechnical structures such as tunnels, foundations and retaining walls the stress-strain behaviour is limited to the pre-failure-yield stress-strain region. Furthermore, the increased complexity in construction projects, such as that of urban construction where the performance of nearby structures has to be maintained, demanding that the deformations be maintained to very small ranges, the understanding of the pre-failure yield property becomes the criteria for design and construction control. This research seeks to clarify the influence of cementation on the pre-failure yield properties of geomaterials, with a focus on a lightly cemented geo-materials.

To achieve the objective, stress path test using a triaxial machine were conducted on 5 types of geomaterials: Toyoura sand (Uncemented), Miho Sand (plastic sand $PI=25.4\%$), Un-weathered Cement Treated Miho Sand (UWCT-Miho Sand), Weathered Cement Treated Miho Sand (WCT-Miho Sand) and Soft Rock (Pleistocene Mudstone). The focus is put on Miho Sand, WCT-Miho Sand and UWCT-Miho Sand. Stress Path tests were selected for this study, as they closely represent the likely complex stress-strain behaviour that can be experienced during construction and in the life of typical structures. During the test elastic stiffness is measured statically and dynamically. The effect of cementation on pre-failure yield properties is discussed in regards to three aspects: the elastic stiffness and quasi-elastic stiffness properties, the kinematic multiple yield loci following the definitions of Kuwano R. (1999) and Jardine R. J. (1992) and the plastic flow properties by checking normality on established yield loci.

The elastic stiffness is defined as the stiffness measured at strains less than or equal to 0.001% strain, with observed behaviour being pre-dominantly linear elastic and strain rate independent. But as has been previously reported, at strains less than or equal to 0.001%, damping can be observed, and some strain rate dependency can be observed, the stiffness measured under such conditions is referred to as quasi-elastic. Two types of stiffness are obtained the: vertical elastic modulus-statically measured and shear modulus-dynamically measured. The statically measured elastic modulus is determined by applying small cycle vertical stress while keeping the horizontal stress constant. Dynamic shear modulus was obtained by shear wave measurements using two pairs of bender elements attached to the sides of the specimens at mid-height. In relation to elastic and quasi-elastic stiffness, the study focused on influence of cementation on stress dependency and the degradation of stiffness with shearing.

It was observed that on elastic stiffness, in addition to increasing the

magnitude of stiffness, cementation minimizes the dependency of elastic stiffness on stress level as has been reported previous, but in weakly cemented soils, the likelihood of isotropic change in structure may result to a shift to increased stress dependency. By standardizing measured elastic and quasi-elastic stiffness measured during shearing, with the maximum stiffness: in the case of Uncemented material, degradation was observed to occur on onset of dilation while for cemented material up to a shear strain invariant of 1% no degradation was observed. Cementation has the effect of delaying dilation.

Three yield loci were established. Y1 which is a locus enclosing a predominantly linear elastic region. Y2 which is a locus enclosing a predominantly nonlinear elastic region and from this point plastic strains start to form rapidly. Y3 which is the outer most yield loci depicting the point from which the overall deformation is mainly plastic. For the highly cemented, Soft Rock, all of its yield loci were ten times larger than those of all other materials. In the case of the lightly cemented material- UWCT-Miho sand- the Y1 and Y2 loci were comparable in size to the denser Miho sand, the effect of cementation was not apparent. However, in the Y3 locus the effect of cementation became dominant with the Y3 of UWCT-Miho sand being greatly enlarged. The effect of weathering the cement treated Miho sand samples was shrinking all the yield loci. It should be noted that the cement treated samples had a degree of compaction of about 85% while that of Miho sand was 95%. This indicates a higher density of the Miho sand had the effect of increasing the contact surface compared to addition of 3% cement by mass to Miho sand. Therefore, having stronger quasi-elastic properties.

By establishing the plastic strain increment direction, and plotting, its directions on the established yield locus, on both Y2 and Y3 locus for all materials, the total and plastic strain increment directions were all rotated. No specific effect of cementation on normality could be reported.