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授与学位	博　士(工学)
学位記番号	理工博甲第681号
学位授与年月日	平成28年３月２日
学位授与の要件	学位規則第４条１項
研究科，専攻の名称	理工学研究科(博士後期課程) システム設計工学系専攻
学位論文題目	Characteristics of Clayey Silts with Low Plasticity Focusing on the Undrained and Partially Drained Shear Strengths and New Approach to Soil Classification
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【学位論文内容の要旨】

In this thesis, characteristics of clayey silts with low plasticity located at western site of Korean peninsula were analyzed focusing on the evaluation of fully undrained and partially drained shear strengths. Several points of soil classification using Casagrande's plasticity chart were discussed and revised Polidori's plasticity chart were suggested through verification of applicability using Korean four different marine clayey soils.

Firstly, it was carried out to investigate the applicability and problems of soil classifications based on the plasticity charts for natural marine soils taken from four different Korean coastal areas, and also through comparison with the plasticity charts in Casagrande and Polidori. The liquid limit and plastic limit of fine-grained soils could be altered according to both the percentages of the silt and clay fraction, therefore, the silt fraction is proposed to be almost as important as the clay fraction in relation between the Atterberg limits and these compositional fractions. In conclusion, Polidori's revised plasticity chart based on the CF=30% borderline proposed by this study appears to be more appropriate for the classification of silt or clay. This is because no distinction exists above the A-line where the natural soils taken from the four different coastal areas lie on the empirical plasticity chart proposed by Casagrande, and these soils were classified as silt by Polidori's plasticity chart.

Secondly, a series of laboratory and in-situ tests were carried out to evaluate undrained strength of clayey silts with low plasticity at Incheon and Gunsan sites. The applicability of UC in determining the undrained strength of these soils was examined. It can be concluded that UC test is not suitable for evaluating the undrained shear strength of low plastic soils. Therefore, in evaluating the undrained shear strength of soil with a low plasticity index, effective confining

pressure that corresponds to typical marine clay should be applied to a soil specimen before shearing in order to compensate for the lost residual effective stress. In this case, the CIU (recompression test) proposed by Tsuchida and Mizukami can be quite useful in duplicating the in situ shear strength of a soil. The undrained shear strength normalized by the yield consolidation pressure, s_u/p'_c, are presented for four coastal sites, that is, Busan/Gwangyang and Incheon/Gunsan having the characteristics of high and low plasticity, respectively. The field vane shear strengths, s_u(FVT), were compared with the unconfined compressive strength, $q_u/2$ which has been used as a representative testing method in Korea.

Many researchers have suggested that the undrained shear strength normalized by the yield consolidation pressure, s_u/p'_c depends on I_p. However, the undrained shear strength normalized by the yield consolidation pressure, s_u/p'_c is in the range of 0.25 to 0.35, independently of the plasticity index, Ip except for $s_u/p'c$, using $q_u/2$ values in case of soils having a low plasticity such as Incheon and Gunsan clayey silts.

Bjerrum's correction factor has been commonly applied to evaluate the mobilized undrained shear strength using the field vane test in Korea. However, the corrected undrained shear strengths using Bjerrum's correction factor, including Morris and Williams' method were considerably underestimated for Korean marine clay when compared with the $q_u/2$ values that have been used as the mobilized undrained shear strength for practical design in Korea.

Thirdly, partial drainage characteristics of clayey silts with low plasticity were analyzed using laboratory and in-situ tests. When estimating whether low plastic soil is under partially drained conditions or not, the approach recently proposed by Schnaid et al., can be quite useful. This approach is based on plotting the normalized cone resistance, Qt, vs. the pore pressure parameter, Bq in combination with the strength incremental ratio s_u/σ'_{vo}, from the CPTU data. It is evident that two-thirds of the results fall in the range where $Bq < 0.3$, corresponding to the domain in which partial drainage prevails when testing normally consolidated soils at a standard rate of penetration (2cm/s).

Fourthly, the comparison of stability analysis regarding fully undrained and partially drained concepts for a low plastic soil, respectively, were carried out to check economic feasibility of each design concept. The replacement depths were estimated by applying a series of internal friction angles to consider its sensitivity under partially drained conditions. The estimated replacement depths (Compulsory replacement method) and replacement ratio, as (SCP method) were drastically changed with a slight change of internal friction angles. Accordingly, selecting appropriate strengths in stability analysis is the most important thing. According to back analysis from field measurement data at completed construction sites applied compulsory replacement method and the analysis of CPTU based strengths, the internal friction angles under partially drained conditions ranged from $\varphi'=5°$ to $\varphi'=15°$. At the present stage, it is very difficult to select appropriate φ' value to design improvement of clayey silts under partially drained conditions beneath gravity type structures such as breakwaters, quay walls, and revetments. Therefore, when applying partially drained concept in designing soft ground improvement, it is recommended that the lowest $\varphi'=3\text{-}5$ ° be applied to stability analysis from the view point of safety side.

From now on, further in-depth study should be carried out regarding the applicability of each design concept focusing on the evaluation of partially drained strength (φ') of the intermediate soil through detailed analysis of dissipation trend in CPTU data.

【論文審査結果の要旨】

低塑性の粘土質シルトが広く分布する地盤に大規模な護岸等の施工を行う際には、支持力あるいは長期沈下に対して高塑性粘性土とは異なる概念で施工が可能となることから、朝鮮半島の西海岸に広く分布する低塑性粘性土の非排水及び部分排水せん断強度特性を調べるとともに、土質分類にあたってポリドリの塑性図を用いた新たな適用法を示した。まず、韓国内の４地域で採取した海成粘土について土質分類を行い、キャサグランデの塑性図の適用性の問題点、すなわち、韓国に分布している低塑性と高塑性粘性土によらず、塑性図においてはA-線の上部に位置するため、粘土として分類されることから、現場において肉眼では明らかにシルトとして判別される場合にも粘土と判定される可能性があることを示した。また、粘土とシルトの位置が塑性図上では逆転するポリドリの塑性図を適用した場合には、細粒分含有率が30%を境界としてポリドリの塑性図を修正することによって、粘土及びシルトに対してより的確に土質分類が行なえることを示した。特に、砂の含有率が増加する場合に同じ液性限界を保つためには、膨張性の高い粘土鉱物の含有が必要で、その場合にはより高い塑性指数を示すことから、ポリドリの塑性図上では粘土とシルトが逆になることを明らかにした。

一方、韓国の仁川及び群山地域の地盤の非排水強度特性を調べた結果、低塑性地盤においては、不攪乱試料を採取する際に拘束圧として作用する残留有効土被り圧が失われ、一軸圧縮試験では強度を著しく過小評価することから、海成粘土の強度評価のために提案された再圧縮三軸試験(簡易CU試験)を用いて、非排水強度を推定することが望ましいことを示した。

さらに、ベーンせん断強度のBjerrumによる補正式は韓国の海成粘土に関しては適用性が低いこと、さらに韓国の海成粘土の地盤改良の設計で広く用いられているSkemptonの強度増加率式も韓国の海成粘土に相応しくないことを示すとともに、強度増加率は塑性限界によらず0.25-0.35の範囲に分布することを示した。

そこで、韓国の仁川地域でコーン貫入試験を行い、コーン貫入抵抗値と間隙水圧の深度分布によって、地盤内の部分排水状態の有無を調べた結果、当該地盤は載荷時には部分排水状態にあることを見出した。また、コーン抵抗値の分布と強制置換深さをもとに逆解析を行って、内部摩擦角の分布を示すとともに、非排水と部分排水状態を想定して、護岸基礎の地盤改良設計を行った。その結果、再圧縮三軸試験(簡易CU試験)の強度と部分排水強度を用いることによって、経済的な施工になり得ることを示した。また、地盤の置換深さは内部摩擦角のわずかな変化によって著しく影響を受けることから、設計で用いるべき部分排水条件下における内部摩擦角の推奨値を示した。

公聴会での主な質問内容は、砂層の連続性、強制置換の土量の推定、一軸圧縮試験の適用性にかかわる展望、韓国と日本の土質の成因の違い、この研究成果の適用性等についてであったが、いずれの質問に対しても発表者から的確な回答がなされた。

以上より、本論文は低塑性粘土質シルト地盤を対象とする施工において新たな知見を与えることから、学術上極めて重要であり、新規性、独創性、信頼性、有効性、実用性ともに優れ、博士（工学）の論文に十分値するものと判断した。

論文内容及び審査会、公聴会での質問に対する応答などから総合的に判断して、最終試験は合格とした。

なお、主要な関連論文の発表状況は以下のとおりである。（関連論文：2編）

1) Wonjin Baek, Juhyun Kim, Hiroshi Matsuda, Ryohei Ishikura, Koouho Hwang : Characteristics of intermediate soil with low plasticity from Incheon, Korea, International journal of offshore and polar engineering, Vol. 24, No. 4, pp. 309-319, 2014.

2) Juhyun Kim, Hiroshi Matsuda, Sangguk Jeong, Wonjin Baek : Applicability to Korean marine clay of the mobilized undrained vane shear strength using correction factors, Marine Georesources and Geotechnology, Vol. 33, 2, pp. 150-159, 2015.