General Report - Session II
Laboratory Testing of Geomaterials: Strength Properties and Treated Soil

Rapport général - Session II
Essais de laboratoire des géomatériaux : propriétés mécaniques et sols traités

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ABSTRACT: This report presents a brief review of 30 papers submitted for the session on Laboratory Testing of Geomaterials II: strength properties and treated soils. The paper topics were very diverse but the papers were separated into four broad categories : 1) shear strength, 2) treated soil, 3) testing method and 4) miscellaneous. Some papers include valuable database of important strength parameters for design and some of the tested soils include special soils. The report includes discussions related to the categories, summarizes the papers, and highlights their major conclusions.

RÉSUMÉ : Ce rapport présente un bref résumé des 30 contributions soumises à la session Essais de laboratoire des Géomateriaux II: propriétés mécaniques et sols traités. Les sujets traités ont été variés, mais finalement les contributions écrites ont été groupées en quatre grandes catégories: 1) résistance au cisaillement, 2) sols traités, 3) méthode d'essai et 4) sujets divers. Certains articles comprennent des bases de données pertinentes de paramètres importants de résistance pour la conception d'ouvrages et certains sols testés font partie des sols spéciaux. Le rapport comprend des discussions liées aux catégories, synthétise les résultats et met en évidence leurs principales conclusions.

KEYWORDS: laboratory test, shear strength, treated soil, testing method, database

1 INTRODUCTION

The theme of this session focuses on Laboratory Testing of Geomaterials II: strength properties and treated soils. The 30 papers submitted to this session are reviewed and summarized in this report. To guide readers to the most relevant papers, Table 1 is provided in the appendix that shows the paper ID and main focus of each paper, subdivided into four broad categories: a) shear strength, b) treated soil, c) testing method, and d) miscellaneous. The first session of shear strength was subdivided by three topics: 1) database of strength and stiffness properties, 2) gas-hydrate bearing soil and mining by-products, and 3) soil fabric and particle characteristics.

The diversity of authors and tested soils truly highlights the international nature of our profession. Authors are from Australia, Brazil, Chile, Denmark, France, Greece, Hong Kong, Hungary, India, Iran, Iraq, Japan, Korea, Mexico, South Africa, Sweden, Taiwan, Thailand, United Kingdom, and United States, based on the first author. Some of the papers include some valuable database such as anisotropic strength ratio of natural clays (2173), drained strength parameters from New Orleans area (2280), over-consolidated Danish clays (2399), soft and stiff Bangkok clays (2872), and rockfill materials (3011). Some of the tested soils include special soils such as gas-hydrate bearing ground in the Lake Baikal (2001), hydrophobic (non-wettable) sand (2178), soil with diatom microfossils in Mexico City (2239), coal mine debris (2782), and copper mine tailings (2800). The report includes discussions related to the categories, summarizes the papers, and highlights their major conclusions.

2 SHEAR STRENGTH

2.1. *Database of Strength and Stiffness Properties*

In the design of getechnical structures, strength and stiffness parameters obtained by well-documented database and/or correlation with index properties are valuably utilized in the early stage of design. This session introduces test database including anisotropic undrained strength ratio, the comparison of drained strength parameters obtained by traxial and direct shear tests, drained strength parameters on OC Danish clay, stiffness and strength parameters for Bangkok clays and rockfill materials. For cohesive soils, strength parameters are correlated with plasticity index and compared with the well-known empirical correlations by Broker and Ireland (1965), Berre and Bjerrum (1973), and Ladd et al. (1977). Strength and stiffness parameters based on Duncan and Chang (1970) model were obtained for Bangkok clay, Baghdad soil, and rockfill materials. Six papers are in this topic and each paper is summarized as below.

In paper 2137, Won developed the relation between anisotropic strength ratio (K_s=S_{uE}/S_{uC}) and plasticity index using the collected database of 203 pairs of triaxial tests performed on NC natural clays from 14 countries. For a consistent comparison, data selection criteria were carefully established. He found that the anisotrophy was strongly influenced by the definition of failure in extension test, and no general trend of anisotrophy with plasticity were observed, once the anisotrophy data are grouped into their depositional environments (Fig.1). It is interesting to note that this is opposite to the well-known trend that anisotrophy decreases with plasticity index and he emphasized the importance of careful consideration of site specific characteristics, spatial variability, depositional and post-depositional environments of the clay.

In geotechnical projects, triaxial and direct shear tests are often used interchangeably to determine drained shear strength parameters without regard to the potential difference. In paper 2280, Castellanos and Brandon performed a series of 63 consolidated undrained (CU) triaxial tests and 146 consolidated drained (CD) direct shear tests on undisturbed samples from New Orleans area to compare the shear strength parameters. They showed that drained friction angles obtained from the CU triaxial tests were considerably higher than those obtained from CD direct shear tests in New Orleans area (Fig 2) because

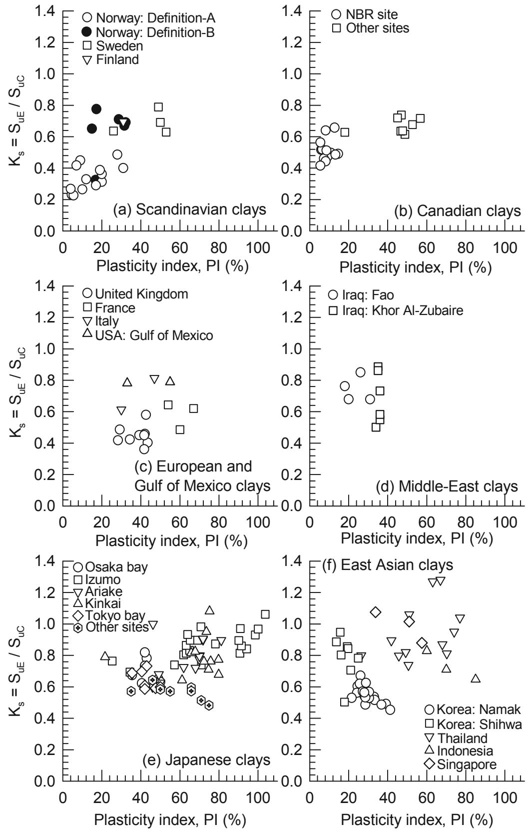


Fig. 1 Anisotropic strength ratio versus plasticity index for different depositional environments from J.Y. Won, paper 2137.

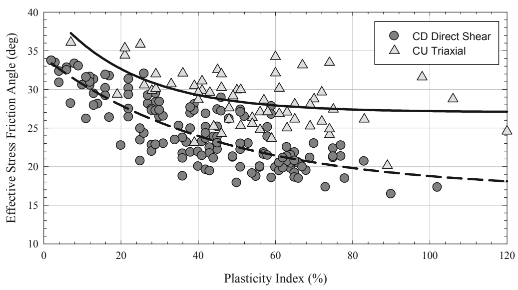


Fig. 2 Relationship between effective stress friction angle and plasticity index for CD direct shear tests and CU triaxial tests on undisturbed samples from Castellanos et al., paper 2280.

natural soils can have a preferred particle orientation or anisotropic fabric based on the deposition of the soil. The difference was much less when remolded specimens were tested.

Empirical correlations between the index properties and the strength and deformation properties of cohesive soils are useful in geotechnical engineering practice. In paper 2399, Sorensen and Okkels have suggested simple correlations between plasticity index and drained peak strength parameters in terms of ϕ'_{oc} and c'_{oc}. The database includes triaxial compression test results on undisturbed OC Danish clays from very low to extremely high plasticity obtained from recent projects including Great Belt bridge, Fehmarnbelt investigation, and Esbjerg Harbour. The proposed correlations give cautious lower bound values of drained strength parameters, which can be used as a first approximation for use in the preliminary design (Fig. 3 and 4).

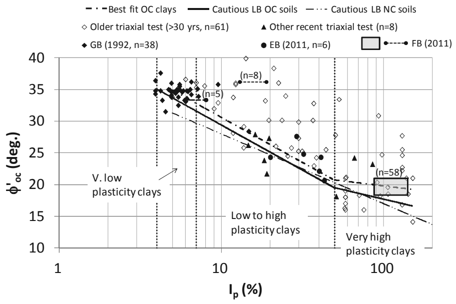


Fig. 3 Relationship between peak angle of shearing resistance ϕ'_{oc} and plasticity index I_P for overconsolidated undisturbed clays from Sorensen et al., paper 2399.

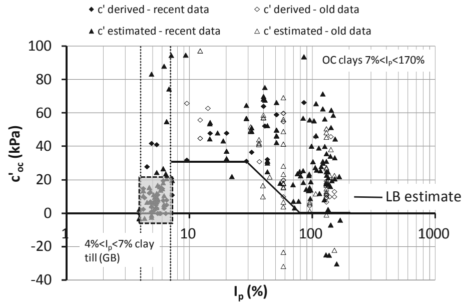


Fig. 4. Relationship between effective cohesion c'_{oc} and plasticity index I_P for overconsolidated undisturbed clays from Sorensen et al., paper 2399.

In paper 2639, al-Damluji et al. provided the bounding surface plasticity model parameters for Baghdad soils by K_o-consolidated compression and extension triaxial undrained tests. They mentioned these parameters can be used in the foundation design in the central Baghdad.

In paper 2872, Likitlersuang et al. re-analysed the stress-strain data of soft and stiff Bangkok clays carried out at Asian Institute of Technology (AIT). Several series of isotropic consolidated drained and undrained compression (CID, CIU) and extension (CIUE, CIDE) tests were carried out at AIT. The finite element software PLAXIS contains the hardening soil model as an extension of the Duncan-Chang hyperbolic stress-strain model. The stiffness and strength parameters required for the hardening soil model to model undrained and drained behaviors were obtained.

In paper 3011, Aghadam and Soroush studied mechanical behavior of thirty types of rockfill materials based on the hyperbolic model under triaxial compression. The rockfill materials are categorized as three types: highly angular, angular, and rounded. The exponent number was found to be dependent on confining pressure due to the particle breakage. The correlations estimating initial Young's modulus and friction angle were suggested based on particle shape, confining pressure, and uniformity.

2.2. *Gas-hydrate Bearing Soil and Mining By-Products*

Energy resource development is a facing problem of mankind. Gas-hydrate is an attractive energy source but the production is challenging due to following uncertainties such as changes in stress condition due to pore pressure changes during phase transition and sediment softening and volume contraction due to loss of hydrate bonding (Lee et al., 2011). Safe and economical storage of by-products in the coal and copper mines is an important geotechnical problem. Three papers are in this topic and each paper is summarized as below.

Gas hydrates(GH) are attracting an attention as a next generation energy source but there are concerns that dissociation of GH and exsolution of dissolved gas can reduce the stability of seabed and may induce seafloor landslides. In paper 2001, Yamashita et al. studied the effects of sample disturbance due to the exsolution of dissolved gas in gas-hydrate bearing deep lake bottom sediments in Lake Baikal. The hand vane shear and cone penetration tests were performed for core samples. The laboratory simulation of stress relief caused by bringing samples to the surface was also performed by CO_2 gas. They showed that the effects of the sample disturbance become larger and the strength is lower with the increase of gas concentration.

The overburden materials in the coalfields of South East Queensland are dominated by uncemented rocks, which rapidly break down on excavation to extract coal and bulk up to a very loose density. In paper 2782, Williams and Kho performed the direct shear test and staged creep compression test on scalped specimens under dry and wet conditions. They found that wetting-up causes a substantial reduction in shear strength and they quantifies the settlement and shear strength of uncemented overburden materials excavated from open pit mining in the coalfields.

Both the increased production in the copper mining industry and the decrease of available space for the construction of tailing deposits led to the design of dam having unprecedented height above 250m. In paper 2800, Campana et al. performed the drained and undrained triaxial tests on four different tailing sands from copper mines located in Chile and Peru by applying confining pressure up to 3 Mpa. The deformation moduli, static and cyclic shear strength under drained and undrained conditions, densities and fine contents have been obtained. It was found that tailing sands have shear resistance and shear modulus values greater than expected in natural sands.

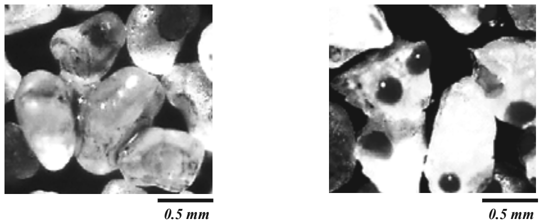
2.3. *Soil Fabric and Particle Characteristics*

Fabric is a collective term to describe the geometric arrangement of grains and voids, and the distribution of inter-particle contacts, and the influence of initial fabric on stress-strain-strength responses received great attention and the uniqueness of critical state has been great challenged (Negussey and Islam, 1994). The particle characteristics such as particle shape, surface roughness, and angularity can affect inter-particle behaviors. Soils in nature often become hydrophobic (non-wettable) due to organic pollutants, wild fire, oil spill, and the difference in surface properties result in clear difference in flow and mechanical behaviour even in macro scale (Kim et al., 2010). Five papers are in this session and two of those are studied by numerical simulations.

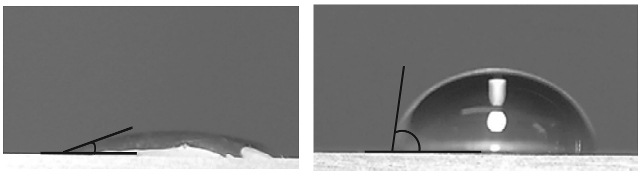
The strength parameters are very important to conduct the stability analysis of earth structures but test results using reconstituted specimens change easily depending on the sample preparation method. In paper 2043, Kotaka et al. studied the effects of initial water content during sample preparation on undrained shear behaviour in gravel-mixed sand. They thought that initial suction in the specimen produce various soil structure and verified using numerical simulation by the SYS Cam–clay model. It was found that numerical simulation can reproduce the various types of experimental shear behaviours of the gravel-mixed sand derived from the different soil structures.

The Jacky's K_o equation is commonly used for the estimation of K_o but uncertain aspect still exists which value of friction angle be adopted because the friction angle is a state-dependent variable. In paper 2166, Lee et al. investigated the effects of particle shape, surface roughness, and angularity on Jacky's ϕ'-K_o relation using normal sand, glass bead, and etched glass bead in the oedometer type thin-wall K_o test. They found that the measured K_o values for loose sand were close to the calculated values using inter-particle friction angle whereas for dense sand, critical state friction angle produced close match to the measured one, implying that the application of peak friction angle may underestimate K_o value. For glass beads, calculated K_o values using critical state angle were in good agreement with measured results in loose and dense states.

In paper 2178, Kim et al. studied the hydraulic and geomechanical properties of non-wettable sands using artificially synthesized hydrophobic sands. Sands without any treatment and with chemical treatment were used. Fig 5 shows water distribution in hydrophilic and hydrophobic sands observed by an optical microscope. They found that surface modification at nano-scale determine the spatial configuration of water phase in pore space and its impact on fluid flow and strength with varying degree of saturation prevails.



(a) Spatial distribution of water in the wettable sands
(b) Spatial distribution of water in the non-wettable sands



(c) Contact angle on the wettable surface (~13°)
(d) Contact angle on the non-wettable surface (~85°)

Fig. 5 Optical observations of water droplet formed on the weattable and non-wettable samples in the micro scale from Kim et al., paper 2178.

Non-coaxial behavior of saturated sands, which refers to the non-coincidence of the principal stress directions and the principal plastic strain rate directions, were studied using hollow cylinder apparatus in paper 2489. Yang et al. found that the effective stress ratio has a significant effect on the non-coaxiality of sand. The volumetric strain of sand induced by cyclic rotation of principal stress axes was mainly contractive and it occurs during first few cycles.

Critical state refers to a state where material undergoes continued distortion at constant volume and constant stresses, and the advances in modern laboratory tests have initiated the discussion on the effect of fabric on critical state and thus its uniqueness. In paper 2960, Yan and Zhang investigated the fabric evolution of idealized two-dimensional assemblages having different initial fabrics subject to numerical biaxial shearing. It was found that a unique fabric of particle orientation and void space is achieved at very large strains where the stresses and volume of the assemblages are constant.

3. TREATED SOILS

Soft soils are prominently found in coastal regions and low land areas where many important infrastructures are located. Various admixtures are currently used to enhance the mechanical and flow properties of clay and sand soils. Historically, Portland cement and lime have been used for this purpose (Tim Newson, 2009). Recently, cement-mixed gravelly soil is used to construct bridge abutments for high speed trains in Japan and lightweight cemented clays are used as a backfill for quay walls and bridge abutments. This session deals with various kinds of treated soils including lime treated soil, cement mixed soft clay, clay with diatom microfossils, cement mixed gravelly soil, asphalt aggregate, and lightweight cemented clay.

In paper 1831, Hibouche et al. studied the small strain behaviours of lime treated soil using small strain triaxial tests equipped with two types of sensors to measure local strains: strain gauges and Hall effect sensors. Both measurements were compared. The elastic moduli derived from cycles in strains less than 10^{-4} were compared with those deduced from the elastic wave speed. Relations between the modulus, the strain level, and the hardening were established.

Compared to other methods of improving the soft ground, deep cement mixing and mass stabilization with binders are rapid techniques of ground improvement. In paper 2174, the interaction of binders with the soft clay and improvement in strength were studied based on water/cement ratio, water content of clay, and curing time. The used binders include cement, lime, fly ash, slag and Sodium Silicate. The unconfined strength increased with decreasing water/cement ratio irrespective of initial water content of clay and the addition of Sodium Silicate to cement enhance the strength significantly.

There are several sites in the world where diatom microfossils have been detected in the soil deposits. Those soil deposits have singular physical and mechanical properties that do not follow the well-established empirical relations. In paper 2239, a series of oedometer tests was performed on artificially prepared mixtures of diatom microfossils and kaolin and it was observed that the presence of diatom microfossils substantially alters the index properties as well as compressibility.

The cement-mixed gravelly soil (CMG) is widely used in geotechnical engineering and it is needed to develop the design and construction procedures. In paper 2287, a series of drained triaxial compression tests were performed on laboratory prepared specimens and rotary core samples from the field. To better correlate the strength and deformation characteristics of CMG, two independent parameters are postulated; the soil skeleton porosity, n_s (representing the structure of the skeleton of gravelly soil particles only), and the cement void ratio, C_r (representing the fraction of the void of the soil skeleton occupied by cement). An empirical equation to predict the compressive strength is proposed using soil skeleton porosity, which controls initial compressive strength, and the cement void ratio which controls the increasing manner of q_{max} with curing time. The effects of grading characteristics on the strength were not significant but the effects of specimen volume were significant.

The soil cement technique has been used in pavement base layers, slope protection for earth dams, as a base layer for shallow foundations, and to prevent sand liquefaction. In paper 2579, the elastic moduli of soil-cement mixtures in terms of shear and constrained moduli at small strain were measured with time based on wave propagation by Consoli et al. Significant increase in stiffness was observed compared to the uncemented sands as curing process continues. The unique relationships linking modulus values with porosity/cement ratio and curing time was developed.

The behaviour of asphalt under slow rates of loading and of the role of the aggregate skeleton is important when pavement is subject to subsidence. In paper 2851, Airey and Prathapa performed a series of conventional drained and undrained triaxial tests on two types of asphalt, stone mastic asphalt(SMA) and dense asphaltic concrete(DAC). Tests without asphalt binder have also been conducted. The behaviour of asphalt was observed sensitive to the details of the aggregate grading. For DAC, the behaviour was controlled by the aggregate particles but little affected by bitumen, whereas the bitumen has a significant effect on stress-strain-strength behaviour for SMA.

Lightweight cemented clays have wide applications as a backfill to reduce the earth pressure, as a fill on soft soil to reduce overburden pressure, and as a method of reducing pressure on the tunnel lining. In paper 3040, Horpibulsuk et al. found that the void/cement ratio, V/C, is the prime parameter governing the strength and compression characteristics. The yield stress in K_o-consolidation and compressive strength increase as V/C decreases and a relationship between strength, void/cement ratio for a particular water content and curing time was proposed.

4. TESTING METHOD

This section describes six papers that review the testing methods for soil properties. The measured soil properties include compaction, particle size distribution, tensile strength of soil, permeability, dispersive soil, and dry density of soil. The importance to understand proper mechanism, reliability of test results, source of errors and the need to develop optimum procedure without ambiguity are discussed in this session.

In paper 2210, Perez et al. studied gyratory compactor which is developed to simulate the field compaction mechanism produced by the sheep foot roller. The controlled variables were gyration angle, vertical pressure, and number of gyrations. The optimum water content was reduced and dry density was increased as the vertical pressure increases, but the compaction curves are similar regardless of gyration angle and rate. It was suggested that using heavy equipment rather than many passes is more effective to increase the dry density.

The particle size distribution of coarse-grained soils is traditionally determined by sieve tests. In paper 2248, Ohm and Hryciw discussed two image-based systems, the Sedimaging (for 2.0 mm to 0.075 mm particles) and the Translucent Segregation Table (TST) (for 75 mm to 2 mm particles). These tests do not require that particles be physically detached from one another unlike previous image-based methods. Testing setup of TST is shown in Fig. 6. Sedimaging uses mathematical wavelets to determine particle sizes and requires a camera magnification that provides at least 3 pixels per particle (PPD=3). The TST uses watershed analysis to digitally detach particles and requires PPD=9. The minimum PPDs must be achieved while capturing entire specimens in the camera's field of view. Extension of the systems to silt sized particles is explored.

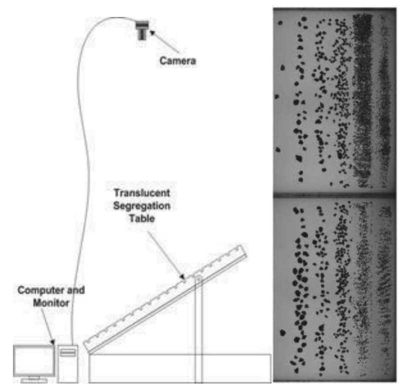


Fig 6. Translucent Segregation Table (TST) from Ohm & Hryciw et al., paper 2248.

The tensile strength of soil is an important parameter in the design of geo-systems, where tensile cracks contribute to the progressive erosion or landslides in excavation, slopes, dams, riverbanks and other earth structures. In paper 2572, Ge and Yang developed indirect indentation method based on an upper bound solution to a split tension failure in limit analysis and performed a series of indentation tests on lightly cemented sand. The limitation of this method is that a certain level of brittleness of the specimen is required so that a split tension failure would occur.

Coefficient of permeability can vary over an order of magnitude depending on the testing method even in a relatively homogeneous layer. In paper 2930, Nagy et al. determined and compared permeability coefficients of a sandy silt and a silty sand obtained by Khafagi probe, Menard probe, water filtration method, constant head and falling head laboratory tests. As shown in Fig. 7, the result showed higher scattering than expected which has a relative error of one order of magnitude. They suggested that it is not practical to use different measurement methods in a single borehole because swapping may result in measured findings showing greater differences than normally accepted.

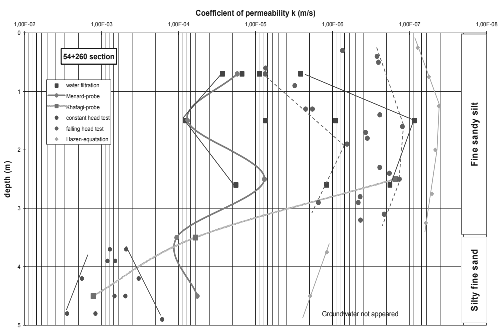


Fig. 7 Measured permeability coefficients from Nagy et al., paper 2930.

The reliable identification of dispersive soil is crucial but recent testing suggests that many shortcomings related to testing of dispersive soils have been overlooked during past routine investigations. In paper 2976, a comparative study involving the testing of three samples using one standard test, the SCS double hydrometer test, was carried out. Maharaj and Paige-Green observed that the variability of the results appears to be the cause of many of the ambiguities and discrepancies in the classification system and stressed the needs to develop optimum procedure which is simple and have as few ambiguities as possible so that no misinterpretation can occur.

In paper 3084, Imre et al. performed a statistical analysis based on the results of two doctoral programs concerning the dry density of sands (Kabai 1974, Lorincz, 1986). They showed that the different dimension of the mold has some impact on the measurement of minimum dry density and the e_{max} test of the German DIN may be biased because of the arching due to the too small ratio of the diameter and height of the mold.

5. MISCELLANEOUS

Hardening due to thixotropy is important mechanism for the very soft dredged soils with high water contents. In paper 2446, Tanaka and Seng studied the thixotropic hardening by measuring change in stiffness and strength with time using bender element and vane shear tests. The effect of thixotropy was found to be significant at around the liquid limit state and the increment of shear modulus due to thixotropy appeared noticeably higher than that in the secondary consolidation.

In paper 2494, Athanasopoulos et al. studied a 30m high slope failure at the Xerolakka municipal solid waste landfill. Field investigations including Lidar survey and shear wave velocity measurements to characterize the MSW materials were performed and numerical analysis was followed. The results indicated that failure was caused by a combination of factors including inappropriate waste disposal practices and compaction, leachate and gas pressure generation and increased steepening of the landfill slopes.

In paper 2705, Sarma and Sarma described the influence of minerals on the elastic behaviour of cohesive soil. They mentioned that the pattern is unique for cohesive soil and is under the possible domination of the existence of a common mineral and extent of its weathering process.

6. REFERENCES

Papers in the session of Laboratory Testing of Geomaterials II: Strength Properties and Treated Soil (please see Appendix-Table 1)

ADDITIONAL REFERENCES

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APPENDIX

Table 1. List of papers in Laboratory Testing of Geomaterials II: Strength Properties and Treated Soil

Title	Author(s)	Test soil	Testing Method	Main Topics
1. Strength				
1.1 Database of strength and stiffness properties				
Anisotropic strength ratio and plasticity Index of natural clays (No. 2137)	J. Y. Won (U.S.A)	Natural clay	CK_0UC, $C K_0UE$ 203 Data Base from 14 countries	The well-known trend between $\frac{S_{UE}}{S_{UC}}$ & PI cannot be justified Careful consideration of site specific characteristics
A comparison between the shear strength measured with direct shear and triaxial devices on undisturbed and remolded soils (No. 2280)	Castellanos & Brandon (U.S.A)	Undisturbed and remolded clays in New Orleans	CU TX test CD DS test	Comparison between drained strengths measured by direct shear and triaxial test Importance of preferred particle orientation based on horizontal deposition
Correlation between drained shear strength and plasticity index of undisturbed overconsolidated clays (No. 2399)	Sorensen & Okkels (Denmark)	Undisturbed OC Danish clays	TXC test (305 data collection from old & recent projects)	Drained peak strength vs Plasticity index Lower bound □*'* and *c'* for preliminary design
Bounding surface plasticity model parameters for Baghdad soils (No. 2639)	Omar al-Farouk Salem al-Damluji et al. (Iraq)	Undisturbed and disturbed soil sample	K_0 & isotropically consolidated TXC & TXE	Parameters for bounding surface plasticity model for Baghdad soil
Duncan-Chang parameters for hyperbolic stress strain behaviour of soft Bangkok clay (No. 2872)	Suched Likitlersuang et al. (Thailand)	Soft and stiff Bangkok clay	Drained & undrained TXC and TXE Data Base from AIT	Undrained & drained strength & stiffness parameters for hardening soil model of Bangkok clay
Interpretation of stress-dependent mechanical behaviour of rockfill materials (No. 3011)	Jannati Aghdam & Soroush (Iran)	Rockfill materials	TXC test 30 types of database	Variations in deformation and strength parameters of rockfill material with confining pressure
1.2 Gas-hydrate bearing soil and mining by-products				
Evaluation of sample disturbance due to the exsolution of dissolved gas in the pore water of deep lake bottom sediments (No. 2001)	Yamashita & Miura Kitami (Japan)	Lake Baikal, Russia gas hydrate-bearing sediment	Field: VST, CPT Lab: UC; Simulation of exsolution of dissolved gas	Effects of exsolution of dissolved gas in the pore water on strength properties Reduction of strength with the increase of gas concentration
Settlement and shear strength of uncemented coal mine overburden materials placed loosed under dry and wet conditions (No. 2782)	Williams & Kho (Australia)	Overburden materials in coal mine	DS test Staged creep compression test	Settlement of overburden material due to self-weight, collapse on wetting and degradation
Shear strength and deformation modulus of tailing sands under high pressures (No. 2800)	Campana & Bard (Chile)	4 tailing sands from copper mines	Drained & undrained TX tests with confining pressure up to 3MPa	Compare strength, modulus, and cyclic shear resistance of tailing sands with natural sands
1.3 Soil fabric and particle characteristics				
Soil structure in gravel-mixed sand specimen and its influence on mechanical behaviour (No. 2043)	Kodaka et al. (Japan)	Gravel-mixed sand	Undrained TX test Numerical simulation	Effect of initial suction during specimen preparation on soil structure and strength
Effect of particle characteristics on K_o behavior for granular materials (No. 2166)	Hun Hwan Lee et al. (Korea)	Jumunjin sand glass beads etched glass beads	Oedometer test to measure K_0	Effects of particle shape, surface roughness and angularity on □*'*-K_0 relation
Non-coaxial behaviour of sand in drained rotational shear (No. 2489)	Yang et al. (U.K)	Leighton Bazzand sand	Drained rotational shear test with hollow cylinder apparatus	Non-coincidence of principal stress directions and principal strain increment directions
Characterization of geomechanical and hydraulic properties of non-wettable sands (No. 2178)	Dae hyun Kim et al. (Korea)	Jumunjin sand	Hydraulic tests DS test	Hydraulic and mechanical properties of non-wettable sands
Fabric and critical state of granular materials (No. 2960)	Yan & Zhang (Hong Kong)	Mono-sized pill shape rigid particle	Numerical biaxial test (discrete element)	Particle orientations and void space at large strains

Title	Author(s)	Test soil	Testing Method	Content
2. Treated soils				
Small strain behaviour of a lime-treated soil (No. 1831)	Hibouche et al. (France)	Lime treated soil	Small-strain TX test	Relations between small strain modulus, strain level hardening time
Mechanisms of binder interactions and their role in strengthening Kuttanad clay (No. 2174)	Suganya & Sivapullaiah (India)	Organic clay Binder : cement, lime, slag, fly ash	UC test	Interaction of binders with soft clay and its effect on strength
Influence of diatom microfossils on soil compressibility (No. 2239)	Diaz-Rodriguez & Gonzalez-Rodriguez (Mexico)	Kaolin with diatomite	Oedometer test	Compressibility of kaolins increase sharply with addition of diatomite
Strength properties of densely compacted cement-mixed gravelly soil (No. 2287)	Ezaoui et al. (France)	Cement mixed gravelly soil	TXC test	Effects of degree of compaction, cement content, curing time, gradation, specimen volume on q_{max}
Experimental analysis of the mech-anical properties of artificially cem-ented soils and their evolution in time (No. 2579)	Consoli et al. (Brazil)	Cemented sand	BE using S and P waves	Characterization of soil-cement mixtures in terms of Go,Mo with porosity/cement ratio and curing time
Triaxial testing of Asphalt (No. 2851)	Airey & Prathapa (Australia)	Stone mastic asphalt (SMA) & dense asphaltic concrete (DAC)	TX test	Asphalt response under slow rate loading and role of aggregate skeleton
A key parameter for strength control of lightweight cemented clays (No. 3040)	Horpibulsuk et al. (Thailand)	Lightweight cemented clay	Oedometer test, UC test	Void/Cement ratio as the prime parameter for strength & deformation
3. Testing method				
Behaviour of fine-grained soils compacted with high shear stresses (No. 2210)	Perez et al. (Mexico)	Clay, silt, sand	Gyratory compactor Standard & modified proctor	Effect of vertical pressure, angle of gyration and number of gyrations on compaction curve
Enhanced soil characterization through advances in imaging technology (No. 2248)	Ohm & Hryciw (U.S.A)	Coarse grained soil	Sedimaging Translucent segregation table	Particle size distribution with imaging technology
Tensile strength of lightly cemented sand through indentation tests (No. 2572)	Ge & Yang (Taiwan)	Lightly cemented sand	Indentation test (Tensile strength)	Indirect method for determin-ing tensile strength of lightly cemented sand
Comparison of permeability testing methods (No. 2930)	Nagy et al. (Hungary)	Sandy silt and silty sand	Field: Menard probe, Khafagi probe, water fiteration Lab: Const. or falling head	Comparison and reliability of various permeability methods
The SCS double hydrometer test in dispersive soil identification (No. 2976)	Maharaj & Paige-Green (South Africa)	Dispersive soil	Double hydrometer test	Ambiguity and discrepancies in the classification system
Some notes concerning the dry density testing standards (No. 3084)	IMRE et al. (Hungary)	Danube and Bochum sands	Density test for e_{min} and e_{max}	Biased in e_{max} measurement due to arching
4. Miscellaneous				
Hardening process of clayey soils with high water content due to thixotropy effect (No. 2446)	Tanaka & Seng (Japan)	Soft clays	BE VST	Thixotropic hardening of clays with high water content
The December 29th 2010 xerolakka municipal solid waste landfill failure (No. 2494)	George Athanasopoulos et al. (Greece)	Municipal solid waste (MSW)	Field: LIDAR, SASW, Remi Numerical simulation	Landfill failure due to inappropriate compaction, leachate and gas pressure generation and steepening slope
Influence of minerals on the elastic behaviour of cohesive soil (No. 2705)	Sarma & Sarma (South Africa)	Cohesive soil	N/A	Influence of prime mineral and its weathering process on elastic behaviour

Nationality is based on the first author
TX : Triaxial, VST : Vane Shear Test, UC : Unconfined Compression, DS : Direct Shear, TXC : Triaxial Compression, TXE : Triaxial Extension, BE : Bender Element test, CPT : Cone Penetration Test