SRI LANKAN GEOTECHNICAL SOCIETY 1986 SLGS

# SLGS NEWSLETTER

SRI LANKAN GEOTECHNICAL SOCIETY

Established in 1986 A Member Society of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE)

## A Message from the Editor

2007 January: No 1

Another year gone, a new year has begun, and this is the first issue of SLGS Newsletter in 2007. This year, SLGS has a lot of activities to celebrate its 20th Anniversary and expects the maximum contribution from the members for its success.
This January Newsletter contains an article from Prof. Kazuo Tani of Yokohama National University, Japan based on his presentation in September Geotechnical Forum on *Measurement of Stress-Strain Relationships of Rock Ground by Field Tests.*
Asia is the most disaster prone region in the world. Among the natural hazards that annually impact Sri Lanka, floods and landslides are known to be the most destructive to property, crops and infrastructure, and landslides is one of the worst for causing death and injury. Now, geotechnical engineers have to come up with innovative ideas and solutions to mitigate these disasters we are often facing. Let's work together and find solutions. If you have innovative ideas, please write to SLGS. We always welcome your contributions and NEWSLETTER is ready to publish them.

SLGS wishes its members a very successful and prosperous year 2007!

Dr. Udeni P. Nawagamuwa – Editor Newsletter.

## New Year Message from the President

It is my great pleasure to extend our readers my best wishes and greetings for the new year 2007 that marks the Sri Lankan Geotechnical Society's 20 years of service to the nation.

The Society was inaugurated on 27th February 1986 as a forum for scientists, engineers and geologists for the exchange and advancement of knowledge in the field of Geotechnical Engineering, especially when the need was much felt at a time of vibrant development activities in the country.

The yeoman service Society has done over the years was not possible without the guidance of our past Presidents late Prof. A. Thurairajah, Prof. B.L.Tennekoon and Eng. D.P. Mallawaratchie and the tireless contribution made by the office bearers and dedicated members who voluntarily served on various committees. The support given by the industry and many well wishers here and abroad helped to keep the society active throughout the period. SLGS is proud of them and appreciates their services.

Today, with many hopes for a peaceful Sri Lanka, we have ahead of us another era of numerous small to large scale development programmes for reconstruction and rehabilitation of all what we have lost due to natural and manmade disasters or negligence and for creating new infrastructure for the national needs. Such development programmes cannot be successfully achieved without the active involvement and participation of Geotechnical professionals who are often needed from planning to well beyond completion of a project.

We also need to realise that there is a severe dearth of geotechnical engineers practicing locally to meet this challenge and it is the duty of the Society to promote developing resources in the geotechnical sector. I openly request all those responsible, including the policy makers, for education & training of personnel and research & development in the geotechnical field to pay due attention on the present status and join us in our efforts.

I believe that our members have tremendous capacity, perhaps yet to be explored or exploited, to take up the challenges. I invite you to actively participate in all SLGS activities. Please share your knowledge and experience by contributing articles, technical notes and papers on projects or research work you are involved in to the newsletter and the journal, or by presenting them at the Geoforums, seminars or conferences. Pose your questions to SLGS for answers by appropriate professionals. At your work place, try to build up enthusiasm among your colleagues on geotechnical interests. Give your suggestions, to improve the activities of the Society for the benefit of larger membership and eventually the public for whom we serve.

**Kirthi Sri Senanayake - President, SLGS**

**The First Sri Lankan Geotechnical Society (SLGS) International Conference on Soil and Rock Engineering, Colombo, August 5-11, 2007 at Hotel Galadari, Colombo**

Pre conference short courses will be held from Sunday the 5th August to Tuesday the 7th. Details of the courses offered and registration process are given in the short course brochure. Please register early and reap the maximum benefits.
International Conference will be held on 8th, 9th and 10th. Participants can register for either 2 days or for all three days. More than 200 abstracts were received and organisers expect that around 150 papers will be published and presented. A number of top researchers, academics and practitioners from all around the globe have contributed with papers on all aspects of geotechnical engineering. Please do not miss this opportunity to meet top geotechnical experts in the world.

Further details on registration are given in page 6.

**Contents**

# Development of In-situ Triaxial Test for Rock Masses

By Prof. Kazuo Tani, Yokohama National University,Yokohama, Japan

**ABSTRACT**

A new field test method was proposed for the purpose of directly measuring average stress-strain relationships and to investigate strength and deformation characteristics of rock masses. The test is conducted on a hollow cylindrical specimen prepared at the bottom of a drill-hole. Average axial as well as lateral strains can be measured in a centre hole and an outer slit by a novel technique of instrumentation for cavity deformation. A set of test equipment for this test method was developed and improved at Central Research Institute of Electric Power Industry, CRIEPI, in Japan. Trial series of tests were carried out at the site of rhyolitic tuffacious rock and psephite of Neogene system. The results, similar to conventional laboratory triaxial tests, proved that the proposed test method was successful to measure average stress-strain relationships of large rock specimens.

*Keywords: Field Test, Rock Mass, Shear Strength, In-situ Test, Strength, Deformation*

## 1. INTRODUCTION

At present, deformation characteristics of rock masses are investigated by plate load tests and pressuremeter tests, while the strength characteristics are investigated by rock shear tests. These conventional in-situ test methods, however, have some problems as follows:

(1) Deformation and strength characteristics are investigated separately.

(2) Test results may significantly be affected by stress relief and disturbance of the loading surfaces.

(3) Stress and strain relationships are not measured directly.

(4) Strength characteristics in deep ground cannot be evaluated.

A new field test method (hereinafter referred to as “in-situ triaxial test for rock masses”) found the solution to the above problems. The test method was proposed in 1997 (Tani, 1999). In the next year, a set of test equipment for this test method was developed at Central Research Institute of Electric Power Industry in Japan, denoted as CRIEPI (Tani, 2001). The rock specimen is prepared at the bottom of a drill-hole. The test can be conducted at any depths and avoid disturbed zones by excavating. Axial and lateral strains are measured in the centre hole and the outer slit of the hollow cylindrical specimen. Since the measurement is done at mid-height on the side of the specimen, any unwanted influence of the bedding errors around the top surface and of the bottom restraints can be eliminated. The outer cell is a hollow cylinder with its inner and outer sides being covered with rubber membranes. Rigid strong body of the outer cell is not needed because the surrounding rock mass takes all the reaction forces induced by the outer pressures.

## 2. TEST PROCEDURE

Figure 1 illustrates the test procedure for the proposed method (Tani et al., 2003). The test starts with drilling the bottom of the drill-hole into a hollow cylindrical shape, hereafter denoted as Drilling stage. Then, this hollow cylindrical rock specimen is loaded axially while being pressurized laterally hereafter denoted as Loading stage.

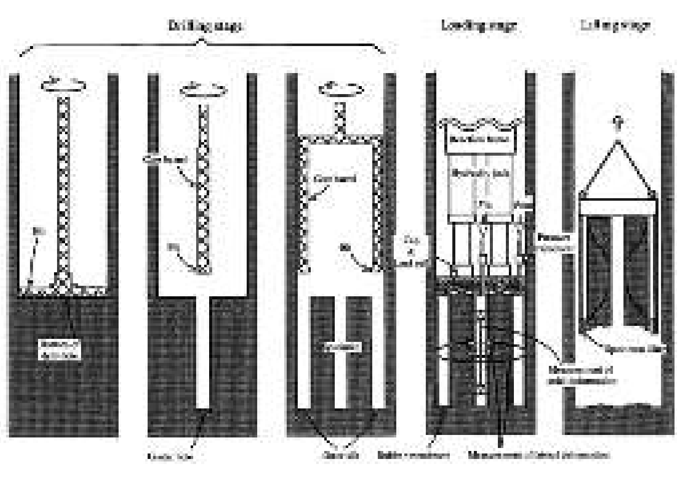

Fig. 1. Test procedure of in-situ triaxial test for rock masses (Tani, 2003)

Finally, the sheared specimen is retrieved out of the drill-hole to the ground surface, hereafter denoted as Lifting stage.

In the Drilling stage, firstly, the bottom of the drill-hole is prepared as a flat surface that will serve as the top of the specimen. Secondly, a conventional rotary drilling technique is used for drilling a centre hole of a small diameter and an outer slit of a large diameter with a suitable width. From the centre hole, a drilled core can be obtained which can provide useful information of the tested ground. In the Loading stage, an inner cell and an outer cell are inserted into the centre hole and the outer slit, respectively. The former is a solid cylinder, while the latter is a hollow cylinder, both of which are equipped with rubber membranes on their lateral sides. Hydraulic pressures $p_{in}$ and $p_{out}$, are provided to both inner and outer cells to apply lateral pressures on the sides of the specimen through the rubber membranes. At the same time, axial force, $Q$, is loaded on the cap which placed on the specimen. After the Loading stage, the specimen is cut at its bottom, and lifted to the ground surface for further observation, thus the Lifting stage. Close inspection is then conducted to collect any useful information as for heterogeneity, discontinuity and shear bands/fractures in the rock specimen. The purpose is two-fold: (1) to judge if the tested specimen is representative of the surrounding rock mass of interest, and (2) to examine its failure mechanism which may help improve interpretation of the test results.

## 3. SPECIFICATIONS OF TEST EQUIPMENT

The size of specimens is determined so that the test results can be considered for rock masses rather than for rock cores, thus designed to be 86mm in the inner diameter, 400mm in the outer diameter, and about 1050mm high. The maximum lateral pressure is 5.0MPa, while the maximum axial force is 8000kN, which is approximately 66MPa in terms of maximum axial stress. A novel technique of instrumentation for cavity deformation, hereafter denoted as ICD, was invented for this deformation monitoring (Tani and Tachikawa, 1998).

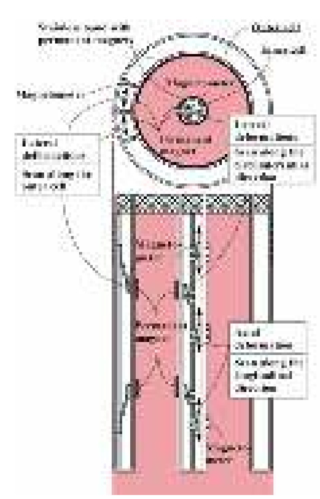

Fig. 2. Locations of ICD (Instrumentation for Cavity Deformation) measurement

Figure 2 schematically explains the conceptual principle of ICD. This ICD utilizes magnetometers as detectors of small pieces of permanent magnets as displacement markers placed on the cavity wall. Both axial and lateral deformations of the cavity wall at any longitudinal location can be monitored by this single system of ICD. Axial movements of a permanents magnet placed on the cavity wall can be measured by a magnetometer that scans along the longitudinal direction. On the other hand, lateral movements of a cavity wall are measured as changes in the circumferences or arc lengths.

## 4. TEST AT THE SITE OF TUFFACIOUS ROCK

*4.1 Outline of test*

Field tests were carried out at the site of abandoned open quarry in Ohya, about 100km north of Tokyo. The tested ground was Miocene deposit of rhyolitic tuffacious rock formation, generally denoted as green tuff formation or ‘Arame (Coarse)’ Ohya stone. A total of seven tests, Test 1 to Test 7, were carried out. Keeping the inner and outer pressures as identical, $p_{in}=p_{out}$, various kinds of triaxial compression tests were attempted. These included six conventional single-step loading triaxial tests (Test 1-4, 6, 7) and one multiple-step loading triaxial test (Test 5; Kovari and Tisa, 1975). Confining pressures, $\Im_c$, were set as 0.0, 0.4, 1.0, 2.0 and 3.5 MPa. The drilled cores, 66 mm in diameter, retrieved from the centre holes demonstrated that the rock mass was generally continuous with scarce joints. The only exception, however, was the one used for the multi-step loading triaxial test 5), where a single distinct joint of discontinuity was observed at 340-346 mm from the top of the specimen.

*4.2 Test result*

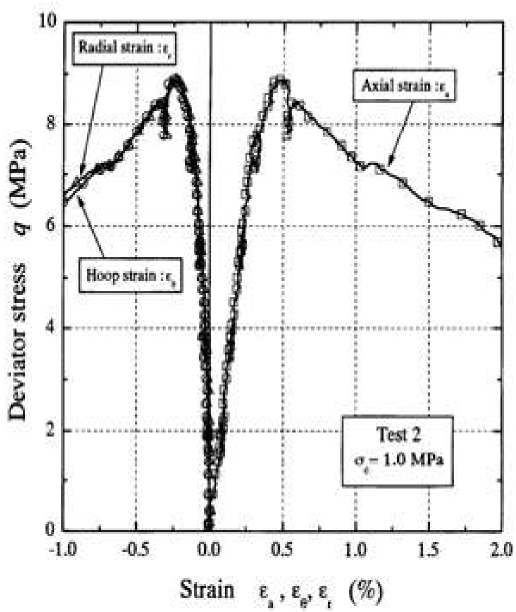


Fig. 3. Relationship between average stress and average strains forTest2 (Tani, 2003)

The test result for Test 2, as the relationships between the deviator stress, $q=\Im_a-\Im_c$, and the axial as well as lateral strains, $\Im_a$, $\Im_3$, and $\Im_r$, is shown in Figure 3 (Tani, 2001). Axial strains, $\Im_a$, are calculated as average axial strains measured within a mid-section which is 567 mm long in the centre hole. Circumferential strains, or hoop strains, $\Im_3$, are calculated as average values measured at two depths in both inner and outer cells. In addition, interestingly enough, radial strains, $\Im_r$, can be measured for this test method, unlike equivalent laboratory triaxial tests where solid cylindrical specimens are used. They are calculated from the radial displacements at the inner and outer sides of the specimen, which are otherwise estimated from circumferential/hoop strains, $\Im_3$, assuming the axisymmetric condition. Figure 4 demonstrates the stress points at peak states together with the deduced Mohr-Coulomb’s failure criteria. The peak strength parameters are found as $c$=2.9 MPa, ℑ =18ℵ for single-step loading triaxial tests, while lower values $c$=1.8 MPa, ℑ=17ℵare obtained from multiple-step loading triaxial test (Test 5). The discrepancy is probably due to the weaker specimen for Test 5, which exceptionally includes a distinct joint in the middle. All the specimens were retrieved to the ground surface after the Loading stage. As shown in Photo.1, the specimen exhibited several shear bands which were steeply oblique, bearing some 50 to 65 degrees from the horizon, in the middle heights.

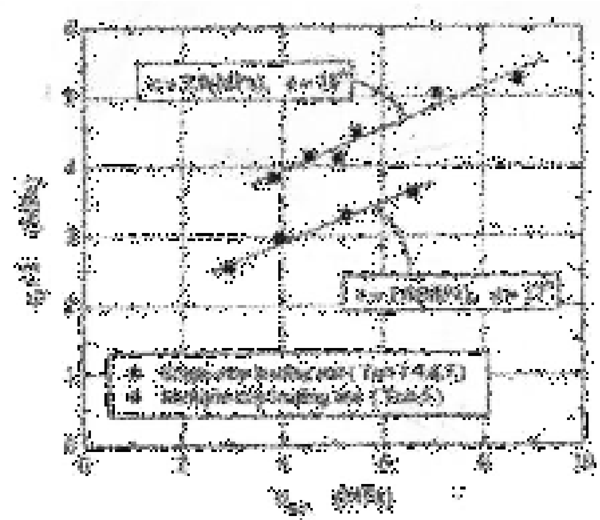

Fig. 4. Peak strength characteristics by in-situ triaxial compression test (Tani, 2003)

## 5. TEST AT THE SITE OF PSEPHITE

*5.1 Outline of test*

Before the tests, improvements on the measurement system were made in order to raise their measurement precision and shorten their sampling interval.

Figure 5 explains the conceptual principle and the arrangement of the displacement transducers. Both axial and lateral deformations of the

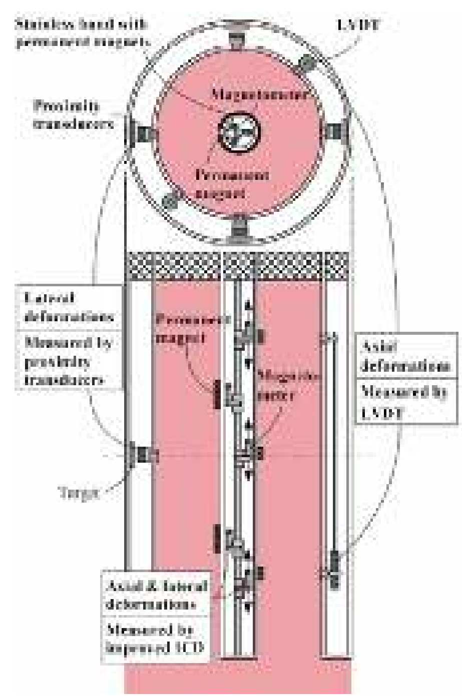


Fig. 5. Improved measurement system Fig. 4. Peak strengths characteristics by in-situ triaxial compression test (Tani, 2003)

specimen can be measured by ICD in the centre hole and by two LVDTs and four proximity transducers (PT) in the outer slit. Field tests were carried out in a 9m-deep exploratory adit (Okada et al., 2006). The rock mass at the site is sedimentary rock of conglomerate of Neogene system. The matrix of the rock is categorized as a soft rock. The compressive strengths of the gravel of the rock are about 20 times as large as the corresponding values of the matrix. A total of six triaxial tests were carried out, hereafter denoted as C-1, C-2, C-3, T-1, T-2 and CY respectively. These included three triaxial compression tests (C-1, C-2, C-3), two triaxial extension tests (T-1, T-2) and a cyclic triaxial test (CY). In C-1, C-2 and C-3, multiple-step loading triaxial compression tests were conducted. Confining pressures of the first step, $\Im_{c0}$ , were set as 0.2, 0.3 and 1.0 MPa. In P-1 and P-2, the specimens were directly extended in the axial direction under confining pressures. Confining pressures, $\Im_c$, were set as 1.0 and 3.0 MPa.

*5.2 Test result*

The triaxial compression test result for C-2, as the relationships between the deviator stress, $q=\Im_a-\Im_c$, and the axial as well as lateral strains, $\Im_a$ and $\Im_\Theta$ is shown in Figure 6. The axial strains measured by

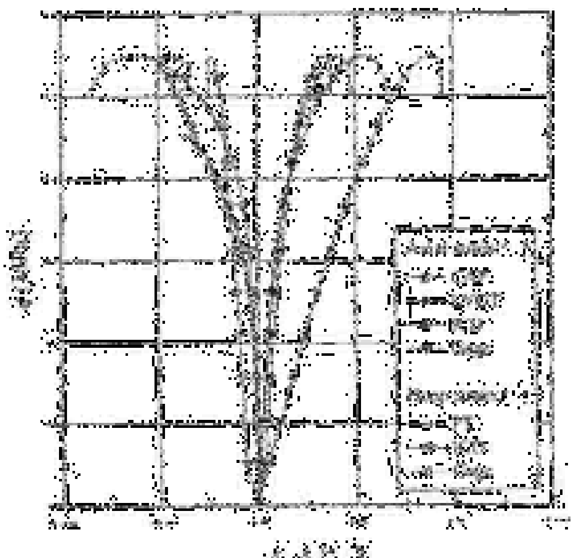

Fig. 6. Relationship between average stress and average strains for C-2

LVDTs, ICD and strain gages were in reasonable agreement with each other. The failure axial strains measured by the external displacement transducers (CAP) are about twice as large as the corresponding values measured by the others on the side of the specimens. The lateral strains measured by ICD approximately agreed with the corresponding values measured by potentiometers (PT). The lateral strains measured by strain gages were different from the others. It should be noted that strain gages with a limited gage length ofℵ90mm are not suitable for measurements of deformation for inhomogeneous rock masses. The above-mentioned tendencies could be seen for the test results in C-1 & C-3. The triaxial extension test result for P-1, as the relationships between the deviator stress, $q=\Im_a-\Im_c$, and the axial as well as lateral strains, $\Im_a$ and $\Im_\Theta$ is shown in Figure 7. Like the triaxial compression test, the axial strains measured by LVDTs, ICD and strain gages were in reasonable agreement with each other. The lateral strains measured by PT approximately agreed with the corresponding values measured by strain gages, however strain values by ICD were different form the others. It can be considered that stainless bands of ICD rounding the rubber membrane of the inner cell might not follow the cavity deformation. The above-mentioned tendencies could be seen for the test results in P-2. Figure 8 compares the test results, as the relationships between the deviator stresses and the effective mean stresses, of laboratory triaxial tests on the small drilled cores and the in-situ triaxial tests on the large specimens. Although further studies

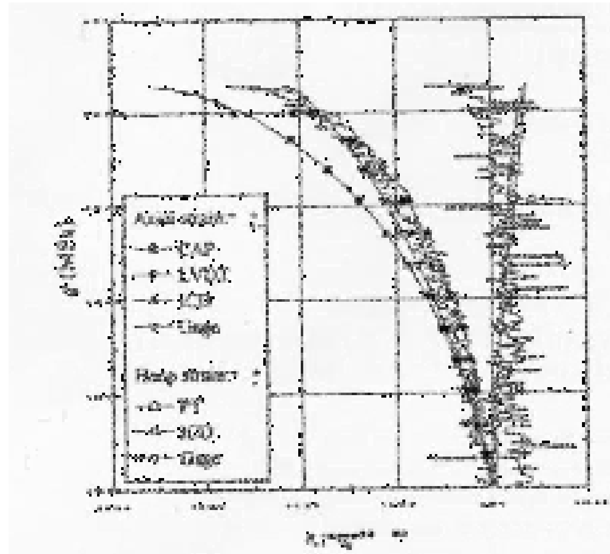

Fig. 7. Relationship between average stress and average strains for P-1

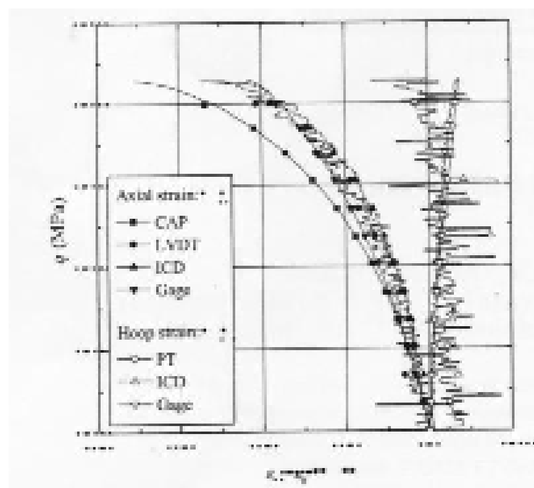


Fig. 8. Test results of laboratory and in-situ triaxial test

are needed regarding scale effect, the strengths of the in-situ and laboratory triaxial tests were in reasonable agreement with each other. Some of the specimens were retrieved to the ground surface after the tests. As shown in Photo.2, the specimen after the triaxial compression test (C-1) exhibited a shear band bearing about 60 degrees to the specimen's axis. Discontinuities observed a little below the middle of the specimen appeared before the test. As shown in Photo.3, the specimen after the triaxial extension test (P-1) exhibited a failure plane developed perpendicular to the specimen's axis in the mid-height.

**6. CONCLUSIONS**

A new field test method was proposed for the purpose of directly measuring average stress-strain relationships and to investigate strength and deformation characteristics of rock masses. Trial series of tests were carried out at the site of rhyolitic tuffacious rock and psephite of Neogene system. The results proved that the proposed test method was successful to measure average stress-strain relationships of large rock specimens for the first time in the world.

We believe that the proposed in-situ triaxial test will substitute plate load test, rock shear test for rock ground investigation in the near future. In order to put this test method to practical use, further examinations are needed to enhance applicability to discontinuous rocks, and thus it is important to improve drilling method of the specimen.


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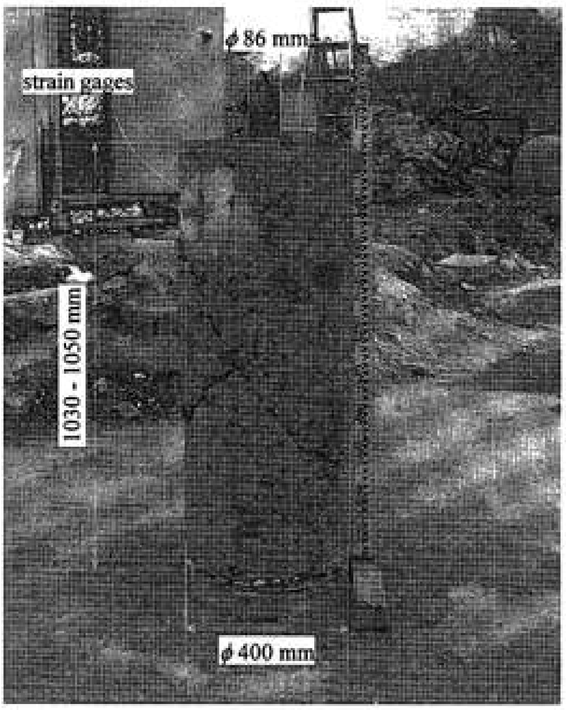


Photo 1. Specimen retrieved after Test 2 (Tani, 2003)

Photo 2. Specimen retrieved after test (C-1)

Photo 3. Specimen retrieved after test (P-1)

**Volunteers needed…………………**

The SLGS Conference Organizing Committee needs desperate support from SLGS members and others who can work voluntarily in the detailed organization, logistical matters and help in secretarial activities to organize The First Sri Lankan Geotechnical Society (SLGS) International Conference on Soil and Rock Engineering, Colombo, from August 5-11, 2007, at Galadari Hotel, Colombo. This is a golden opportunity for active young engineers to take part in organizing the conference. Active volunteers' professional career will be benefited from the knowledge through exchange of information and discussions that would take place at these gatherings. Further, that will also give opportunities to develop new friendships and renew old friendships with participants from all over the world.

If your university/ institution prefer to nominate persons who can help in these activities, please be kind enough to communicate with the local co-chairs whose contact details are given below. We are waiting for your prompt response…….

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Mr. Kirthi S. Senanayake
Conference Co-chair
Consultant
National Building Research Organization
Sri Lanka
Email: senanayakeks@hotmail.com

## Forthcoming Conferences

(1). III Asian Conference on Unsaturated Soils (21 – 23 April), Nanjing, China, www.geohohai.com/english/unsat.htm

(3). Geotechnical Engineering for Disaster Prevention & Reduction (25 – 27th July 2007), Yuzhno – Sakhalinsk – Russia. Contact: Prof. Askar Zhusupbekov, askarz@nets.kz

(4). X ANZ Conference on Geomechanics (21 – 24 October), Brisbane, Australia anzgeo2007@ccm.com.au

(5. XIII Asian Regional Conference on Soil Mechanics and Geotechnical Engineering (10 – 14 December), Calcutta, India. www.13arc2007.com

(6). **First Sri Lankan Geotechnical Society International Conference on Soil and Rock Engineering (6-11th August,**
b **2007), Colombo, www.slgssr2007.org**

The SLGS Newsletter comes to you in volumes of four fascicles issued in January, April, July and October in each year.


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*Note: The views expressed by authors are not necessarily the views of SLGS.*

## Geotechnical Forums since the last issue

*Geotechnical Aspects and Inputs in a Lake Conservation and Management Project by Mr.Kirthi Sri Senanayake, Consultant, National Building Research Organization on 2nd November 2006*

*Behavior and Stabilization of rail tracks constructed on soft unstable formations by Prof. Buddhima Indraratna, Head, Faculty Postgraduate Studies, School of Civil, Mining and Environmental Engineering, University of Wollongong, Australia on 19th December 2006*

*Role of Public in Natural Disasters by Dr. A.G.H.J. Edirisinghe, Senior Lecturer, University of Peradeniya on 25th January 2007.*

**First Sri Lankan Geotechnical Society International Conference on Soil and Rock Engineering.**
Sri Lankan participants have the option to register for either two days or for all three days. Presentations that are of special relevance to Sri Lanka will be covered in two days.
Registration fee for two days is Rs 7500/= and for three days Rs10,000/=
Registration fee covers the conference kit(conference bag with a CD on accepted papers, hard copies on abstracts and keynote lectures) and lunch and refreshments. For further details refer the web site.
**www.slgssr2007.org**

## SLGS and ISSMGE Membership Fees

All the ISSMGE Members who still have not paid their membership fees for the years 2005 & 2006 are requested to pay any dues immediately to ensure their names are not deleted from the ISSMGE Membership List.
**Members are informed that following membership fees are effective from year 2007.**

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| Membership Admission Fee | Rs. 200/= |
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| ISSMGE Fee | Rs. 1000/= |

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