N.Z. GEOMECHANICS NEWS

No. 22

JUNE 1981

A NEWSLETTER OF THE N.Z. GEOMECHANICS SOCIETY

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C O N T E N T S

Persons interested in applying for membership of the Society are invited to complete the application form at the back of this newsletter. The basic annual subscription rate is $12.00 and is supplemented according to which of the International Societies, namely Soil Mechanics ($5.00), Rock Mechanics ($7.50), or Engineering Geology ($3.50) the member wishes to be affiliated. Members of the Society are required to affiliate to at least one International Society.

EDITOR'S NOTES

1. Article on Contour Blasting

This issue contains an article by Ian Brown on contour blasting in underground openings. Blasting is undertaken in most rock engineering projects, and in the last decade there have been significant advances in explosive technology. Many problems in rock construction projects can be attributed to uncontrolled blasting. Research into blasting techniques and their effects has recently been initiated by the Engineering Geology Section of the N.Z. Geological Survey.

2. Letters to the Editor

This issue, for the first time for a number of years, contains no letters to the Editor. It is hoped that the situation is not permanent as there certainly is sufficient activity on the Geomechanics scene to generate commentary on topical points.

3. Membership Application

To assist Society members in recruiting new members, an application form can be found at the back of this issue. Please note that to facilitate the management committee's task of scrutinising the applications, prospective members are required to be nominated by existing financial members of the Society. Prospective members are requested not to send subscription fees with their applications.

4. Change of Address

Members are reminded that changes of address should be notified to the Institution Secretary, using the form provided in the back of this newsletter.

5. Contributions Wanted

Contributions to N.Z. Geomechanics News may be in the form of technical articles, notes of general interest, letters to the Editor, or book reviews, and may cover any subject within the fields of Soil Mechanics, Rock Mechanics and Engineering Geology. Articles on site investigations, construction techniques or design methods which have been successfully used in New Zealand, and which would be of help to other members, would be particularly welcome. All contributions should be sent to:
The Editor, N.Z. Geomechanics News, C/- N.Z. Geomechanics Society,
P.O. Box 12-241, Wellington North.

S.A.L. Read
Editor

PUBLICATIONS OF THE SOCIETY

The full proceedings of the Third Australia-New Zealand Conference on Geomechanics held in Wellington in May 1980 have been printed. They comprise 3 volumes, the first two being the papers presented, the third a transcript of the discussions and various invited papers presented by visiting dignitaries.

Topics dealt with at the conference include rockfill, house foundations, buried structures, piles, soft ground, reinforced earth, soil properties, tests and specifications, in situ test methods, engineering geology, rock mechanics, landslides, rock slope stablity, soil slope stability, stress-strain models, mining,underground work, mathematical analyses. Titles of the papers are listed in volume 20 of Geomechanics News.

The following publications of the Society are available:

(a) From the Secretary, NZIE, P.O. Box 12-241, Wellington North:

- "Stability of House Sites and Foundations - Advice to Prospective House and Section Owners". (Published for the Earthquake and War Damage Commission) Price $0.50.
- Proceedings of the Third Australia-New Zealand Conference on Geomechanics, Wellington, May 1980. Price $90.00 for the three volume set.
- Proceedings of the Hamilton Symposium "Tunnelling in New Zealand", November 1977. Price $18.00 to members, $20.00 to non-members.
- Proceedings of the Second Australia-New Zealand Conference on Geomechanics, Brisbane, July 1975. Price only $25.00.
- Proceedings of the Wanganui Symposium "Using Geomechanics in Foundation Engineering", September 1972. Price $8.00 to members, $10.00 to non-members.
- Proceedings of the Christchurch Symposium "New Zealand Practices in Site Investigations for Building Foundations", August 1969. The last copies of a limited reprinting are available at $8.00 to members, $10.00 to non-members.
- Copies of all back-issues of "New Zealand Geomechanics News" are available to members at a nominal price of $2.00 per copy.
- The following back issues of the I.A.E.G. Bulletin are available. Price $3.00 to members.

Issue	No. available	Issue	No. available
13	1	16	2
14	3	17	2
15	12		

(b) From Government Bookshops:

- "Slope Stability in Urban Development" (DSIR Information Series No. 122) Price $2.00

The following publications of the Society have been sold out:

- Proceedings of the Nelson Symposium "Stability of Slopes in Natural Ground", 1974.
- Proceedings of the Wellington Workshop "Lateral Earth Pressures and Retaining Wall Design", 1974.

T.J. Kayes
Publications Officer

DRAFT METHOD OF SOIL DESCRIPTION

FOR ENGINEERING USE

Comments on the "Draft Method of Soil Description for Engineering Use" circulated with volume 21 of Geomechanics News has drawn response from a moderate number of members. The committee (convened by S.A.L. Read with P.J. Millar) to review the contents is presently being formed and it is hoped to review progress in volume 23 of Geomechanics News.

Comments from a wider range of members would make an invaluable contribution to the final document. Further comments will still be received with interest, and should be sent to the Management Secretary.

The comments so far received varied widely in content, generally accepting the principle of the description method. Alterations to the order of descriptions, and definition of terms (including pointing out inconsistencies with other published methods) were the most common points made. Several correspondents indicated that they would like the description method extended to also include rocks.

An additional point of interest is that the British Code of Practice for Site Investigations (BS 5930:1981) has recently been issued (30 April 1981). The code replaced CP 2001 and is published by the British Standards Institution.

S.A.L. Read

GEOMECHANICS IN URBAN PLANNING

PALMERSTON NORTH, 29 APRIL - 1 MAY 1981

The symposium, which continued the sequence of symposia staged by the Geomechanics Society on specific geotechnical topics, was organised jointly by the N.Z. Geomechanics Society and the N.Z. Planning Institute.

The symposium, whose purpose was to examine how the geotechnical characteristics of different areas of land may be taken into consideration in the urban planning process, was attended by 101 people.

Technical sessions began with a review of hazards. The review was followed by examples of how each had affected urban areas in the past, then a discussion of current ideas on how they should be avoided or mitigated in the planning process.

It was a timely review of the 'state-of-the-art', with urban expansion and development presently marking time. If there was a single message arising from the symposium, it was the need for improved communication between the technologist, the planner and elected officials - particularly the latter. Since there seemed to be very few such officials represented, it could perhaps be seen as a shortcoming of the symposium in that much of the 'preaching' was to the 'converted'. It was advocated that technologists might get their message through to laymen, councillors and the like by means of well-organised extension activities. Furthermore, plain words are needed to get ideas and concepts across effectively - which must also stand up to scrutiny. Without such improved communication, the need for improved input of geomechanics in urban planning may not be achieved and many otherwise available losses will continue.

A resume of the symposium technical programme with a list of the papers presented is given below:

29 April
evening Geotechnical Hazards to Urban Development — *D.K. Taylor, C.P. Gulliver, N.C. Rogers*

A Review of Relevant Recent Litigation — *P. Horsley, R. Worth*

30 April "WHAT HAS HAPPENED"
morning "Technical Reviews of Examples"

(a) Volcanic		*V.E. Neall*
(b) Earth Deformation and Shaking		*G.J. Lensen*
(c) Mining		*N. Fowke, D. Depledge*

Discussion

(d) Settlement	1. of natural ground	*G.E. Orbell*
	2. of man-made ground	*T.J. Kayes*
(e) Landslides	1. general	*M.J. Crozier*
	2. a case history	*C.P. Gulliver*

Discussion

afternoon

Discussion of a to e

(f) Soil Dispersion	*D.H. Bell*
(g) Shrinkage and swelling	*M.A. Wesseldine*

Discussion

(h) Flooding	*P.W. Williams*
(i) Coastal hazards	*J.G. Gibb*

Discussion

Audio-visual presentation of Manawatu Urban Growth Strategy Study

evening

An assessment of present statutory powers and responsibilities — *D.F.G. Sheppard*

Discussion on the Abbotsford report, led by — *R.D. Northey*

1 May "WHAT SHOULD HAPPEN"

morning

"Planning to Prevent Problems"

(a) A Geological View	*G.T. Hancox*
(b) Urban Capability Surveys	*J.H. Lawrence* *M.R. Jessen*
(c) Upper Waitemata Harbour Study	*P.W. Williams*
(d) Making Use of Survey Information in the Preparation of District Schemes	*K.J. Tremaine*

Discussion

In view of the high cost of investigations, what field/laboratory/analytical work is it reasonable to expect shall be done at each stage of urbanisation.

(a) Regional and District Scheme Preparation (Urban capability surveys)	*J.H. Lawrence*
(b) Scheme Plan and Concept Plan Preparation and approval	*J.P. Blakeley*
(c) Issuing of Building Permits	*T.N. Costello*

afternoon

Discussion on the above, followed by a "structured discussion" on particular questions including:

"How should the results of geotechnical investigations be presented, so that they may be used appropriately by planners?"

"What should planners present on district scheme plans?"

"What must local authorities (and other parties) do in order not to be liable when the failures occur?"

"If all parties do all those things that can reasonably be expected of them, will the E and WD Commission give cover for failures which occur in spite of this? To what extent will they cover existing areas which were urbanised with little or no professional advice?"

Closure

B.W. Riddolls

CONTOUR BLASTING IN UNDERGROUND OPENINGS

Ian Brown

Introduction

Contour blasting is a term used to describe blasting that produces a geometrically clean-cut contour, and includes the methods of smooth-blasting and pre-splitting. There may be several reasons why contour blasting is specified in a tunnel design. The reduced amount of damage that is caused to the rock adjacent to the contour is beneficial in all underground openings, although in very good rock conditions the extra cost of contour blasting may not significantly reduce the cost of tunnel support. Contour blasting reduces crack propagation into the surrounding rock, hence increasing the tendency for the rock to be self-supporting and decreasing the requirements for temporary and final support. Reduction in amount of overbreak can also lead to reduced concrete volumes in the final tunnel lining. In an unlined hydraulic tunnel, the smooth shape of the tunnel from contour blasting will reduce friction losses caused by wall roughness.

The adverse effects of air blast, water shock, ground vibration, flyrock and contour damage that occur during blasting in an underground opening, can be reduced by the use of controlled blasting techniques.

Crack Formation during Blasting

In the simple case of blasting in a homogeneous brittle material, three zones of cracking occur around a drill hole fully loaded with high explosive. Adjacent to the drill hole, where there are extremely high detonation pressures, a large amount of energy is dissipated. Material close to the hole is plastically deformed or crushed, and a very high density of cracking occurs. Beyond the zone of plastic deformation, shear cracking occurs and the crack density decreases. Further away from the hole, radial cracking is the dominent mode of failure.

During the initial stages of crack extension, the radial outward flow of material is set in motion by the sudden expansion of the hole diameter, and is considered as a dynamic process. The latter stages of crack extension are regarded as quasi-static, where equilibrium is sought between gas pressure and the elastic resistance of the material to deformation. In thin cracks, there is a resistence to the flow of gas, and initially a high pressure gradient occurs along a short section of crack near the hole. Gas pressures reduce quickly due to leakage and increasing hole and crack volume. These effects tend to limit the distance of radial crack propagation, and only about 5-7 randomly oriented cracks extend for a significant distance from the hole.

Where blasting is carried out near a free surface, two of the long radial cracks that are favourably oriented will extend to the free surface, and a triangular piece of rock will break loose. This is because as the free surface moves away from the drill hole due to the stress waves, favourably oriented radial cracks will widen and gas flow will move further along the crack.

When blasting occurs in a discontinuous material, such as fissured or jointed rock, the pressure of crack formation is modified by the influence of pre-existing planes of weakness. Shear and tensile failure, which occurs along discontinuities as a result of dynamic shear and tensile stresses, is

influenced by the amount of rock to rock contact along the discontinuities.

Crack Control during Blasting

The most important feature of contour blasting is the control of cracking during blasting. If the amount of cracking can be reduced, the remaining rock will have an increased strength. During crack initiation it is necessary to control the number of cracks to be initiated and to control the location of initiation sites. Once crack propagation occurs it is necessary to provide a stress field that will produce the stress intensity required to maintain a sufficiently high crack velocity. The stress intensity must also be sufficiently large to avoid crack arrest until the crack has reached the required length. Control of the direction of crack propagation is also an important consideration. If the number of radial cracks can be reduced, it is necessary that those that are formed are so oriented such that the burden can break loose.

For a constant drill hole diameter, a reduction in volume of explosive will limit the extent of zones of plastic deformation and shear cracking. In contour blasting specially prepared small diameter charges are commonly used, for example the Nitro Nobel GURIT and NABIT charges (Figure 1, after Svanholm et al. 1977). NABIT is a nitroglycerine sensitised explosive with a strength approximately equal to that of ANFO. GURIT is also a nitroglycerine explosive but has a low gas volume and explosion energy. Charges can also be made from ordinary dynamite. Cartridges are cut lengthwise and placed on a wooden stick so that the concentrated charge is less than 0.25 kg/m.

The loose coupling of explosives to rock reduces the intensity of the primary shock waves but still allows gas pressures to work on the rock. Ideally the charge does not touch the rock and spacers are used to surround the charge with an annular ring of air. Sand-stemming is sometimes used to cushion the blast; it is thought that the sand may block the entry of gas into unfavourably oriented discontinuities, and force cracking along the contour.

To reduce the amount of damage due to cracking around a blast hole, the diameter of the hole and the charge can be reduced. In a given volume of rock containing discontinuities, a large blast in a large diameter hole will affect a great number of the discontinuities than a smaller blast in a hole with a smaller diameter.

The location of crack initiation sites can be controlled in several ways. A method proposed by Dally and Fourney (1977) uses notches in the side of the charged drill hole. The notches cause local stress concentrations and for a narrow range of explosion pressures, cracks will initiate at the notch location. This method of crack control requires re-entering a hole after drilling to make a notch (increasing the cost of drilling) and does not appear to have been widely accepted as a practical method. Uncharged guide holes can be used to control the location of crack propagation, however these are usually only used in special circumstances, such as where a contour is required with a small radius of curvature.

Simultaneous detonation of charges in adjacent holes is desirable to maximise the interaction of both charges in the zone of rock between the holes. Svanholm et al. (1977) considered that there can be some latitude in the time scatter for detonation because the extension of a crack between adjacent holes involves the relatively slow motion of a considerable mass of material within the burden.

Pre-splitting

Pre-splitting (or pre-shearing) is a method that is seldom used in tunnels, however it is more frequently used in large caverns where careful excavation of the walls is required. A row of closely spaced and highly charged holes are detonated simultaneously along the contour of an excavation. These holes are detonated before any other holes in the blast. The resulting stress waves interact and reinforce to produce cracking in the region between holes. The highly charged holes cause extensive cracking around the hole and degrade the quality of the wall, however cracking along the contour reduces any further damage to the wall from blasting of other holes. Simultaneous detonation of large charges also causes high ground vibrations that may be best avoided. However, the adverse effects caused by highly charged holes can be reduced using methods already discussed. Usually this is accomplished by reducing charge size and hole spacing.

Smooth-blasting

In smooth-blasting, the contour charges are fired last in the round. The charges fired first in the round remove most of the rock required to be excavated leaving a small burden that has to be removed by firing the contour holes. The contour holes are closely spaced and lightly charged to minimise damage to the rock adjacent to the contour. Perimeter hole spacing should be about 15 times the drill hole diameter, and the burden on the perimeter holes at the time of firing should always be greater than the spacing of the perimeter holes (Hendron and Oriard 1972). A burden of 1.5 times the spacing of the perimeter holes is commonly used, but may have to be altered slightly for various rock conditions.

A Comparison of Smooth-blasting and Pre-splitting

Both of these methods of contour blasting use a very low charge density compared to that in normal blasting. The low initial pressure in the hole and the interaction of each closely spaced hole limits damage to a narrow zone close to the contour, and forces a crack to extend from drill hole to drill hole. Because no rock is broken loose in pre-splitting, a closer spacing of contour holes is required, about 50-75% of that required for smooth-blasting (Figure 2, after Svanholm *et al.* 1977). Svanholm *et al.* (1977) consider that an extra blasting round is required with pre-splitting, however it is not clear why the contour holes could not be fired before the other holes in a normal blasting sequence. An extra blasting round obviously increases the cost of tunnel excavation, as does the extra drilling required for closely spaced pre-split holes, hence the method is not often used in tunnels.

Smooth-blasting requires detonation of contour holes at the end of a round, and they are usually detonated with half-second delay detonators. Because of a large time scatter with half-second delay detonators (100-200 milliseconds), the results of smooth-blasting are often not as good as they would have been if detonated as a separate round using millisecond delay detonators.

The accuracy of contour holes, and all other holes in a blast, can have an important effect on the quality of the contour. The drill hole is used to place the required amount of explosive in a position where it can be most effective. The contour holes must be drilled parallel with the axis of the tunnel; the alignment of holes should be specified by giving a target and an allowable deviation from the target. With modern drilling equipment a deviation of 12 mm per 300 mm of drill hole can reasonably be expected.

If contour blasting is used in an underground opening, many of the adverse effects associated with normal blasting will be reduced. Contour blasting is usually used to maintain the quality of the rock around a tunnel. However, small sized charges used in a controlled manner also help reduce the effects of air blast, water shock, ground vibration and flyrock. The use of contour blasting methods alone will not lead to the reduction of adverse effects unless adjacent blasts are carried out in a careful manner.

References

DALLEY, J.W.; FOURNEY, W.L. 1977: Fracture control in construction blasting. 18th U.S. Symposium on Rock Mechanics, Keystone, CO; 2A6-1-2A6-7.

HENDRON, A.J.; ORIARD, L.L. 1972: Specifications for controlled blasting in civil engineering projects. Proceedings North American Rapid Excavation and Tunnelling Conference, Chicago, IL; 1585-1609.

SVANHOLM, B.O.; PERSSON, P.A.; LARSSON, B. 1977: Smooth blasting for reliable underground openings. Rockstore 77 (preprints).

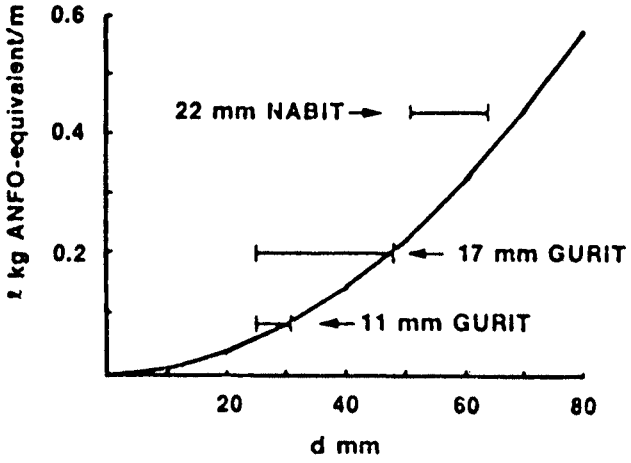

FIGURE 1 Curve of minimum linear charge concentration required for smooth-blasting and pre-splitting as a function of hole diameter (equation of curve $l = a.d^2$ where $a = 90$ kg/m^3). Recommended practical hole diameter ranges for NABIT and GURIT charges.

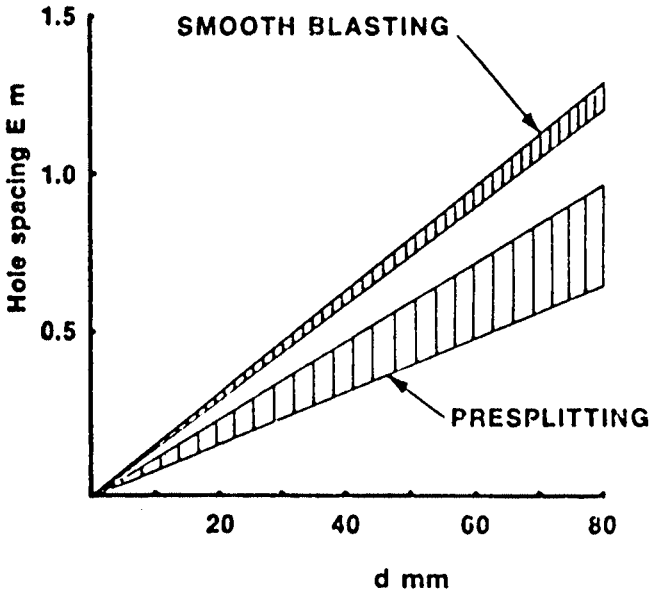

FIGURE 2 Recommended ranges of hole spacing as a function of hole diameter for smooth-blasting and pre-splitting.

NEWS FROM THE MANAGEMENT SECRETARY

1. Management Committee

The Management Committee for 1981 is:

I.M. Parton	(Chairman)	Auckland
A.J. Olsen	(Secretary)	Tauranga
J.H.H. Galloway		Wellington
J.G. Hawley		Palmerston North
T.J. Kayes	(Publications Officer)	Wellington
P.J. Millar	(Vice-Chairman, Rock Mechanics)	Wellington
R.D. Northey	(Vice-Chairman, Soil Mechanics)	Wellington
B.R. Paterson	(Vice-Chairman, Engineering Geology)	Christchurch
S.A.L. Read	(Editor, Geomechanics News)	Wellington
D.K. Taylor		Auckland

2. Australasian Vice-President ISSMFE

Dr R.D. Northey has been appointed as the Australasian Vice-President of the International Society for Soil Mechanics and Foundation Engineering (ISSMFE). Dr Northey's term will be for 4 years and commenced with the confirmation of his appointment during the 10th International Conference of the ISSMFE in Stockholm from 15-19 June 1981. The Society extends its congratulations to Dr Northey on his appointment and offers its best wishes to him for a successful term of office.

3. Chairmen for Local Branch Activities

The following have agreed to act as Chairmen for local branch activities:

Auckland	M. Wesseldine	Manukau City Council
Wellington	D. Jennings	Ministry of Works and Development, Head Office
Christchurch	B. Paterson	N.Z. Geological Survey

4. 1982 NZIE Conference

The Conference is to be held at the School of Engineering, University of Canterbury from 8-12 February 1982. As in past years, the Geomechanics Society will contribute to the conference. It is intended that the Society's activities will be in the form of a seminar and field trip on "Stabilisation of Dispersive Soils", organised by the Christchurch Group.

Other authors who wish to put forward papers for nomination to the conference by the Geomechanics Society may still do so. Intending authors are reminded that synopses should be submitted to the Management Secretary by 18 August 1981. The deadline for submission of draft papers for reprinting will be 1 November 1981.

The Annual General Meeting of the Society will take place during the Conference.

5. UNESCO Task Force on Hazards

UNESCO is presently undertaking a world-wide survey on hazards. The Geomechanics Society has been requested by the New Zealand Committee to make contributions on the following hazards in New Zealand - expansive soils, subsidence, liquefaction, and organic-rich materials. Any person who is interested in making a contribution to any of the above topics may obtain further information by writing to the Management Secretary.

6. Australian Geomechanics Computer Users Newsletter

The source of funds for the AGCU Newsletter has been the subject of protracted discussions. As it is felt that the Newsletter fulfils a useful role and has considerable potential, it has been resolved that rather than fade from existence, the Newsletter's circulation be very limited. Only an original (or high quality copy) of the text of the Newsletter will be sent to New Zealand.

Members of the Geomechanics Society who wish to receive copies of the Newsletter should contact the Management Secretary.

7. 2nd ANZ Conference on Soil Mechanics and Foundation Engineering, Christchurch, 1956

A request has been received from the Secretary-General of the ISSMFE for the proceedings of the above conference, of which the ISSMFE library does not have a bound copy. If any member of the Society has a copy that he/she no longer wants to retain, or is aware of an untenanted copy, could they please contact the Management Secretary so that arrangements can be made to forward the proceedings to the ISSMFE.

A.J. Olsen
Management Secretary

RECENT CONFERENCES IN NEW ZEALAND

1. 1981 NZIE Conference

The annual conference of the NZIE was held from 9 to 12 February 1981 at the University of Auckland. The Geomechanics Society supported two sessions, both of which were well attended.

In the first session Mr Michael Wesseldine gave a very enthusiastic, well illustrated and stimulating presentation of his paper "House Foundation Failures due to Clay Shrinkage caused by Gum Trees". The high quality of the paper and its presentation was reflected in Mr Wesseldine gaining the premier award of the Institution - the Fulton-Downer Gold Medal. The Society extends its congratulations to Mr Wesseldine for gaining this distinction.

In the second session Mr Paddy Luxford presented the paper he wrote in conjunction with Mr D.H. Bell entitled "Geotechnical Investigations of the Claverly-Oaro Section of the South Island Main North Line". The well illustrated presentation highlighted the nature of many of the problems associated with the design and implementation of measures to ensure the protection of a railway in rugged topography with highly variable geology and slope erosion processes.

Mr Peter Goldsmith then introduced "Pressuremeter Tests" which summarised recent developments in this field, particular those relating to the self-boring pressuremeters. The presentation was complemented by a display of several models of pressuremeter, including those currently under development at the University of Auckland.

The Annual General Meeting of the Society was held at the conclusion of the sessions. The meeting was attended by 22 members of the Society, an improvement on previous years.

S.A.L. Read

2. Geological Society of N.Z. Conference

The annual conference of the Geological Society of N.Z., held from 24-27 November 1980, was attended by one hundred and eighty-three participants. The School of Engineering on the University of Canterbury campus provided ideal facilities for the presentation of papers and poster displays; accommodation and social events also being held on the campus. Because of the large number of papers and variety of topics offered, several sessions were subdivided into three different themes which were run concurrently. A variety of interests were also catered for by the numerous options offered for the two half-day excursions.

One of the specialist sections was Engineering Geology which attracted the following eight presentations:

Engineering Geological Characterisation of Soft Sedimentary Rocks
Read, S.A.L. & Riddolls, B.W.

Assessing the Field Strength of Materials
Salt, G.

NEWS FROM THE INTERNATIONAL TUNNELLING ASSOCIATION

1. The International Tunnelling Association (ITA) recently published Vol 1 No 1 of its journal entitled "Advances in Tunnelling Technology and Subsurface use". The aims of the journal, which is published 3 times a year, is to publish papers covering the development of new uses of underground space and results of research into better, more cost-effective methods for the planning, geo-investigation, design, construction, operation and maintenance of underground structures, and to also provide a forum for the international, interdisciplinary developments in underground technology - including reports from ITA working groups.

2. The ITA currently has nine working groups, whose current activities are summarised below.

(a) STANDARDISATION. A 4-language glossary has been drafted on terms concerning full section boring machines and is published in the Vol 1 No 2 of the Association journal. A second glossary is under preparation on the traditional excavation process. A synthesis has been prepared on the standardisation of profiles.

(b) RESEARCH. The general report on shield tunnelling is to be published in the Vol 1 No. 3 of the Association journal. The group has continued its investigations on tunnel boring machines, and the report will be presented to the 1982 annual meeting. A link will be established with the International Society of Rock Mechanics. Another topic concerns the problems caused by water in underground works, especially during construction. The ITA report No 1 on Research Organisations and Projects has been updated.

(c) CONTRACTUAL SHARING OF RISKS. Recommendations on performance bonds and award of contractors have been prepared. The group also pursued its works on insurance, measurement of works, role of the engineer and ground characterisation. The group accepted recommendations made to it on "Ground Support" and "Mobilisation Payments". Two sub-committees have been formed to promote the recommendations throughout the world.

(d) SUBSURFACE USE. Documents supplied by seven countries have been examined and the group will pursue its investigations in 1982 in all fields in connection with the subsurface use.

(e) CATALOGUE OF WORKS IN PROGRESS. The catalogue of works has been complemented by answers supplied by 7 countries, making a total of 16 countries that have now submitted a list of tunnels. In 1982 the group will continue listing data on tunnels under construction and tunnels being planned. The working group proposed a change of the name to "Catalogue of Tunnels".

(f) MAINTENANCE AND REPAIR OF UNDERGROUND WORKS. The group has defined a working schedule and an ITA member will be asked to produce a list of publications and the position of each country concerning maintenance and repair. The intention is to publish a general report with case history studies related to its fields of activity.

(g) STRUCTURAL DESIGN MODELS. The final draft of the "synopsis" has been prepared and will be published in the Association Journal under the title "Views on Structural Design Models for Tunnelling". Co-operation will be established with the International Society of Rocks Mechanics and the committee "Geomechanics Computer Programmes".

(h) SEISMIC EFFECTS ON UNDERGROUND STRUCTURES. Collection of data on seismic damage forces continued. An outline of a design manual on seismic effects will be presented in 1982. Each country is encouraged to develop instrumentation programmes and to collect data on the reaction of underground structures to seismic forces.

(i) SAFETY IN WORK. The name of the group was changed to "Health and Safety in Work" and recommendations are under progress. Seven additional safety signs have been designed.

3. The next annual meeting of the ITA will be held in Brighton (United Kingdom) from June 6 to 9 1982 in conjunction with "Tunnelling 1982" organised by the Institution of Mining and Metallurgy. The ITA member nations are requested to encourage their members to submit papers to be presented during the Symposium.

R.L. Preston

LOCAL ACTIVITIES

1 AUCKLAND GROUP

1.1 Committee 1981

The Auckland Group Committee now comprises:

Mr M.A. Wesseldine - Chairman
Mr R.J. McKelvey - Secretary
Dr M.J. Pender
Dr T. Larkin
Messrs P. Riley; W. Litherland; G. East; R. Melville-Smith
Ms Yolande Thorpe

Ms Thorpe has accepted an invitation to join the Committee and replaces Mr Bryce Hadfield who has decided to stand down. Thanks are due to the outgoing secretary, L. Wesley, who is also standing down.

R.J. McKelvey

1.2 Shrinkable Clays in Auckland

The first meeting of the year was held on Thursday, 9 April 1981. The attendance was 130, 50% of whom were members of the general public enticed along by an article which had been published in the Auckland Star advertising the meeting.

The speakers were:

Dr Colin Harvey - Clay Mineralogist from Ceramco Ltd
Alan Pickens - Tonkin & Taylor Ltd
Peter Riley - Beca Carter Hollings & Ferner Ltd

The topic was timely, as the past summer has been notable for the large number of cases of building damage occasioned by shrinkage of clay. The main problem is related to the weathered profile developed on Waitemata group sediments of Miocene Age. The profile typically is rich in Kaolin where the clay can develop in the oxidising environment above the permanent water table, and rich in Montmorillonite in the reducing environment below. It is when this lower Montmorillonite layer is exposed in the cut to fill regime of present urban subdivision that the problem due to shrinkage arises.

These susceptible clays are now exposed to ravages of the environment and, in particular, the fluctuations of the water table and abstraction of water from the soil by drainage or vegetation.

In the past, recognition of clay types has been the province of those with access to X-ray diffraction equipment, however, a simpler technique has now been developed, based upon moisture absorption and ignition loss as outlined below:

Clay Type	75% Relative Humidity Absorption %	Ignition Loss 100° - 1000°C %
Well Crystalline Kaolin	0 - 3	14
Poorly Crystalline Kaolin	3 - 9	14
Illites	9 - 14	8 - 11
Mixed Clay Layers	14 - 17	7 - 10
Montmorillonite	17 - 20	5 - 7

Typically damage to buildings is caused by differential settlement which is most severe where different parts of the clay profile are spanned or where water is abstracted from one part of the profile faster than elsewhere. In less severe cases, relief has been obtained by the removal of trees or saturation of the ground. With more severe cases structural underpinning needs to be resorted to.

R.J. McKelvey

1.3 Onerahi Chaos Breccia

The distribution and properties of the Onerahi Chaos Breccia of North Auckland was discussed at a meeting on 11 June 1981. The meeting, held at the Auckland University, on this controversial geological material was well attended by 85 people.

Dr P.F. Ballance of Auckland University described the Onerahi Chaos as having ages of from 100 million years to 20 million years, but with the age sequence frequently reversed and the chaos material often overlying the younger Waitemata formation. The jumbled material has been measured at depths of greater than 2,000 metres in an oil prospecting bore at Waimamaku and can occur above and below the Waitemata formation. Overall the formation is known as the Northland Allochthon which was formed 25 million years ago. The allochthon can comprise blocks of rock 1 km thick and tens of kilometres long, and also includes the Tangihua volcanics which are blocks of ocean floor volcanic material. Considerable erosion then occurred, and the Waitemata formation was then deposited on top of it, together with the Waitakere and Whangarei Heads volcanics. Block faulting then occurred with further displacement of this material to give the Onerahi Chaos as we know it, implaced by gravity sliding on top of the Waitemata formation.

The Ministry of Works and Development have frequent problems with the Onerahi Chaos throughout North Auckland and this was described by Mr G.R.W. East of the MWD laboratories. Approximately 15% of the roading budget is spent solving problems produced by the Onerahi Chaos. With the aid of slides, problems of large scale slope failures were demonstrated. Investigations have shown many of these failures to be related to high water pressures in aquifers behind the slope. Water pressure measurement in these aquifers has allowed detailed back analyses to be carried out on the sliding material.

Dr D.V. Toan of Beca Carter Hollings & Ferner then described the particular problems associated with subdivisions in Onerahi Chaos in the Rodney County. The Onerahi Chaos is a very weak material when saturated and exhibits high creep movement. The moisture variation is large and is 3 times what would be expected in the Waitemata formation. The reason for this is that the Onerahi Chaos can contain up to 30% of

Montmorillonite clay. Movements generally occur on a layer parallel to the ground surface containing clay and mudstone chips. Damage results when additions to houses move down hill and when retaining walls are pushed over by shrinking and swelling movements. Brittle materials suffer most in these circumstances.

Mr M.A. Wallace, County Engineer for the Rodney County Council, then desscribed the legal condition that this material creates. An amendment to Section 641 of the Local Government Act 1974, enacted as a result of the Abbotsford disaster, requires that the Council shall refuse to grant a permit to erect a building or alteration until the Council is satisfied that the land is safe from erosion, slippage, subsidence, inundation by stream or sea or any other source. There is provision in the Act for performance bonds to be entered into regarding particular work needed on properties. With considerable areas of Onerahi Chaos, the Rodney County has set up a guideline procedure to illustrate what is required for investigation prior to building. The County must make its decisions consciously and a chart has been prepared to give a basis for that.

A lively discussion on geological definition of this material followed, leading onto legal questions on the Chaos.

P.B. Riley

1.4 Next Meeting

The next meeting will be combined with a meeting of the NZIE Auckland Branch (Structural Group) on 20 August 1981, in the Professional Club, Kitchener Street at 6.30 pm., with a prior social hour. The meeting topic is "Piled Foundations" and will be addressed by 4 speakers:

Susan Jackson	- Discussion of her recently completed thesis
Glyn East	- MWD experience with piled foundations
Rodney Melville-Smith	- Driven timber piles
Bryce Hadfield	- Piling headaches!!; a practitioner's point of view

The topic is very stimulating, interesting and with a high local content. Everybody welcome.

M. Wesseldine

2 WELLINGTON GROUP

2.1 Poro-O-Tarao Railway Tunnel

On 10 November 1980, Dr Graham Ramsay of the Ministry of Works and Development gave a talk on geomechanics aspects of the new Poro-O-Tarao Railway Tunnel.

The tunnel, which is 1.4 km long and 5.5 m in diameter, was opened on 10 November and replaced an earlier tunnel constructed in the 1880's. The original tunnel had inadequate clearances for present day traffic, due to (a) the smaller original diameter and (b) the tunnel had closed by up to 600 mm at the invert level. The latter occurred after the invert was lowered in the early 1900's, removing lateral support from the brick arch lining.

The replacement tunnel was driven through "papa" using a Dosco Roadheader machine. Although the tunnel designer originally specified a shotcrete and mesh lining, the tunnel was eventually lined with conventional steel sets and cast in situ concrete. The abandonment of the shotcrete lining was largely a result of industrial problems related to the use of the shotcrete which contained a corrosive liquid accelerator.

Dr Ramsay commented on the results obtained from instrumentation carried out in both the main tunnel and a test drive constructed for investigation purposes. The instrumentation consisted of settlement gauges, borehole extensometers, convergence measurements, and strain gauge readings on the steel sets. Particular reference was made to the loads recorded by the strain gauges on sets at two locations in the tunnel, where geological conditions (and Rock Mass Classification ratings) were similar. The loads were distinctly different with light loaded sets at one location and overloaded sets at the other.

The south portal of the tunnel is located in an area where there was evidence of slope instability in surface colluvium. Dr Ramsay described the measures undertaken to improve the stability of the area, which included the installation of a curtain of vertical sand drains discharging into a drainage drive, inclined drains, lining of surface water courses and the recontouring of the slopes. The immediate approach to the portal is through a bored pile strutted retaining structure. Dr Ramsay commented on water level readings taken over the site and recordings of discharges from inclined and vertical drains. In particular the colluvium slopes appear to be non-homogeneous with respect to permeability and the discharges from closely spaced drainage holes varied considerably.

The investigations and analyses carried out to assess the stability of the slope were discussed. Experience showed that best definition of the interface between the surface colluvium and underlying papa was obtained from large diameter bored shafts. The effect of the remedial measures in lowering the water table has been to improve the factor of safety of the slopes above the portal from 1.0 - 1.1 to 1.4 - 1.5.

Dr Ramsay referred those interested in further details to the following references:

1. Parton, I.M. (1974). "Assessment of Slope Stability at Poro-O-Tarao South Portal". Proc. Symp. on Stability of Slopes in Natural Ground. N.Z. Geomechanics Society, Nelson.

2. Borrie, G.W. and Riddolls B.W. (1980). "Engineering Geological Investigations in Soft Rock Terrain, Poro-O-Tarao Tunnel". Proc. 3rd A.N.Z. Geomechanics Conference, Wellington, New Zealand.

3. Ramsay, G. (1980). "Stabilisation of a Mudstone Derived Colluvium Slope". Proc. 3rd A.N.Z. Geomechanics Conference, Wellington, New Zealand.

D.N. Jennings

2.2 The East Abbotsford Landslide

At a very successful joint meeting of the Wellington NZIE Branch, the Geological Society, the Geology Section of the Royal Society, and the Geomechanics Society was held on Thursday, 4 June. The technical aspects of the East Abbotsford landslide were discussed. Over 70 people attended

this meeting, the subject of which was recently addressed by a Commission of Inquiry.

Guest speakers at the meeting were Graham Hancox from the New Zealand Geological Survey and Graham Ramsay from the Ministry of Works and Development. The address was divided into two sections: Graham Hancox described the development of the slide, its physical extent and geology; and Graham Ramsay discussed the stability of the slide and its possible causes.

INTRODUCTION

The East Abbotsford landslide occurred on 8 August 1979 in the residential area of Abbotsford, Dunedin. It was a translational block slide covering some 18 hectares and involving approximately 5 million cubic metres of material which moved about 50 metres. There had been evidence of the development of the slide for several months prior to the final movement. No lives were lost in the slide but 69 houses were either destroyed or rendered inaccessible.

GEOLOGY

In the Abbotsford area, very weak Tertiary sediments dip 8^{o} south east towards the Kaikorai Stream. Over the past several thousand years natural processes of erosion in Miller Creek and the Kaikorai Stream have removed material down dip and formed the slope on which the landslide is situated.

The stratigraphic sequence basically consists of a minor surficial loess deposit which rests on bouldery colluvium, a solifluction sheet some 12 metres thick in some places. This in turn rests on the Green Island Sand, which is a fine sand with minor clay content, and this sand is laid conformably on the Abbotsford Formation. The top 30 m of the Abbotsford Formation at East Abbotsford consists of grey sand with thin clay layers, below which is grey mudstone. Sand in the Abbotsford Formation is of similar grading to the Green Island Sand. There is a sharp colour change between the light yellow coloured Green Island Sand and the dark grey coloured Abbotsford Formation sand.

POST SLIDE INVESTIGATIONS

Initial post slide investigations, using small diameter drill holes, did not reveal any materials which were sufficiently weak to explain the slope failure. Typically ground water levels were found to be some 10-20 metres below the ground surface. For failure to occur on a slope of 8^{o} with this order of ground water it was considered that some very weak material must be present in the slope.

With this objective 1 metre diameter shafts were sunk to enable a more thorough examination of the stratigraphic sequence. This was not an easy operation and many problems were encountered, particularly in penetrating the layer of boulder colluvium. The effort was rewarding as several thin layers of clay were found in the upper region of the Abbotsford Formation and typically within 1 metre of the upper contact with the Green Island Sand. These clay layers varied in thickness up to 50 millimetres and most significantly they contained slickensided surfaces indicative of movement.

Samples of the clay layers were recovered and subjected to laboratory tests. These tests indicated residual strength parameters of the order $c' = 0\text{-}20$ kPa and $\emptyset' = 5^{o} - 10^{o}$ which are amongst the lowest reported in the literature.

STABILITY AND CAUSES

A number of possible natural and man-induced causes of the slide were investigated including the effects of rainfall, changed land use, a leaking water main up slope, the excavation of a sand quarry at the toe, and seismic activity. It was found that any one of the above appeared to result in only a very small change in stability of the order of 0-2 per cent. Depending on the input assumptions the effect in some cases could be an improvement or reduction in stability.

Although it is open to debate Dr Ramsay said that for the purposes of analysis it had been assumed that one or more of the clay layers was continuous. This was considered reasonable because of the continuous nature of the Green Island and Abbotsford Formations. Back analysis of the slide has shown that clay strength parameters of the order $c' = 0$, $\emptyset' = 8^{o}$ would produce failure.

Dr Ramsay said he considers that the basic cause of the landslide was geological and arose because of the existence of a thin weak montmorillonite rich clay layer within the top few metres of the Abbotsford Formation. The ancient Sun Club Slide which forms part of the Abbotsford slide mass, is evidence of the marginal stability of the slope to the west of Miller Creek.

COMMENT

The spontaneous discussion which followed the speakers' presentation was an indication of the level of interest which this significant event has generated in the geotechnical world. It is to be hoped that the various people involved with the technical aspects of the slide will make a contribution to the literature in the near future. In the meantime for those seeking more information, the Commission of Inquiry's report is very good reading.

D.N. Jennings

3 CHRISTCHURCH GROUP

One meeting has been held this year and judging by the attendance of 20 and the discussion generated, it was very successful. The speaker was Mr D.H. Bell, Senior Lecturer in Engineering Geology, University of Canterbury, who presented an illustrated talk on "The progress of lime stabilisation techniques in loessial soils".

David Bell has been very active in research into the special properties of loess and the construction problems they present, and has recently been involved in the application of chemical stabilisation techniques particularly in the Christchurch area. These techniques are gaining acceptance as a practical solution to erosion in a wide variety of construction involving loess. A number of these were discussed during the talk.

B.R. Paterson

FROM THE INTERNATIONAL VICE-CHAIRMEN

1. ROCK MECHANICS

1.1 5th ISRM Congress, Melbourne, 10-15 April 1983

The 5th Congress of The International Society for Rock Mechanics will be held in Melbourne, Australia on 10-15 April 1983. The Congress is being organised by The Australian Geomechanics Society, a technical unit of The Institution of Engineers, Australia and The Australasian Institute of Mining and Metallurgy. The theme of the Congress is:

ROCK MECHANICS FOR RESOURCE DEVELOPMENT,

MINING AND CIVIL ENGINEERING

A. Site Exploration and Evaluation.

- . Geophysical Testing and Exploration
- . In-situ and Laboratory Testing
- . Classification, Prediction, Observation and Monitoring
- . Hydro-Geology

B. Surface and Near-Surface Excavations.

- . Stability of Rock Slopes
- . Foundations on and in Rock, including dam foundations
- . Near-surface construction especially in cities

C. Deep Underground Excavations.

- . Mining excavations and mining methods including caving
- . Permanent underground excavations including tunnels, power stations and storage caverns
- . Coal mining including ground control and gas outbursts
- . Prediction, control and measurement of subsidence

D. Rock Dynamics.

- . Drilling and Blasting
- . Crushing and grinding
- . In-situ fracture methods for resource development

E. Special Topics in Rock Mechanics.

- . Fracture and flow of the earth's crust, including tectonic stresses
- . Future developments and directions in rock mechanics

Pre-Congress and Post-Congress tours will be arranged to both Mining and Civil Engineering operations in Australia.

Persons interested in presenting a paper or in attending the Congress are invited to write to:

Organising Committee,
5th I.S.R.M. Congress,
P.O. Box 310,
CARLTON SOUTH, Vic, 3053.

The first circular for the Congress should be available during July 1981.

The conference provides an excellent opportunity for New Zealand's contributions to Rock Mechanics to be presented. Start planning now and support the conference with a high number of contributions and level of attendance.

P.J. Millar

2. SOIL MECHANICS

2.1 Death of Mr K. Nash, Secretary-General of ISSMFE

Mr K. Nash, who was a very enthusiastic and dedicated Secretary-General of the ISSMFE for 16 years, died suddenly on 24 April 1981. A message of sympathy on behalf of the Australian Geomechanics Society and New Zealand Geomechanics Society was sent to members of the late Mr Nash's family by the Australasian Vice-President (Mr A. Hoskings).

2.2 Geotechnical Abstracts and Retrieval Systems

The Information Advisory Committee of the ISSMFE recently circulated the following reminder.

The ISSMFE endorses the following two services:

(a) Geotechnical Abstracts published by the German National Society on behalf of the ISSMFE.

(b) The Geodex International Inc. retrieval system.

Further information on the services offered by these organisations may be obtained from:

(i) Geotechnical Abstracts,
Deutsche Gesellschaft für
Erd-und Grundbau
35 a Kronprinzenstr
3400 Essen
West Germany

(ii) Geodex International Inc.
P.O. Box 279
Sonoma, California
USA 95476

We should make every effort to support these first class services. Our support is required to ensure that we all continue to receive the type of geotechnical abstracts and access that we all need and want.

R.D. Northey

3. ENGINEERING GEOLOGY

3.1 Death of Dr R. Wolters, Secretary-General of IAEG

Dr R. Wolters, Secretary-General of the IAEG since its inception in 1968, died unexpectedly on 10 March 1981. Arrangements for a wreath to be placed at the funeral service, accompanied by the following message, were made by the Australasian Vice-President (Prof. D. Stapledon).

"On behalf of all IAEG members in Australasia, I wish to pay tribute to the great work carried out by Dr Wolters and to extend our deepest sympathy to his family."

3.2 4th International Congress of the IAEG

The Congress will be held in New Delhi, India on 1-6 December 1982. A first circular was circulated in May last year. The Congress will have the following themes:

(a) Engineering geological studies for environmental evaluation and development.

(b) Engineering geological problems of tunnelling and excavation of cavities.

(c) Soil and rock as construction materials.

(d) Engineering geological problems of natural and man-made lakes.

(e) Engineering geological problems of sea-coast and shelf-areas.

(f) Seismic and seismo-tectonic investigations of engineering projects.

(g) History and development of engineering geology.

There will be pre- and post-Congress tours and an exhibition of equipment and services related to engineering geology.

Titles and abstracts of papers should have been submitted to the Management Secretary of the Geomechanics Society by 30 May 1981. No titles and abstracts have been received. Authors who wish to submit a title and abstract (less than 300 words) may still do so until 30 September 1981. Full papers with abstracts in English and French would need to be submitted to the Management Secretary by 31 December 1981.

Further information on the Congress and correspondence related to the Congress should be addressed to:

Mr K.N. Scrivastava, Secretary
Secretariat of IV ICEG
47-48 Pragati House
Nehru Place
New Delhi - 110019
India

Telex 31.3248 INDIA

B.R. Paterson

NEW ZEALAND SOCIETY ON LARGE DAMS

At a meeting held in Auckland during the NZIE Conference the rules of the recently established Society on Large Dams were adopted, and the first management committee established. Membership of the committee comprises:

P.R. Goldsmith
C.A. Keith
G.A. Pickens
P.B. Riley

who were elected as representatives of the Members and the following who were endorsed as the representatives of Corporate Members:

R.W.J. Fookes	for NZIE
R.K. Howard	for NWASCA
S.A. Astwood	for NZE
J.H.H. Galloway	for MWD

Membership of the Society is open to any individual with a direct personal interest in the technology of dams. No special technical or academic qualifications are required. Organisations wishing to support the objects of the Society or with a direct involvement with dams can apply to become Corporate Members. Over fifty individuals have applied to join the Society and were accepted as inaugural members at the Auckland meeting. An application has been lodged with Council for the Society to become a Technical Group of NZIE.

The objects of the new Society are:

(a) To promote the study and practice in New Zealand of engineering in relation to dams of all sizes and to encourage individual interest in dam technology among New Zealanders.

(b) To provide a New Zealand National Committee of the International Commission on Large Dams and to implement the constitution and bylaws of the International Commission on Large Dams (ICOLD) within New Zealand.

These objects obviously intersect those of the Geomechanics Society and some other Technical Groups of NZIE and the Society's rules allow for specific links to be formed with such organisations. I believe it will be mutually beneficial to do so, but it will be up to the two Management Committees concerned to work out a suitable arrangement.

Dams are one of the most demanding engineering structures and warranted special mention in Dr Northey's 1979 Geomechanics Lecture, "The Acceptability of Geotechnical Risk", because of the hazards they pose. To ensure that these hazards do not give rise to unacceptable geotechnical risks New Zealand must establish and maintain an adequate pool of experts and expertise in dam technology. I believe the new Society will be an effective means of doing this, and will do so without undermining support for the Geomechanics Society. After all Geomechanics would be viable whether or not dams were built but only the rash would design or build a major dam without the help of Geomechanics.

It will be a little while before the Management Committee of the new Society finds its feet but in the meantime I am happy to act as contact for your readers. I can be contacted through Power Division, MWD, P.O. Box 12-041, Wellington North or by phone on Wellington 729-929 ext. 763.

J.H.H. Galloway
Interim Chairman
N.Z. Society on Large Dams

DETERMINATION OF THE DENSITY OF "SOFT ROCKS"

S.A.L. Read and S.A. Miller

1.0 INTRODUCTION

Much of New Zealand is composed of sandstone, mudstone and siltstone of Tertiary and early Quaternary age. Many of these rocks, which collectively can be referred to as 'soft rocks' (Read et al. 1981), are known to shrink and swell or disintegrate on cyclic drying and wetting. During investigations into the engineering properties of 'soft rocks' by the Engineering Geology Section of the New Zealand Geological Survey and Ministry of Works and Development Central Laboratories, in a project for the National Roads Board, it became apparent that there was no satisfactory published technique to obtain the dry density of these rocks. The various techniques used over the past 5 years had not given reliable and consistent results.

Density (the mass of a body per unit volume) is one of the basic physical properties used in geomechanics for the classification of rock and soil materials. As defined in SANZ (1980) NZS 4402 Part 1; four kinds of density may be measured - 'bulk', 'dry', 'saturated' and 'solid density of particles' and there are numerous published standards or suggested methods for their determination in the laboratory. To obtain bulk and dry density values of soils, volume is normally measured at the natural water content (SANZ, 1981), while for rock, it is commonly measured after oven drying and subsequent saturation in water (ASTM, 1979). Clearly the latter is not appropriate for rocks which disintegrate on saturation, or shrink and swell with change in water content. Shrinkage on change in water content can significantly affect volume determinations, and hence density values, yet few existing techniques appear to have taken this into account.

This paper outlines the techniques available to determine the density of 'soft rocks' in the laboratory and summarises an investigation which resulted in a recommendation for a test procedure. A fuller account of the investigation is given in Read and Miller (1980).

2.0 TECHNIQUES TO DETERMINE DENSITY

Only direct methods requiring the measurement of mass and volume of intact materials are considered. Mass is measured using a balance capable of an accuracy of $\pm$ 0.01 gms. Volume can be measured by either direct measurement or by displacement, or buoyancy techniques.

2.1 Direct Measurement

The volume of a specimen with a regular shape (e.g. cylindrical core, prism) may be calculated using the mean of a minimum of 10 or 12 measurements to an accuracy of 0.1 mm made by micrometer or vernier calipers (ISRM, 1979; Lama and Vutukuri, 1978).

2.2 Liquid Displacement

The volume of a regular or irregular specimen may be obtained from the volume of water or mercury displaced from a calibrated container or pycnometer. The method is generally not favoured because it is difficult to achieve accuracy, particularly when using small specimens.

2.3 Buoyancy

The volume of a regular or irregular specimen may be determined using Archimedes principle, and is most conveniently done using a top-loading balance (Chleborad et al. 1975). With a container or water on top, the balance is tared to zero and the specimen suspended wholly within the water. Assuming the density of water = 1.00 t/m^3, the reading on the balance directly gives the volume of the specimen.

2.4 Preparation of Specimens for Immersion

A specimen that can be saturated in water under vacuum without detrimental effect may have its volume determined by immersion immediately after saturation. Rocks which shrink and swell, or are unstable (e.g. friable) while in contact with water, need to be coated with a suitable impermeable membrane, or alternatively the water in the voids replaced with another fluid (e.g. Kerosene).

2.4.1 Specimen Coating

Specimens may be coated with wax (commonly beeswax, paraffin wax, petroleum or similar mixtures), saran resin (Brasher et al. 1966) or a self sealing clinging plastic (Carter & Mathews, 1977).

Wax requires adequate facilities for its melting prior to coating, and problems with air entrainment may be encountered. Saran resin, which is dissolved in the methyl ethyl ketone (m.e.k.) solvent at ratios of 1:4 - 1:8 by weight, provides a thin and extremely tough coating which adheres very closely to the specimen. It is however volatile and needs ventilation if used in a confined space. Clinging, self-sealing plastic (e.g. Gladwrap) presents problems with air trapped inside the wrapping.

2.4.2 Replacement of Water

Replacement of water in the voids of a specimen with another fluid by saturation requires either oven drying of the specimen prior to saturation, or techniques using a retort apparatus. The replacement fluid may be kerosene, naptha, or water estimation spirits (a proprietary mixture of low-aromatic petroleum ethers). Neither technique appears to be commonly used.

2.5 Summary of Techniques using Buoyancy

The buoyancy technique is the most commonly used and simplest method to determine specimen volume. Table 1 summarises known methods using this technique, indicating the immersing liquid and the specimen volume used to calculate dry density.

3.0 INFLUENCE OF TEST TECHNIQUE ON DRY DENSITY

During the investigation it became apparent that the values of dry density depended on the water content at which the specimen volume was determined. To investigate this dependency, the bulk and dry densities of four unweathered 'soft rocks' were determined over a range of water contents between saturation and oven dry. The specimens used were NX diameter cores with a length to diameter ratio of 2:1 and volumes were determined by:

(a) direct measurement

(b) saran-coating using the buoyancy technique with a top-loading balance.

	Specimen Treatment	Immersing liquid	Volume used calculate dry density *
IRSM (1979) Part 1	Saturation in water of rock specimen at natural water content. Method not suited to friable, swelling or slaking rocks	water	v_{nat}
ASTM (1979) - Des C127-77 Earth Manual (1974) - Des E10-D	Saturation in water of oven dried coarse aggregate or gravel clasts	water	v_{sat}
Gyenge (1977)	Coating of oven dried rock specimen with parafin wax	water	$v_{o'dried}$
SANZ (1981) NZP4402 (Part 2) - Test 17(D)	Coating of soil specimen at natural water content with parafin wax. Other suitable coating materials may be used	water	v_{nat}
USBR Earth Manual (1974) - Des E10-E	Coating of soil specimen at natural water with wax	water	v_{nat}
API (1960) RP 40 Ch 3.31	Saturation of uncoated rock core in liquid of unknown density, such as kerosene	saturating liquid	v_{sat}
Duncan (1969) Ch3	Coating of oven dried rock specimen with wax	water	$v_{o'dried}$
Lama and Vutukuri (1978) Ch12	Saturation of oven dried rock specimen in water or naptha	water or naptha	v_{sat}
Chleborad et al. (1975)	Coating of saturated or oven dry rock specimen with parafin	water	v_{sat} or $v_{o'dried}$
Carter and Matthews (1977)	Coating of oven dry rock specimen with water-tight, clinging, self sealing plastic	water	$v_{o'dried}$
Hatherton and Leopard (1964)	Saturation of oven dry rock specimen in water or if extremely friable coating of oven dried specimen with wax	water	v_{sat} or $v_{o'dried}$
Bryant and Olsen (1978)	Saturation in water estimation spirits of 'soft rock' specimen at natural water content in retort apparatus	water estimation spirits	v_{sat}

* v_{nat} is volume at natural water content, v_{sat} at saturation, and $v_{o'dried}$ after oven drying.

$$\text{Dry density} = \frac{\text{mass of solids}}{\text{volume}}$$

TABLE 1. Summary of techniques using the buoyancy principle to determine the volume of a specimen and its dry density

The four samples were mudstone (EN320 and EN352), siltstone (EN269) and fine-medium sandstone (EN323).

3.1 Results

The values of dry density obtained are shown on Figure 1. For each sample the graph clearly demonstrates a general steady increase in value of dry density with decreasing water content, which is due to the decreasing volume of the specimens (i.e. shrinkage). The greater increase with saran coating is due to absorption of the resin into the specimens.

For each sample there was no significant difference between the values obtained at the natural "as received" water content, and saturation water content as well as between the two techniques of volume determination at these water contents. The "as received" water contents were close to those at saturation, giving saturation ratio values of >95%. The majority of New Zealand 'soft rocks' exist at this high degree of saturation prior to drying out which, when it occurs, takes place on exposure to the atmosphere (Read et al. 1981).

The results thus demonstrate that the dry density of 'soft rocks' can be successfully determined at the natural ("as received") water content where it is close to saturation.

4.0 CONCLUSIONS

The investigation of laboratory methods to determine the density of New Zealand 'soft rocks' has shown that:

(1) Most published techniques for use on rocks are inappropriate for use on 'soft rocks'. Most 'soft rocks' either cannot be saturated after oven drying without disintegrating, or they decrease in volume with decreasing water content. The reduction in volume is accompanied by an anomalous increase in the value of dry density.

(2) As many New Zealand 'soft rocks' occur in the field at or close to their saturation water contents, the determination of their dry density is best done on specimens whose volume is measured at these water contents.

(3) The volume of irregular specimens can be most conveniently measured using the buoyancy technique and a top-loading balance. Specimen protection during immersion can be given using an impermeable membrane of saran resin.

5.0 REFERENCES

API 1960: API Recommended Practice for Core-analysis Procedure. API (American Petroleum Institute) Publication API RP40. 1st Edition. 55 p.

ASTM 1979: Annual Book of ASTM Standards. Part 14. Standards and Tentatives Relating to Concrete and Mineral Aggregates (Including Manual of Aggregate and Mineral Testing). ASTM (American Society for Testing and Materials) Philadelphia. 810 p.

Brasher, B.R., Franzmeier, D.P., Valassis, V. & Davidson, S.E. 1966: Use of Saran Resin to Coat Natural Soil Clods for Bulk-density and Water-retention Measurements. Soil Science 101(2): 108.

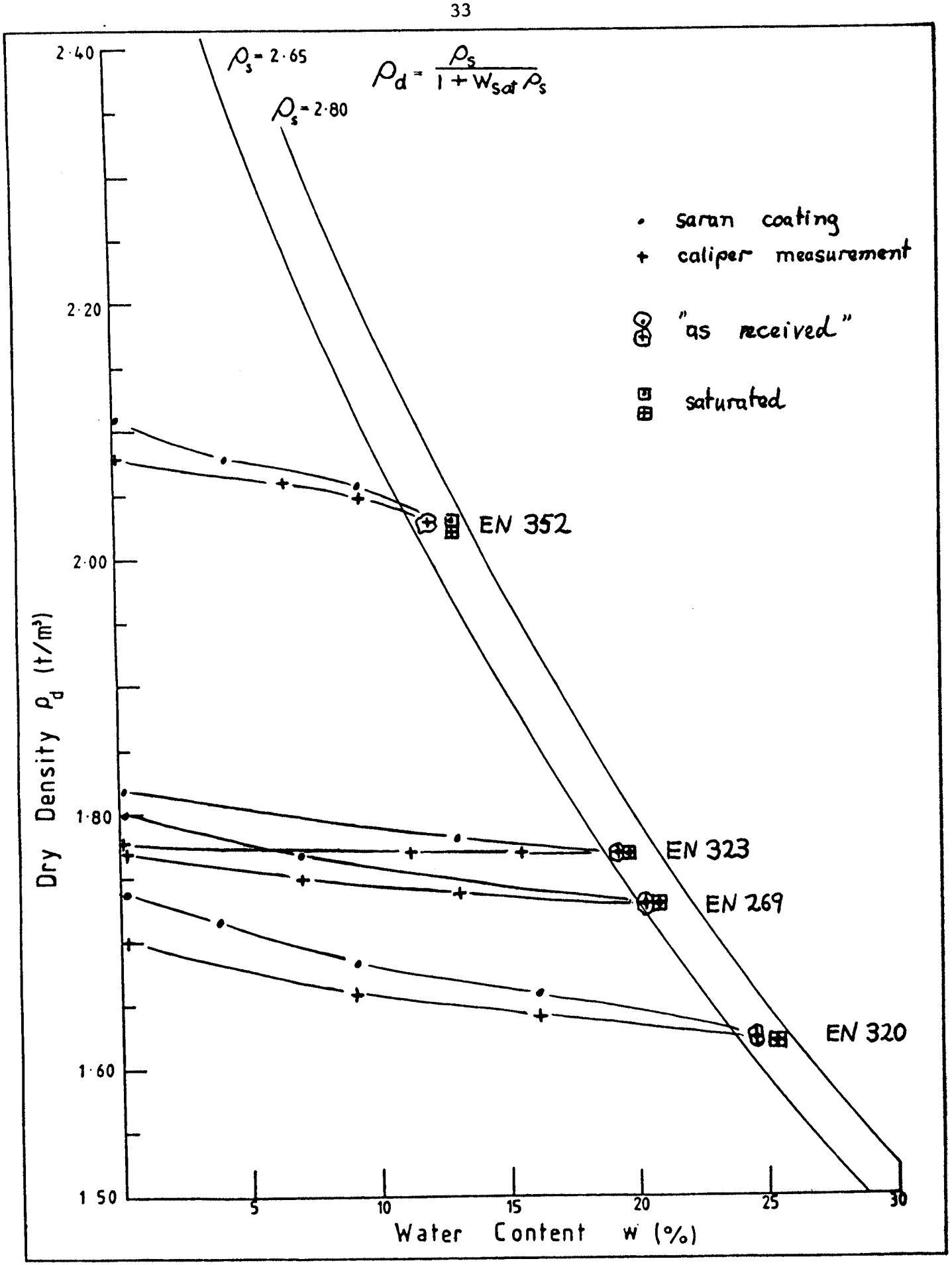

FIGURE 1 DRY DENSITY v WATER CONTENT

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APPLICATION FOR MEMBERSHIP

of

New Zealand Geomechanics Society

A TECHNICAL GROUP OF THE NEW ZEALAND INSTITUTION OF ENGINEERS

The Secretary,
N.Z. Institution of Engineers,
P.O. Box 12-241,
WELLINGTON.

I believe myself to be a proper person to be a member of the N.Z. Geomechanics Society and do hereby promise that, in the event of my admission, I will be governed by the Rules of the Society for the time being in force or as they may hereafter be amended and that I will promote the objects of the Society as far as may be in my power.

I hereby apply for membership of the N.Z. Geomechanics Society and supply the following details:

NAME _____
(to be set out in full in block letters, surname last)

PERMANENT ADDRESS _____

_____

QUALIFICATIONS AND EXPERIENCE _____

_____

NAME OF PRESENT EMPLOYER _____

NATURE OF DUTIES _____

Affiliation to International Societies: (All members are required to be affiliated to at least one Society, and applicants are to indicate below the Society(ies) to which they wish to affiliate.) Affiliation fees are in addition to the Geomechanics Society membership fee of $12.00.

I wish to affiliate to:

International Society for Soil Mechanics and Foundation Engineering	(ISSMFE)	Yes/No	($5.00)
International Society for Rock Mechanics	(ISRM)	Yes/No	($7.50)
International Association of Engineering Geology	(IAEG)	Yes/No	($3.50)
	($8.00 with Bulletin)		

Signature of Applicant _____

Date _____ 19__

PLEASE DO NOT SEND FEES WITH THIS APPLICATION, AS AN ACCOUNT WILL BE RENDERED ON YOUR ACCEPTANCE INTO THE SOCIETY.

Nomination:

I _____ being a financial member of the N.Z. Geomechanics Society hereby nominate _____ for membership of the above Society.

Signed _____ Date _____ 19 __

NEW ZEALAND GEOMECHANICS SOCIETY

NOTIFICATION OF CHANGE OF ADDRESS

The Secretary,
N.Z. Institution of Engineers,
P.O. Box 12-241,
WELLINGTON

Dear Sir,

CHANGE OF ADDRESS

Could you please record my address for all New Zealand Geomechanics Society correspondence as follows:

_____

_____

_____

Name: _____

Address to which present correspondence is being sent:

_____

_____

_____

Signature _____

Date _____