

N.Z. GEOMECHANICS NEWS

No. 12

MAY 1976

A NEWSLETTER OF THE N.Z. GEOMECHANICS SOCIETY

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	<u>Page</u>
Editor's Notes	1
Local Geomechanics Activities	3
Production of Wedge Failures in Rock	5
Rock Mechanics Testing Equipment in New Zealand	10
Temporary Support of Bulk Excavations	13
Report on 2nd Annual Meeting of the International Tunnelling Association	18
Letters to the Editor	20
Piling and Vibratory Compaction in the City of Auckland	21
News from the Management Secretary	22
Report on N.Z. Geomechanics Society Annual Meeting 1976	24
Ground Vibrations	25
Guidelines for Preparing Engineering Geological Reports	30
Activities of the Wellington Section of the Aust. I.M.M.	34
Membership Application Form	35
Change of Address Form	36

THIS IS A RESTRICTED PUBLICATION

"N.Z. Geomechanics News" is a newsletter issued to members of the N.Z. Geomechanics Society. It is designed to keep members in touch with recent developments. Authors must be consulted before papers are cited in other publications.

Persons interested in applying for membership of the society are invited to complete the application form at the back of this newsletter. Members are required to affiliate to at least one of the following international societies; Soil Mechanics, Rock Mechanics or Engineering Geology.

EDITOR'S NOTES1. Election of Management Committee by Postal Ballot

Some concern has been expressed by members of the Management Committee that only a small proportion of the members of the Society are able to participate in the election of officers to the Committee. In the past, elections have been held at the Annual General Meeting, which has been held at a time to coincide with the N.Z.I.E. annual conference. It was felt that members of the society who were attending the conference could also attend the Annual General Meeting and, hopefully, the maximum number of Society members would be able to attend.

Section 6.2 of the rules of the Society states: "The Management Committee shall comprise ten members of the Society. Eight members of the Committee shall be elected by all members of the Society, and two shall be appointed by the Council of the Institution". The wording of the rules implies that the maximum number, if not all, of the members of the Society shall participate in the election of the Management Committee.

At the last meeting, the Management Committee decided that the next election of its members would be by postal ballot. A call for nominations will be sent out about mid-October. Nominations, together with brief biographical details of each candidate should reach the Secretary by 1 November. Ballot papers will be sent out with the November issue of Geomechanics News, to be filled in by Society members. A postal ballot will give every member of the Society an opportunity to participate in the election of the Management Committee.

2. Nelson Symposium on Stability of Slopes in Natural Ground

In November 1974 the Society held a symposium entitled "Stability of Slopes in Natural Ground". The symposium was at Nelson and a wide range of topics relating to slope stability were discussed. Papers presented covered legalities of slope stability, classification of landslides, geological assessment of slope stability, case histories, instrumentation, engineering assessment of slope stability and stability of rock slopes. The proceedings contain 244 pages, including 15 papers and reports of discussion at each session. Copies of the proceedings are available at \$18 and may be purchased through:-

The Secretary
NZ Institution of Engineers
P O Box 12-241
WELLINGTON

3. N.Z.I.E. Annual Conference, Christchurch, 1977

Following established practice, the Geomechanics Society has reserved time at the 1977 N.Z.I.E. Annual Conference to hold a technical group session. A call is made to members of the Society for papers of general Geomechanics interest.

Synopses are required to be submitted to the Management Secretary by July 31. Following reviewing of received papers, successful authors will be advised of acceptance. Completed papers are required by November 1976. Synopses should be sent to:

Dr J Hughes
N.Z.G.S. Management Secretary
c/o Civil Engineering Dept
University of Auckland
Private Bag
AUCKLAND.

4. New Zealand Geomechanics Society Symposium, 1977

The management committee of the Society is considering holding another symposium in the later part of 1977. The format of the symposium would conform with that of previous Society symposia.

At present the management committee has three broad themes, one of which could be developed into a symposium topic, depending upon response from members of the Society. The three themes under consideration are:

- 1) Tunnelling in New Zealand
- 2) Engineering and Geological Properties of Soft Rocks
- 3) Groundwater in Civil Engineering

The Management Committee invites comments from members of the Society, and other interested parties, who feel they could contribute technical papers on one or more of the themes. Comments should include preferred theme, brief description of topic and authors related experience. This is not a call for papers and comments received will not be binding in any way. Comments should reach the Management Secretary by August 1976.

5. Preparation of Engineering Geological Reports

There is an increasing awareness in geotechnical engineering of the need for accurately prepared and detailed engineering geological reports. To the knowledge of the editor, there are not established formats or guidelines for the preparation of these reports in New Zealand, and some engineers may be unaware of the role of these reports.

Guidelines for the preparation of engineering geological reports for submission to the Department of Public Works, County of Ventura, California are presented in a publication which was brought to the attention of the editor. While the guidelines will require modifications to suit New Zealand conditions, they may well be an adequate starting point for the preparation of a set of New Zealand guidelines. Conversely, it may be the opinion of engineering geologists that a set of guidelines for preparation of reports in this country are not required.

The editor welcomes any correspondence on this matter.

6. Contributions to New Zealand Geomechanics News

Contributions to New Zealand 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
 New Zealand Geomechanics News
 c/o New Zealand Geomechanics Society
 P.O. Box 12-241
 WELLINGTON

I.M. Parton
 EDITOR

LOCAL GEOMECHANICS ACTIVITIES

AUCKLAND:

Since our previous report (N.Z. Geomechanics News No.11, November 1975), the chairmanship of the local committee has passed from Mr R. Gilmour to Mr J.P. Blakeley. The new secretary of the committee is Mr T.J. Kayes. Acknowledgement is made of the great efforts of Mr Gilmour over many years in forming this committee and maintaining a lively interest in geomechanics matters in the Auckland region. At the same time it has been decided that the committee will become the Auckland Group of the N.Z. Geomechanics Society rather than the Geomechanics Sub-committee of the N.Z.I.E. Auckland Branch. (This is in line with local committees of other N.Z.I.E. Technical Groups.) However, close links will still be kept with the Auckland Branch so that the organisation of meetings can be fitted in to the overall Branch programme.

Topics of interest in the activities of the Auckland Group are:

"Symposium on House Foundations in the Auckland Area".

The proceedings of this 2½ hour symposium held in April 1975 are still available from Mr J.P. Blakeley, P.O. Box 6345 Auckland, at a cost of \$2.00 per copy. The 32 page volume includes the full text of the three papers presented at the symposium together with authors' comments during presentation, prepared discussion from the local branch of the N.Z. Institute of Architects, general discussion from the audience and a list of the 100 participants.

"Temporary Support of Bulk Excavations".

A report on this meeting held in November 1975 at which the speakers were Messrs. B.C. Hadfield and F. Kratky appears elsewhere in this issue of N.Z. Geomechanics News.

"Register of Borehole Information in the Auckland Metropolitan Area".

Mr W.M. Prebble of the Geology Department of the University of Auckland has taken over responsibility for the maintaining of this register which is housed in the library of the School of Engineering at the University. It is hoped that the various organisations who have contributed cards to the index system in the past will continue to do so as information from recent site investigations becomes available. Completed cards may be sent or given either to Mr Prebble or to the librarian at the School of Engineering. Supplies of blank cards are available from Mr Prebble.

House Foundations Exhibit

This continues to be displayed at the Auckland Building Centre and there is a steady sale of the House Foundations booklet which accompanies the exhibit.

PROGRAMME OF MEETINGS FOR 1976

1. The first meeting of the year was held from 5.30 - 7 p.m. on Tuesday 13 April. The subject was "Legal Aspects of Geotechnical Works" and the speaker was Mr D.F.G. Sheppard, an Auckland barrister and solicitor. A lively discussion followed the speaker's presentation and the meeting was attended by about 30 people. It is hoped that a full report on this meeting will appear in the next issue of N.Z. Geomechanics News.
2. A 2½ hour "Symposium on the Geology of the Auckland Region" is planned from 3 - 5.30 p.m. on Tuesday 12 Oct. at the School of Engineering, University of Auckland. It is hoped that a panel of five speakers will participate under the convenership of Mr W.M. Prebble. The symposium will of course be directed towards engineering geology and will have the objective of informing practising engineers and others concerned

with engineering geology in the Region rather than as a discussion between specialists in this field.

3. A meeting on the subject of "Pole Houses" is planned from 5.30 - 7 p.m. on Tuesday 10 August. A panel of three speakers will include a Local Authority engineer, an architect and a consulting engineer. This meeting will be convened by Mr M. Wesseldine.

It is hoped that this advance notice of the July and October meetings will assist all interested people to be present at these meetings.

J.P.B.

WELLINGTON:

The programme of activities planned in the Wellington area for this year is a most interesting one, even if we are making a rather late start! It is intended to have monthly meetings between June and December.

For the last two years we have met in Lower Hutt at 7.30 p.m. It has been suggested that a greater number of members might be able to attend the meetings if they took place in Wellington, rather than in Lower Hutt, and at 5.00 p.m. rather than 7.30 p.m. Thus we intend to meet this year in the Vogel Building Conference Room, for a trial period at least.

The topics for the various meetings are as follows:

- June: Coal mining in N.Z. - History and future developments.
- July: Tunnelling '76 - a Report from a participant
- August: Joint meeting with Wellington Branch of N.Z.I.E.
- September: Engineering Geology in California. Consulting practice and natural phenomena
- October: Earth Deformation measurements in N.Z.
- November: Draft code of practice for residential subdivisions and the use of the nuclear density meter in such work.
- December: Any suggestions?

The dates are not yet finalised but will be towards the middle of the month. A circular will be sent to local members with further details in the near future.

THE PREDICTION OF WEDGE FAILURES IN ROCK SLOPES

I.R. Brown

1. Introduction

In a rock mass, the intersection of continuous defects can form rock wedges dipping out of the slope face (Fig.1). These rock wedges commonly fail by sliding along one, or both, defect planes. This type of failure is prevalent in rocks with at least two well developed fracture directions, for example, in the greywacke-type rocks that are widespread throughout New Zealand.

This is the final paper in a series of three dealing with the collection and analysis of rock defect data (Brown 1975a, 1975b).

2. The Orientation of Rock Defects

Before designing a cut slope in hard rock it is desirable to collect as much field data as possible relating to the nature of rock defects. This may be done from natural rock exposures or investigation trenches, using methods described in a previous article (Brown 1975b). The location of continuous defects should be plotted on a large-scale map.

The evaluation of preferred defect directions can be made most readily by plotting all poles of defects on an equal-area stereographic projection and contouring their density. This procedure cannot take into account a continuous defect with low shear strength that may exert a considerable influence on stability, such as a clay-filled fault zone. These features, although possibly low in frequency of occurrence, must be treated as a defect set in their own right.

The continuity and spacing of defect sets must also be considered. Potential wedge failures may occur partly by failure along non-continuous subparallel defects, and partly by failure through intact rock. In this case, the peak shear strength along the failure plane will be higher than for a continuous defect. Wedge failures are most common over the height of one or two benches, and become less prevalent as the height of the slope increases. This is because defect planes are most likely to be found with a continuity of the order of bench heights.

3. Kinematic Analysis of Wedge Stability

As a first step in a prediction of wedge failures it is useful to consider whether movement is kinematically possible. This analysis does not need to take into account rock volume or shear strength of rock defects and can be quickly carried out using an equal angle stereographic projection.

If the line of intersection of two defect planes dips out of a slope, the wedge formed by the intersection is kinematically unstable. The plunge along the line of intersection of the two planes must be less than the apparent dip of the slope face along this line (Fig. 2). If the line of intersection does not dip out of the slope, the wedge will not be able to fail by sliding along the two defects (Fig.3).

A large number of intersections is possible if each plane measured in a defect survey is considered intersecting every other plane. In most cases it is adequate to consider the intersection of mean directions of defect sets. Using this approach, it should be possible to see how changes in slope orientation can cause a reduction in the number of wedges dipping out of the slope. Only those intersections that form kinematically unstable wedges need be analysed using limit equilibrium methods.

4. Resolution of Forces Using a Stereographic Projection

The stereographic projection can be used to show the direction of forces

acting on a rock mass. As an example of how vectors can be manipulated on a stereographic projection, consider a defect plane with dip direction/dip of $180^{\circ}/30^{\circ}$. The following forces act on the plane:

\bar{W}	the weight of rock
\bar{U}	the porewater force (equal to $0.44W$)
\bar{N}	the normal reaction
\bar{S}	the maximum shear force
\bar{A}	an external force (equal) to $0.6W$, trend 225° , plunge 10°

As a summation of moments is not carried out it is not necessary to know the location of these forces. The shear strength of the plane is expressed in terms of the friction angle ϕ . The reaction force at failure, R_L ($R_L = N+S$) is orientated at the angle of friction ϕ from the normal to the plane (Fig.4). The orientation of S is dependent on the direction of sliding, so a friction cone is drawn to show the possible orientations of R_L . A friction cone is constructed by marking off ϕ degrees from N on great circles passing through N ; N is not always in the centre of the circle formed by the friction cone (Fig. 6).

The summation of a series of vectors cannot be performed using the stereographic projection alone, because there is no method for showing magnitudes of forces. The orientation of a resultant vector can be determined using the stereographic projection in combination with the graphical addition of vectors two at a time. To find the resultant vector $B = W+U+A$, W and U , and W and A are added graphically (Figs. 4 and 5) and their orientation from the vertical in the plane of the two vectors determined. When the vectors $W+U$ and $W+A$ are plotted on the stereographic projection, the direction of B is found by the intersection of the planes containing $W+A$ and U , and $W+U$ and A . As B lies outside the friction cone, sliding will occur in the direction of the plane (great circle) containing B and N , i.e. along the line of S trending 207° and plunging 25° .

5. Limit Equilibrium Analysis of Wedge Stability

The method of resolution of forces acting on one plane can be extended to enable a limit equilibrium analysis of wedge stability. Two defect planes orientated $144^{\circ}/62^{\circ}$ and $266^{\circ}/40^{\circ}$ dip out of a slope face. The line of intersection of the planes trends 207° and plunges 40° . A stereographic projection (Fig. 7) is used to plot the forces acting on the wedge. The normal forces N_1 and N_2 act at the poles to planes 1 and 2. The shear forces S_1 and S_2 act in the direction of sliding and plot at the same point as the line of intersection. The reaction force R_{L1} must be in the same plane as N_1 and S_1 i.e. a great circle through N_1 and S_1 . The intersection of this great circle and a friction cone round N_1 gives the orientation of R_{L1} when sliding occurs along the line of intersection. The orientation of R_{L2} is found in the same way. The resultant of R_{L1} and R_{L2} lies on a great circle through R_{L1} and R_{L2} , but the position of the resultant will depend on the orientation of the disturbing forces that act on the wedge.

The resultant of the disturbing forces can be found by summation of a series of vectors. In order to cause sliding of the wedge, the resultant vector must lie outside that area of the stereographic projection bounded by the friction cones and the great circle between R_{L1} and R_{L2} . If B is the resultant disturbing force, sliding will occur along the intersection of the two planes. The angle between $R_{L1} + R_{L2}$ and N_1+N_2 (33°) and $R_{L1} + R_{L2}$ and B (180°) are measured along a great circle drawn through B and S_1, S_2 . The factor of safety can be calculated:

$$F.S. = \frac{\text{maximum shear force available}}{\text{actual shear force mobilised}} = \frac{\tan(33^{\circ})}{\tan(33^{\circ}+18^{\circ})} = 0.53$$

This type of analysis can give a quick appraisal of generalised wedge stability. Areas of stability and instability, with different modes of failure depending on the location of the resultant disturbing vector, are outlined on Figure 7.

6. References

- Brown, I.R. 1975a: Analysis of Geological Structures using Stereographic Projection N.Z. Geomechanics News 10: 3-8
- Brown, I.R. 1975b: The collection of rock defect data for engineering purposes. N.Z. Geomechanics News 11 : 3-9

7. Bibliography

- Goodman, R.E. 1964: The resolution of stresses in rock using stereographic projection. International Journal of Rock Mechanics and Mining Sciences 1 : 93-103
- Hoek, E.; Bray, J. 1974 : Rock Slope Engineering. The Institution of Mining and Metallurgy, London, 309 pp.
- John, K.W. 1968: Graphical stability analysis of slopes in jointed rock. Journal of the Soil Mechanics and Foundation Division A.S.C.E., 94 SM2 : 497-526
- Londe, P.; Vigier, G. ; Vormeringer, R. 1970: Stability of slopes - graphical methods. Journal of the Soil Mechanics and Foundation Division, A.S.C.E. 96 SM4 : 1411-1434

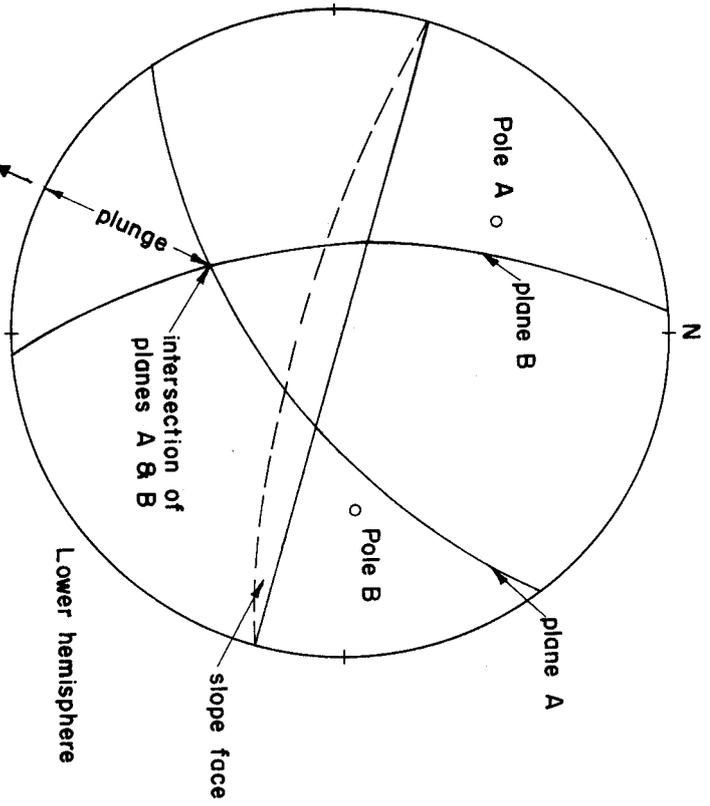


Figure 2. Kinematically unstable wedge

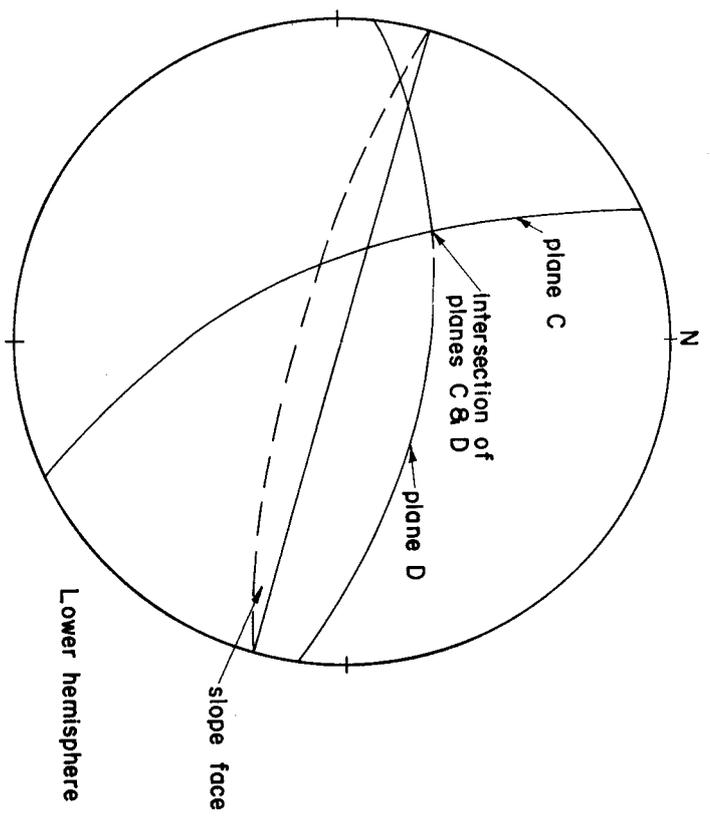


Figure 3. Kinematically stable wedge

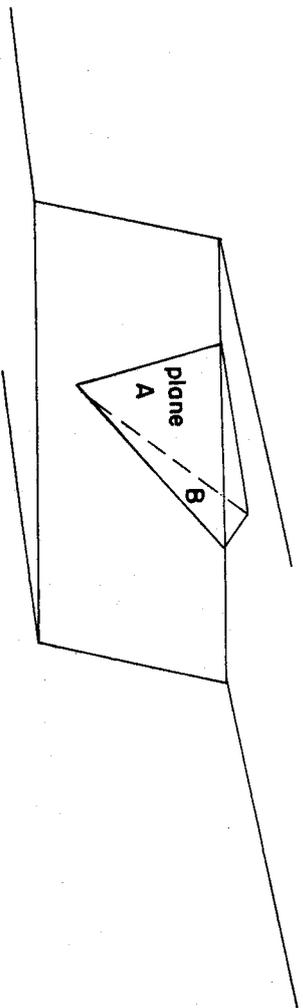


Figure 1. Wedge formed by intersection of two defect planes

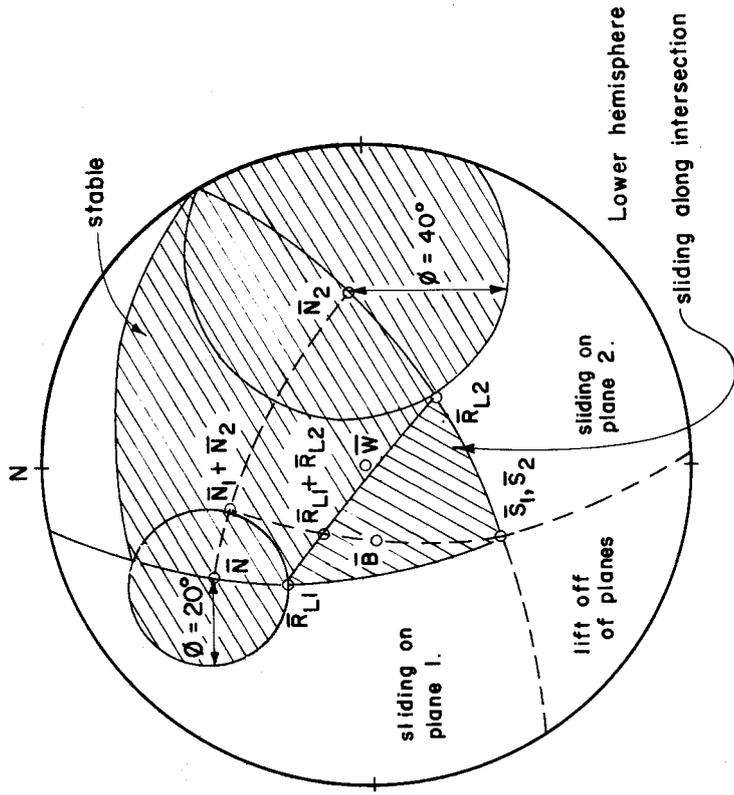


Figure 7. Stereographic projection of force vectors acting on rock wedge.

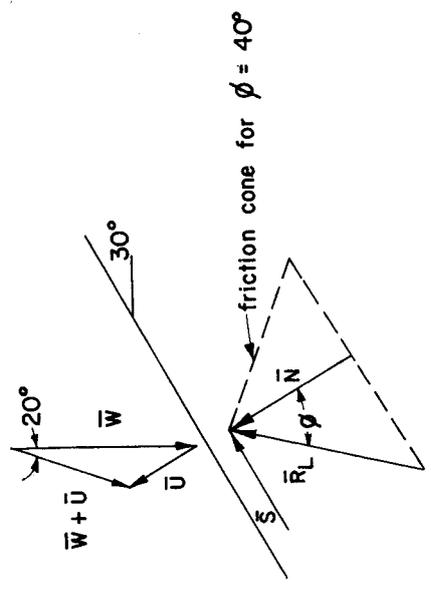


Figure 4. Vertical plane orientated 180° (along dip of defect plane)

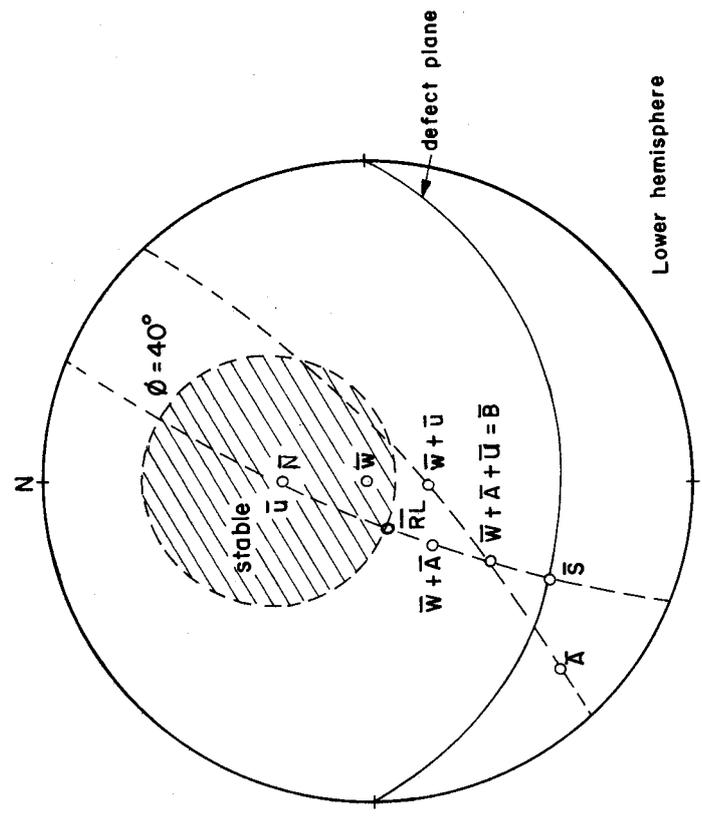


Figure 6. Stereographic projection of force vectors shown in Figs. 4 & 5.

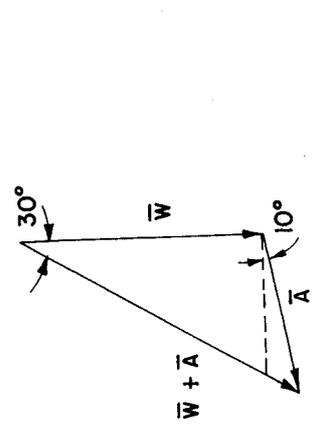


Figure 5. Vertical plane orientated 225° containing \bar{W} & \bar{A} .

ROCK MECHANICS TESTING EQUIPMENT IN NEW ZEALAND

D.H. Bell

INTRODUCTION

"Rock mechanics is the theoretical and applied science of the mechanical behaviour of rock; it is that branch of mechanics concerned with the response of the rock to the force fields of its physical environment". (1)

Whether we necessarily agree with such a wide definition of the scope of rock mechanics, and whatever we consider to be "rock", testing methods group basically into laboratory and in situ techniques. Rock mass behaviour under changing stress conditions is governed both by the mechanical properties of the intact rock material, and by the spacing, orientation and nature of discontinuities within the rock mass itself. Because the mechanical properties of intact rock under laboratory testing may differ significantly from the in situ stress response of the rock mass from which the laboratory samples were abstracted, there has been increasing emphasis placed on in situ testing equipment and procedures. However, laboratory testing equipment still plays a major role in rock mechanics investigations, both theoretical and applied.

This brief review of rock mechanics testing equipment in New Zealand is based on a questionnaire survey conducted by The New Zealand Geomechanics Society during 1975. In this article, available testing equipment is summarised: The wider question of rock mechanics research and its future in New Zealand will be considered in a later article in Geomechanics News.

TESTING EQUIPMENT QUESTIONNAIREAims

The aims of the Rock Mechanics subcommittee of The New Zealand Geomechanics Society, in circulating the questionnaire on rock mechanics testing equipment in New Zealand, were to increase communications between interested parties, to present information on equipment and techniques available, and hopefully to enable some standardization of testing methods. The questionnaire requested information on details of testing apparatus (such as make, function, range and units of measurement), staff involvement in rock mechanics investigations, and any general comments (such as the role envisaged by various organisations for rock mechanics investigations).

The questionnaire was sent to Geomechanics Society members affiliated with the I.S.R.M., and to various University departments, Government organisations, local bodies and private firms which might have been expected to carry out, or at least have an interest in, rock mechanics investigations. In all, over forty individuals and organisations were circularised, although it is certainly possible that some interested groups were not contacted.

Reponse

Despite reminders, the response to the questionnaire was poor, with considerably less than half of those contacted replying at all: Whilst it has been assumed that no reply meant no rock mechanics testing equipment, it was certainly gratifying to receive a number of negative responses. In all, ten organisations indicated some involvement with rock mechanics testing equipment, and as expected most of these were University departments or Government organisations. Results of the testing equipment questionnaire are summarised in the attached table.

(1) quoted by D.U. Deere in ROCK MECHANICS IN ENGINEERING PRACTICE, edited by Stagg and Zienkiewicz, published by John Wiley & Sons, 1968.

ANALYSIS OF QUESTIONNAIRE RESULTS

As anticipated, the survey has shown that most of the rock mechanics testing equipment in New Zealand is held by the School of Engineering, University of Auckland, and by the Engineering Geology Section, N.Z. Geological Survey, Lower Hutt. Equipment is available at Auckland for uniaxial and tri-axial compression testing of rock cores, and a direct shear machine has been developed there for the measurement of strength and deformation characteristics of rock joints. Similar equipment is in use by the Engineering Geology Section at Lower Hutt.

At the University of Canterbury, the Civil Engineering Department has both compression and universal uniaxial testing equipment which could be adapted for rock mechanics research, but which is used at the present time only to introduce undergraduate civil engineering and geology students to the principles of rock mechanics and to testing methods. The Geology Department has recently acquired a sophisticated uniaxial compressive testing machine, and a coring device is under construction to enable preparation of test specimens in any orientation.

Ministry of Works and Development Central Laboratories, Lower Hutt, hold only limited rock mechanics testing equipment. The Green Island Testing Laboratory (Dunedin) and Tongariro Power Development Project each have unconfined compression testing machines which are used sporadically for rock mechanics investigations, whilst limited in situ rock mechanics testing equipment is also held at Turangi.

Geotechnics Ltd. and Beca, Carter, Hollings and Ferner Ltd., both of Auckland, have limited testing equipment which is used from time to time for rock mechanics investigations, particularly in weathered rock. W. Stevenson and Sons Ltd., Otahuhu, whilst having a wide range of testing equipment used primarily for aggregates, do also have equipment which could be of at least indirect use in rock mechanics studies.

Staff involvement in rock mechanics investigations in New Zealand is not great, in keeping with the limited equipment available. The maximum time allocation is 90 man hours/month by M.W.D. Central Laboratories, Lower Hutt, and most organisations have no more than one professional staff member and/or technician engaged part-time in rock mechanics studies. The Engineering Geology Section of N.Z. Geological Survey, Lower Hutt, has recently appointed a full-time technician for its rock mechanics investigations.

It is clear from the survey that the science of rock mechanics is very much in its infancy in New Zealand. Future trends reported include the development of in situ testing capabilities by the Engineering Geology Section of the N.Z. Geological Survey, and the possible establishment of rock mechanics facilities by the Department of Mines for investigations related to strata control in coal mining operations. Whether the general lack of rock mechanics investigations in New Zealand is due to the limited availability of suitable equipment, or reflects an absence of practical rock mechanics problems, or is due to other factors, will be discussed in a later article.

CONCLUSIONS

1. Equipment in New Zealand specifically for rock mechanics testing is limited to selected University departments and Government organisations: Some private engineering firms have geotechnical testing equipment which is occasionally adapted for rock mechanics studies.
2. Laboratory equipment available includes uniaxial and triaxial compressive testing apparatus, for determination of rock strength and deformation characteristics: Direct shear machines are also available for rock discontinuity studies.

3. There is an apparent lack of in situ testing equipment for rock mechanics investigations, although this has been developed for certain sites as required: This practice will undoubtedly continue in the future.

SUMMARY OF ROCK MECHANICS TESTING EQUIPMENT IN NEW ZEALAND

Organisation	Number	EQUIPMENT Function	Comments	STAFF INVOLVEMENT	
				Professional staff	Technicians
School of Engineering, University of Auckland, Private Bag, Auckland Phone: 74-740	1	100-ton compressive testing machine	Used for rock strength and elastic parameter determinations	3 part-time (20 man hrs/mth)	1 part-time (16 man hrs/mth)
	2	Hoek triaxial cells (AX/NX)	Confining pressures up to 25 MPa		
	1	Direct shear machine	Maximum vertical and shearing loads 250 kN		
Dept. of Civil Engineering University of Canterbury Private Bag, Christchurch Phone: 71-649	1	Compression testing machine (600,000 lb. max.)	Could be readily adapted for rock mechanics work	None	As required
	2	Universal testing machines	25,000 and 250,000 lb max. loads, respectively		
	1	Dynamic shear modulus tester	Designed and built for rock and soil testing		
Department of Geology, University of Canterbury Private Bag, Christchurch Phone: 71-649	1	Uniaxial compression tester (50,000 lb max. load)	Used for deformation and strength studies	2 part-time	2 part-time
	1	Seismic analyser		(use irregular)	
	1	Slake-durability tester			
	1	NX rock coring and lapping equipment	Under construction		
Engineering Geology Section N.Z. Geological Survey, D.S.I.R. P.O.Box 30-368 Lower Hutt Phone: 699-059	1	Rock shear box	Discontinuity studies; soft rock investigations	1 part-time	1 full-time 1 part-time
	2	Hoek triaxial cells (EX/NX)			
	1	Point load strength tester	Field and laboratory use		
	1	Slake durability tester			
Central Laboratories, Min. of Works & Dev. P.O. Box 30-325 Lower Hutt Phone: 683-119	1	In situ rock stress measurement	Overcoring device	1 part-time (30 man hrs/mth)	1 part-time (60 man hrs/mth)
	1	Point-load strength tester			
	-	Apparatus for sonic wave velocity studies			
	-	Test specimen preparation equipment			
Tongariro Power Development Project M.W.D. Private Bag, Turangi Phone: 7799	1	Unconfined compression test machine	Max load 320,000 lb	None	As required
	4	Freyssinet flat jacks	Max load 112 tons	(No regular rock mechanics testing)	
	1	Borehole deformation gauge			
Dist. Testing Lab. M.W.D. Green Island Dunedin. Phone: 33-553	1	10 ton universal testing machine	Occasional use for rock mechanics work	None (No regular rock mechanics testing)	As required
	2	Unconfined shear testers	10,000 and 250,000 lb max loads	1 part-time (15 man hrs/mth)	1 part-time (5 man hrs/mth)
Beca, Carter, Hollings and Ferner Ltd. P.O.Box 6345 Auckland Phone: 73-410	1	Brazilian tester			
	1	Triaxial test machine			Investigations often form part of larger projects (e.g. foundations)
Geotechnics Ltd. P.O. Box 5271 Auckland Phone: 397-687	3	Compression testing mach.	200 tons, 50 kN and 100 kN ranges, respectively		Staff available as required: Testing usually restricted to soil and concrete investigations, but can be adapted to rock mechanics studies
	1	Pressuremeter	Soft rock and soil only		
W. Stevenson & Sons Ltd P.B. Otahuhu		Various testing equipment available of indirect applicability to rock mechanics studies: Principal uses in aggregate assessment.			

TEMPORARY SUPPORT OF BULK EXCAVATIONS

A meeting on this topic was held in November 1975 by the Auckland Group of the New Zealand Geomechanics Society. The speakers at the meeting were Mr B.C. Hadfield of the Gilberd-Hadfield Pile Co. Ltd. and Mr F. Kratky of the Auckland City Council.

Mr B.C. Hadfield

The meeting commenced with Mr Hadfield outlining his approach to temporary retaining structures based on his past experience.

1. TYPES OF TEMPORARY RETAINING STRUCTURE

- (a) Timber shoring is relatively inexpensive and is suitable for depths of up to about 2 metres. The timber can either be driven vertically for bottom support or else it must be supported by a system of timber walers and struts at both the top and the wall.
- (b) Steel sheet piling which can be driven and later extracted. Where the retained depth exceeds about 3.5 metres, the bending moment capacity of the sheet piling is likely to be exceeded unless walers are used to support the wall. The walers will in turn be supported either by horizontal struts or by means of earth or rock anchors.
- (c) Steel soldier piles. These may either be driven into the ground, or alternatively placed in pre-drilled holes with the hole later being filled with sand or concrete to provide a fixed base. These soldier piles are generally used with horizontal timber laths which are fitted into place as excavation proceeds. As the cost of timber lathing is relatively low compared with the cost of steel sheet piling, this method becomes more economical than sheet piles for deeper excavations. However, for deeper excavations it is generally necessary to support the soldier piles either using horizontal struts or by means of earth or rock anchors to prevent the soldier piles from being overstressed in bending.
- (d) Segmented bored pile system. Bored piles are constructed adjacent to one another to provide a continuous wall. This system can become economic where the wall can also be used as a permanent load bearing wall in the final basement design which hence obviates the need for a separate temporary retaining structure.

2. INFLUENCE OF NATURE OF FOUNDATION SUBSOILS ON SELECTION OF WALL TYPE

The type of wall chosen for a temporary retaining structure and the economics of the wall are greatly influenced by the nature of the subsoils. For silt and clay soils, timber shoring is likely to be the most economic method for relatively shallow excavations and steel sheet piles for deeper excavations. However, for sandy soils, timber shoring may not be practicable if the sand will not stand unsupported, and hence steel sheet piles may be the chosen solution even for relatively shallow excavations. Where silts and clays overlie hard sandstone or rock which is in within about 1 metre of the excavated depth, it may be necessary to use a pre-drilled soldier pile system since sheet piles cannot be driven more than about 0.5 metres into sandstone and cannot be driven at all into harder rock. In Auckland, the presence of hard sandstone or a basalt lava flow near the base of an excavation can often prevent sufficient penetration at the toe of the wall unless pre-drilling is carried out.

3. DESIGN EARTH PRESSURES AND LOADINGS FOR TEMPORARY RETAINING STRUCTURES

Typical Auckland subsoils can vary from volcanic tuffs (in the Shortland Street, High Street and Khyber Pass areas) which if cut to a vertical face are often free standing for several metres height and exert little or no horizontal pressure (but should be protected against weathering) to clays such as those derived by weathering from the Waitemata Formation which, depending on moisture content, are notoriously unstable and likely to develop large horizontal pressures.

In addition to these factors, for many of the sites (particularly in the Auckland Downtown area) a surcharge loading from adjacent existing buildings and heavy vehicles must be allowed for.

The design of these supporting walls is in many cases based on the equivalent fluid pressure concept of triangular distribution of pressure, but the actual distribution of horizontal pressure will be dependent on the method of construction and on the effective yield of the completed wall. Yielding or deflection of the earth face will allow a redistribution of the ground pressure, and if walings and bracing are not placed within a short period, the bank may deform at the top, middle or bottom. Conversely, the very act of fixing and wedging struts or stressing ground anchors to the walings and thus applying localised pressure to the earth face can alter the nature of the soil and cause a redistribution of the earth pressure. Therefore, depending on the type and method of construction, Terzaghi's trapezoidal distribution of pressure would be a more realistic approach than a triangular pressure distribution for the design of temporary support walls.

4. METHODS OF BRACING AND TYING BACK

- a) Strutted or braced excavation. Support for the walls of the excavation by this method is relatively inexpensive to construct but does very much restrict the working space and hence makes the construction of the permanent basement wall much more difficult. Such a support system is simple and relatively quick to install but on the other hand it is sometimes difficult to remove without cutting as the braces can become "locked in".
- b) Rock or ground anchors. These are generally expensive to install. Another disadvantage is that delays of two to three weeks occur for grout curing prior to stressing of the anchors. If any failures occur during anchor stressing, further delays of another two to three weeks will occur while additional anchors are installed. Another factor to be considered is that there could be legal complications where anchors are installed under existing buildings or roads. The legal position regarding anchors which encroach on to other properties is not at present very clear. The great advantage of rock or ground anchors is that they leave the site uncluttered for maximum ease of construction of the permanent basement.
- c) Sheet pile or similar "dead man" anchors. These may be used where there is sufficient space beyond the periphery of the temporary wall to enable dead man anchors at the required positions to be constructed from the ground surface.

5. ECONOMICS OF TEMPORARY RETAINING STRUCTURES

Specialist contractors involved in the construction of temporary retaining works are usually given little foundation information on which to base their design. Generally they are asked for a price per square metre of retained face for an excavated hole of a given depth and usually find it impossible to get all the information that is needed for a rational economic design in

that particular situation. The main building contractor will want the cheapest possible wall with a factor of safety as low as practicable and at the same time will want the specialist contractor who installs the wall to take full responsibility for it. Obviously the more information which is available at the time of tender, the better and more economic the design of the temporary retaining structure can be made. Generally only preliminary soils information for the design of the foundations of the structure will be available at this stage and this may or may not have the required information for adequate design of temporary retaining structures.

Mr F. Kratky

Mr Kratky then outlined the local body engineer's viewpoint as follows.

The Building By-law, Amendment No. 82, 1974 requires that an excavation permit shall be required for any excavation within 20 metres of an adjacent public place or property boundary where the slope below the ground level at the boundary exceeds 1 vertical to 2 horizontal, and that excavation shall not be carried out until a permit has been issued.

Where an excavation permit is required, plans shall be supplied in duplicate showing details of the proposed excavation in relation to the site boundaries, existing buildings and services on the site and in adjacent public places.

The applicant must satisfy the local body engineer that:

- (i) The proposal will not endanger the public or adjacent buildings or services.
- (ii) A certificate is produced that the proposal is satisfactory to the authorities responsible for services likely to be affected.
- (iii) The owners of all adjacent properties have been notified in writing of the intended work.

In connection with the requirement under (i), the proposal shall show that lateral support is adequately provided during the excavation operations. For any building permit application, it is required that the applicant should supply plans in duplicate, specifications in duplicate and structural calculations. Generally these documents shall be supplied with the building permit application for the whole project, although in some cases it will of course be necessary to provide these documents in advance.

Local body engineers generally prefer that prior to the design of an excavation support system, the whole proposal should be discussed with them. This should be taken as a free service of advice and help. Often the areas where a new project is proposed will be well known to a building inspector or the local body engineer. Such additional information as they can give will always be of help and sometimes may be very important. The designer would also be well advised to get some site investigation test bores drilled to verify the nature of the subsurface strata and to obtain more reliable information about likely earth pressures.

Knowledge of the depth to the ground water-table is very important in the design of the excavation support system. Also, seasonal fluctuations between summer and winter will be important. The designer should also discuss with the local body engineer whether surcharge is to be considered and if so what intensity should be taken in the design.

The local body engineer will not ask the designer for any particular support system. This is the designer's prerogative. However, the local body engineer will want to make sure that all factors which may affect the design of the

excavation support system have been taken into consideration. The Auckland City Council does not approve supporting systems with cantilevered members along the top edges of the excavation. These members can deflect and the ground can then start to crack and move. Subsequently and very often, heavy damage can occur to footpaths, carriageways and underground services.

In connection with by-law requirements, Mr Kratky also mentioned Auckland City Council By-law No. 3053 which refers to driving or extraction of piles, sheeting or casing and soil compaction using vibration techniques within 100 metres of any residential building which is on any land zoned residential. This is prohibited on the ground of nuisance but if any person wishes to do so, he must apply to the Director of Works for permission and if the Director of Works is satisfied that the techniques to be employed will not constitute a nuisance he may grant a permit. A note on the Auckland City Council by-laws is included elsewhere in this issue of Geomechanics News.

The use of British Standard Codes of Practice (e.g. Earthworks, Earth Retaining Structures, Foundations and Site Investigations) are quite acceptable. Trapezoidal pressure distributions are preferable for design. Any excavation shall comply with the Construction Act 1959 and its amendments.

When all the above requirements have been complied with, why is it that there are still collapses of excavations, slips, damage and even loss of life? There are, of course, many reasons. The local body engineer's job is to eliminate as many of them as possible because the ultimate aim is that the excavation shall be safely supported.

Some reasons for unsatisfactory support to excavations are:

- (i) Inadequate design (e.g. the design was properly prepared but the actual earth pressure was larger than anticipated). In the event of this happening, action shall be taken immediately the first signs of larger pressures are noted.
- (ii) The Contractor wrongly assessed the situation and opened up too much ground or allowed unsupported faces of excavations to be open for too long. Here, bad weather very often is the main factor and the contractor has taken too large a risk.
- (iii) The contractor is not sufficiently experienced in this kind of work or he wants to save some money and does not do exactly what the plans and specifications required.
- (iv) Bad workmanship or faulty material.

Mr Kratky completed his talk by showing slides of a number of underground excavation support systems of which he has knowledge.

DISCUSSION

Following the presentation of the two papers, the following matters were raised during general discussion.

Mr Kratky was asked if corrosion was a factor in the failure of ground anchors as illustrated on one of his slides. He replied that corrosion was unlikely to have been a factor and there was trouble with the system from the beginning. The problem was that the anchorage was not able to take the design load because dirt was left in the drillholes, i.e. they had not been cleaned out properly. Observations of lateral movements were kept and these were of the order of 1 inch at the top of the excavation. The movements were occurring in the top clays which overlaid harder strata beneath.

The question as to what stress cables should be locked off at was raised. A limiting stress of 70% of the ultimate stress is generally accepted as a rest load. With a factor of safety of 1.5 this is equivalent to about half the ultimate strength of the cable as a working load. However, the designer may choose to lock off the cable at a lower load than the working load.

The problem of the legal aspects regarding ground anchors in adjacent properties was raised. Legal opinion is that the ownership of the ground beneath any section goes to a great depth. Hence it is necessary to get the permission of the adjoining owner before any ground anchors are taken beneath his property and if any anchor is placed under some person's property without his permission there can be serious trouble as a result. When it is proposed to place anchors underneath a street, the permission of the local body will usually be forthcoming providing they can be persuaded that the work will be carried out in a proficient manner.

It was pointed out that if an excavation is carried out on adjacent land which would appear to be endangering the property of a landowner, he cannot stop the work until some damage has actually occurred unless he takes out a Court injunction. In this case the landowner can expect to have to stand the cost of issuing such an injunction.

It was pointed out that grouting operations for ground anchors can increase pore pressures in the ground in the adjacent property. The law says that the natural support of land must be maintained and this presumably could include the effects of changing pore pressures in that ground.

Also the pumping of water from an excavation cannot be stopped until subsidence can be proved to have occurred in adjacent properties as a result of this draining of water. Providing this can be proved then damages can be claimed.

It was pointed out that the common law situation for the support of ground is that if negligence can be proved, i.e. work is carried out in a negligent manner, then the offending party can be sued for damages and this would apply in particular to professional engineers. Two most significant factors in ground movement problems which occur alongside excavations are:

- (i) Where triangular earth pressure distributions have been used for the design of strutted walls, this invariably gives inadequate support at the top of the wall and anchors can fail as a result with consequent movements at the ground surface.
- (ii) It is not sufficient to design for a certain pressure distribution on a wall and expect no movements to occur. To do this it is necessary to replace the pressure balance before the movement occurs, i.e. the support system must be designed to take up the slack before movement can occur as the excavation is in progress. In order to achieve this it is necessary to stress to 100% of design working load to prevent any movement at all. However, if the stress is too high then it is possible to push the wall back into the country, which also would be undesirable as this could cause damage (although it is less likely to do so).

It was also pointed out that seasonal ground movements could be a problem alongside a supported excavation. (i.e. seasonal swelling and shrinking of the ground.) To prevent this from happening it may sometimes be possible to stop the ground water-table level from fluctuating during a job.

SECOND ANNUAL MEETING OF THE INTERNATIONAL TUNNELLING ASSOCIATION
LONDON, ENGLAND - FEBRUARY 26-28, 1976

This second annual meeting was hosted by the British Tunnelling Society and was held just prior to the international symposium "Tunnelling '76" in London. Twenty-two member countries are now affiliated with the ITA. These countries are: South Africa, German Federal Republic, Canada, Algeria, Australia, Denmark, Spain, United States, Finland, France, Iceland, Italy, Japan, Norway, New Zealand, Netherlands, United Kingdom, Sweden, Switzerland, Greece, Turkey, and India.

The general objectives of the ITA are to improve, both within member countries and internationally, the conditions in which planning, design, construction, and operate of underground works can thrive. International working groups, in each of which about 8 to 10 member countries participate, have been established in the following subject areas: standardization, research planning use of the subsurface, contractual sharing of risks, and safety. The working groups are engaged in exchange of information and studies anticipating recommendations, as appropriate, for improving education, techniques, procedures, and management of subsurface development and utilization. Three other subjects are receiving attention through member country co-operation with the ITA Secretariat rather than through specialised working group projects. These subjects are exchange of information, demand forecasting, and inventory of completed works.

The New Zealand Ministry of Works and Development acts on behalf of New Zealand on the ITA. The New Zealand delegates were, Messrs J.D. Bennion and J.C. Rutledge.

INTERNATIONAL SYMPOSIUM - "TUNNELLING '76"
MARCH 1-5, 1976 LONDON, ENGLAND

Five hundred participants from 38 countries discussed technical papers and viewed exhibits and demonstrations at this well-planned and -conducted international symposium. The technical papers included documented case histories of advanced technology, including:

- * Bentonite slurry machine tunnelling in Warrington, England, and Hamburg, Germany
- * Machine tunnelling in deep-level gold mines in South Africa
- * The National Coal Board developed tunnelling machines in British coal mines
- * The Dittaino-Ogliastro Tunnel in Sicily
- * Machine driven mini-tunnels in Australia
- * An undersea tunnel for the Madras atomic power station in India
- * The Kaimai railway tunnel in New Zealand
- * The Noguchi soft-ground tunnel in Japan
- * An inclined, twin-tube escalator shaft in Budapest
- * A hydroelectric pressure tunnel and a large motorway tunnel in Italy
- * An oil storage cavern in Finland

Research investigations and results were described for a wide variety of topics, including: performance of tunnel support systems in an experimental tunnel in mudstone; tunnelling machine data acquisition and processing;

laboratory, pilot, and full-scale experiments in tunnel boring; use of latex concrete for pressure tunnels; analysis of rock bolting; measurements of ground-lining interaction in an underwater tunnel in mudstone; design procedures in mining subsidence areas; factors influencing cutting performance of a selective tunnelling machine; location and support of tunnels in deep-level gold mines; and in-situ ground and lining studies for the proposed Channel Tunnel.

The symposium was sponsored by the Institution of Mining and Metallurgy with the co-operation of the British Tunnelling Society, the Institution of Mining Engineers, and the Transport and Road Research Laboratory. The papers, discussions, and authors' responses to questions will be published in a proceedings volume and may be obtained, in late 1976 or early 1977, from the Institution of Mining and Metallurgy, 44 Portland Place, London W1N 4BR, England.

LETTERS TO THE EDITOR

The following correspondence has been received by the Editor.

"Dear Sir,

ON THE
GEOMECHANICS OF GEOMECHANICISTISTS

On the subject of earthy names, the Oxford Dictionary has the situation well taped with

Pedology, n., Science of Soils. Hence
Pedologist, n., (Gk pedon ground)

Yours faithfully,

Sgd. Nigel S. Smith"

THE AUSTRIAN SOCIETY FOR GEOMECHANICS

A-5020 SALZBURG/AUSTRIA, Paracelsusstrasse 2

Will hold on October 14 and 15, 1976, in the Congress Hall of Salzburg a

HANS-CLOOS-COLLOQUY

in memory of the originator of the conception of Geomechanics and pioneer of geomechanical investigation in tectonics.

It will be the

25th GEOMECHANICS COLLOQUY

of the Salzburg Geomechanical Group, established in 1951. We have the pleasure to invite you to this meeting.

The papers are to deal with

Geomechanics of orogenetic events

Mechanical evaluation of tectonic phenomena, tectonic, residual and actual stress phenomena, etc. and their

Effects on the construction of rock structures on subsurface and underground

Influence of fabrics and stresses in the earth crust.

An exhibition of historic drawings, sketches and documents will be arranged in addition.

Official languages will be English and German, with simultaneous translation of the papers and discussions.

PILING AND VIBRATORY COMPACTION IN THE CITY OF AUCKLAND

Two or three years ago, an underground vibrating method for compaction of sands was being used at a development site in Auckland's eastern suburbs. The object was to densify the sands to ensure that liquefaction would be unlikely in an earthquake. The Auckland City Council had indicated that the possibility of liquefaction should be considered in foundation design.

The vibration was noticeable in nearby houses, but was not so severe as to cause structural damage. Residents complained to the Council and legal action was taken to stop the work. The following by-laws were passed very shortly after:-

509. It is hereby declared that the driving or extraction
- (a) of piles, sheeting, or casings, and below surface soil compaction using vibration techniques, in each case within one hundred meters of any residential building that is on any land zoned Residential in the Council's Operative district scheme for purposes of site preparation shall be deemed to be a nuisance for purposes of paragraph 8 of subsection 1 of section 386 of the Municipal Corporations Act 1954, on account of the effect of the resultant vibrations upon residents and their properties adjacent to the activity.
 - (b) Accordingly the same is prohibited in terms of the said paragraph 8.
 - (c) Notwithstanding the foregoing prohibition, any person wishing to undertake work in any of the foregoing categories may apply to the Director of Works for permission to do so, generally or in any particular case, and the Director of Works may authorise the same if he is satisfied that the techniques to be employed will not constitute a nuisance, having regard to ground conditions and other factors that would minimise vibration to an acceptable level.
 - (d) After commencement of work pursuant to any such authorisation, the Director of Works may by notice in writing require the person in charge of that work to cease operations if he is satisfied on reasonable grounds that a nuisance is in fact being caused thereby in the particular instance.
- 510 No pile driving shall take place in proximity to any unreinforced brick bearing wall building if in the Engineer's opinion it could cause damage to that building.

NEWS FROM THE MANAGEMENT SECRETARY1. MANAGEMENT COMMITTEE 1976

D.K. Taylor (Chairman)	Auckland
D.H. Bell (Vice-Chairman - Rock Mechanics)	Christchurch
J.B. Blakeley	Auckland
W.M. Bullock	Auckland
G.L. Evans	Christchurch
J.H.H. Galloway	Wellington
J.M.O. Hughes (Management Secretary)	Auckland
R.D. Northey (Vice-Chairman - Soil Mechanics)	Wellington
I.M. Parton (Editor - Geomechanics News)	Wellington
B.W. Riddolls (Vice-Chairman - Engineering Geology)	Wellington
P.W. Taylor (Australasian Vice-President, ISSMFE)	Auckland

2. NEW MEMBERS

New members elected to the Society since the last list was published in issue No. 11 are as follows:-

T.R.A. Clark, I.J. Grant, G.S. Halliday, A.H. Kent, R.J. Lewandowski, J.P. O'Brien, W.R. Sparrow, Dr. D.V. Toan, N.M. Wilson.

3. FORTHCOMING CONFERENCES AND SYMPOSIA

Listed below are Conferences and Symposia in the 1976-77 period which we know about. Members may be interested in attending or obtaining Proceedings. Further details can be made available on request.

1976

20-25 June	Second International Conference on Numerical Methods in Geomechanics. Blacksburg, Virginia, U.S.A.
1-6 August	First Brazilian Congress on Engineering Geology, Rio de Janeiro
10-14 August	I.S.R.M. Regional Conference. Investigation of Stress in Rock, Sydney
16-26 August	25th Session of the International Geological Congress, Sydney
9-10 September	Seminar on diaphragm walls and anchorages, London
12-17 September	Symposium on Applied Glaciology, Cambridge, U.K.
18-19 December	Symposium on Foundation and Excavation o Weak Soil, Calcutta.

1977

3-7 January	Symposium on Soil Structure Interaction, Roorkee
4-6 July	Fifth South East Asian Conference on Soil Engineering, Bangkok, Thailand
7-8 July	International Symposium on Soft Clay, Bangkok, Thailand
11-14 July	Ninth International Conference on Soil Mechanics and Foundation Engineering
3-7 September	Rockstore 77. A Symposium on storage in excavated rock caverns. Stockholm.

4. PROCEEDINGS, NELSON SYMPOSIUM ON THE STABILITY OF SLOPES IN NATURAL GROUND, NOVEMBER 1974

Copies of the Proceedings are available from the Secretary, N.Z.I.E. at a cost of \$15.00 for Society members and \$18.00 for non members.

5. BACK ISSUES, NEW ZEALAND GEOMECHANICS NEWS

Copies of most back issues are available to members at a nominal cost of 50c per copy from the Management Secretary.

J.M.O. HUGHES
Management Secretary.

N.Z. GEOMECHANICS SOCIETY
SUMMARY ACCOUNT OF ANNUAL GENERAL MEETING
11th FEBRUARY 1976
AT THE N.Z.I.E. CONFERENCE IN DUNEDIN

The Annual General Meeting was held, as has become customary, during an evening session of the N.Z.I.E. annual Conference. Some 14 members attended. From 9 nominations for the elected members of the management committee the following were successful on ballot:

Mr D.H. Bell	Geology Department University of Canterbury
Mr J.P. Blakeley	Consultant, Auckland
Mr W.M. Bullock	Contractor, Auckland
Mr J.H.H. Galloway	M.W.D. Wellington
Dr R.D. Northey	D.S.I.R. Wellington
Dr I.M. Parton	M.W.D. Wellington
Dr B.W. Riddolls	D.S.I.R. Wellington
Mr G.L. Evans	Consultant, Christchurch

and the two N.Z.I.E. nominees are:

Prof. P.W. Taylor	University of Auckland
Mr D.K. Taylor	Consultant, Auckland

An amended statement of Income and Expenditure to 30.9.75 was received from the Secretary N.Z.I.E. and tabled at the meeting. The amendments relate to costs of Dr Wroth's visit and to travel expenses; neither have a material effect upon our financial position which is sound.

The meeting endorsed the proposal to conduct future elections for the Management Committee by postal ballot and this will be put into effect during 1976.

The meeting also asked the Committee to pursue further with N.Z.I.E. the question of prohibition of advertising in Geomechanics News.

Mr Peter Scoular, Vice President, N.Z.I.E. attended the meeting to express his Council's appreciation of the work done by the Geomechanics Society and to assure the continuing support of N.Z.I.E.

The small attendance at the A.G.M. is probably typical of such meetings, and not really indicative of the state of the Society, which is much better judged by attendance at our technical meetings and the effect which we have upon Geotechnical matters throughout New Zealand.

D.K. TAYLOR

GROUND VIBRATIONS

P.W. Taylor and I.M. Parton

From time to time people living near quarries or construction sites are troubled by ground vibrations caused by blasting or heavy construction activities. The residents in the immediate vicinity may notice a small crack in a plaster ceiling, about the same time, and immediately conclude that the crack was caused by the vibration. Complaints of excessive vibration are sometimes made to local authorities and, if considered to be serious, may be investigated further by specialised personnel with sensitive equipment capable of detecting and measuring small ground vibrations.

The Civil Engineering Department of the University of Auckland has developed equipment which is capable of measuring ground vibrations. The sensing instrument is a Willmore seismometer, a highly versatile instrument sensitive enough to record tremors from an earthquake hundreds of miles distant, yet rugged enough to measure larger vibrations. Although an apparently sophisticated device, the principle on which this seismometer operates is simple. A heavy permanent magnet is suspended on a spring and located centrally inside a coil of copper wire. Vibration causes the magnet to move, inducing an electric current in the coil. This electrical output may be recorded on film, on magnetic tape or on a chart recorder. The instrument may be operated in the horizontal or vertical mode. The electrical output from the Willmore seismometer is proportional to the velocity of the ground surface.

The most common operations which lead to noticeable ground vibrations being generated are tunnelling, rock excavation for foundations, quarrying, and pile driving. When explosives are being used to excavate rock, the contractor or the owner's engineer is faced with determining the maximum weight of explosives which may be detonated without damaging structures on adjacent property. If the weight of explosives is overestimated, the related damage to adjacent structures may result in costly lawsuits. But if the engineer or contractor is too conservative and the weight of explosive per detonation becomes too restrictive the progress of the project may be curtailed and the cost of the excavation will increase accordingly.

The problem of determining the quantity of explosive which may be used without damaging an existing structure may be resolved into two parts. First the engineer must be able to predict the intensity of ground vibration as a function of charge weight, distance from detonation and the properties of the transmitting medium. Second it is necessary to know the level of ground vibration which can be tolerated by different types of structures without causing damage. In this regard it is also necessary to establish the parameter which best describes the intensity of the ground motions that correlate with structural damage i.e. maximum displacement, maximum particle velocity, maximum acceleration or frequency. Generally, it is found that particle velocity is most closely related to building damage. A future article will discuss in more detail the available information relating to charge sizes, estimation of maximum ground vibrations and damage levels.

While research on damage criteria has been carried out in many countries, no very clear results have emerged. From analysis of 124 cases in three countries, Duvall and Fogelson concluded that damage did not occur if the ground velocity was less than 50 mm/s. This is also the limit proposed in the draft New Zealand code on the use of explosives (DZ4403) to avoid damage to structures. On the other hand, Sweden relates permissible velocities to building type and soil type, with limits as low as 5 mm/s for older buildings on soft soil. (This low limit was found to be exceeded

when trucks passed nearby.)

Research into human perception of ground vibrations has resulted in the following suggested classification of response:-

1 mm/s	-	distinctly perceptible
3 mm/s	-	strongly perceptible
7.5 mm/s	-	disturbing
15 mm/s	-	very disturbing

The draft N.Z. Code on the use of explosives (DZ 4403) specifies maximum ground velocities as a function of frequency to avoid "discomfort" to persons. The figures are 50 mm/s at 3Hz or below, down to 5 mm/s at 20 Hz or above.

In recent years the University Civil Engineering Department has investigated a number of cases where complaints of annoying or excessive vibrations have been received. Two typical cases are described below.

The Lunn Avenue quarry in Auckland is situated adjacent to a developed residential area. The quarry owners go to considerable trouble to ensure that vibrations caused by blasting the basalt do not exceed permissible limits. Instead of one large explosion, delays are incorporated in the firing system so that a number of smaller 'shots' occur at intervals of about one fiftieth of a second. This method gives rise to very much less vibration than if the same quantity of explosives were detonated at one time.

The Town Planning regulations of the Auckland City Council define maximum allowable ground displacement as a function of frequency. These limits approximate to a maximum permissible velocity of 12 mm/s over a wide frequency range. At numerous residential sites where the University Civil Engineering Department has carried out measurements the velocities have been less than 4 mm/s. This is less than one third of that permissible under the Town Planning regulations, less than levels likely to cause cracking of plaster, and is best described as 'perceptible' to humans.

A second case of annoying vibration was reported during the construction of an underpass on the Auckland Urban Motorway, adjacent to an historic church. Concern was expressed for the safety of the church and surrounding buildings, due to excessive vibration caused by earthmoving and construction equipment working nearby. Ground vibrations recorded during a wide range of construction activities revealed a maximum velocity of 1 mm/s, obviously far below damaging levels. The fact that concern had been expressed for the safety of the building can probably be explained as follows. When a building is subjected to vibration, the greatest amplitude will be found to exist in the centre of a suspended floor. The measurements there will usually be much greater than those made on a nearby wall or window ledge, yet the latter would probably be more representative of the general level of vibration in the building. Most floors have resonant frequencies in the same range as is found for soil and rock vibrations (10-30Hz) and the possibility of resonance must therefore be considered.

It is not really surprising that complaints have been received as human beings are, themselves, sensitive vibration detectors, and may find vibrations vaguely troublesome when they are only a fraction of the severity needed to cause damage to buildings. Large earthmoving machinery, even when operating several hundred metres distant, can cause similar vibrations, and these are likely to be more troublesome as they may continue for hours at a time. At least the quarry vibrations are over in about a second!

The question of minor damage to houses, apparently caused by blasting vibrations, can be explained in several ways. In a new house, timber shrinks

as it dries out and this may cause cracks in woodwork and plaster. The most common cause is movement of the foundations. Particularly on clay soils, this may be considerable. During the summer the clay partially dries and shrinks, then rewetting in winter months causes it to swell again. Trees, with roots extending beneath the foundations may cause settlement by extracting water from the soil.

If a house is already stressed as a result of foundation movement, but not quite to the point where cracks appear, it is possible that even small vibrations may prove to be the 'last straw' and act as a trigger, resulting in a crack appearing. The basic cause is still the movement of the foundations.

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GEOMECHANICS AT THE N.Z.I.E. ANNUAL CONFERENCE, 1976

About 40 people attended the sessions organised by the New Zealand Geomechanics Society on the morning of Wednesday February 11th, 1976, at the N.Z.I.E. Annual Conference in Dunedin.

The first session began with the presentation by Mr G.L. Evans (consultant soil engineer) of a paper entitled "Erosion and Stability in Loess on the Port Hills" in which he described some case histories of tunnel gully erosion affecting housing on the Port Hills, Christchurch.

Mr I.B. McKellar (N.Z. Geological Survey DSIR) then gave a talk on slope stability in the Dunedin area.

These two addresses were followed by discussion.

Mr P.A. Thomson (Blenheim) described the Wither Hills situation where loessial soils have experienced, under rural use, much more severe tunnel gully erosion than has occurred on the Port Hills. Gullies 7 m deep were common, and remedial measures included complete excavation to below tunnel level on a herringbone system with a bench moving progressively uphill. The only compactive effort was that (small amount) provided by the tracked bulldozer, and the direction of working was slightly downslope towards the spurs.

Despite the small amount of compaction no slipping occurs. Runoffs are substantially reduced and growth (600 mm/yr rainfall) is greatly increased. In effect the treatment eliminates the extensive drainage system provided by tunnels and gullies, and creates relatively uniform soil moisture conditions. The increased growth protects the surface from excessive drying and cracking and ensures a much higher and more uniform water table.

A relevant inference from this experience to the Port Hills situation, he thought, was that removal of stormwater in an urban drainage system could lead to excessive drying and cracking. The ingress of relatively small volumes of water could then cause troubles.

The relationship which Mr Evans had described between erosion vulnerability and clay/silt proportions Mr Thomson suggested might more basically be shown to exist between erosion vulnerability and shrinkage characteristics. In conclusion Mr Thomson questioned whether areas such as the Port Hills should be allowed to be developed for urban use.

Mr T.A.H. Dodd (Canterbury) pointed out that shrinkage as measured in the laboratory would not be achieved in the field because of the smaller range of water content.

Mr Dodd recollected that early maps showed that pre-European afforestation on the Port Hills was sparse or non-existent on the Barry's Bay Loess areas and it was these areas which experienced the most severe erosion.

Mr Dodd said that reworked loess in trenches eroded very easily and that the addition of some cement (4-6% by weight) could stabilise such material. Once reworked loess had been allowed to stand for a year or more it regained its 'undisturbed' strength.

Dr Hawley (Lower Hutt) described some work which had been almost completed (by B. Trangmar) as an M.Sc. project. Mr Trangmar who had been studying at Lincoln and was recently appointed to DSIR Soil Bureau staff had produced a map of a portion of the Port Hills area showing not only soil types and susceptibility to erosion, but relating type of erosion to soil type. If it

were true as Mr Thomson and others had indicated, that improved drainage was liable to be counterproductive in areas susceptible to tunnel gullyng, then such maps could be extremely useful. While areas with a soil type which was susceptible to more conventional forms of landslip may generally be improved by better drainage, areas susceptible to tunnel gullyng must be treated in quite a different fashion to achieve the reduction in drying out and cracking described by Mr Thomson. It is hoped that Trangmar's maps will be published shortly. He is at present extending his mapping onto other nearby areas on the Port Hills.

Speaking to Mr McKellar's talk on the Dunedin area Mr R.G. Brickell urged that the term 'factor of safety' be dropped in favour of some term such as 'risk factor', which had overtones of the profound uncertainty which always exists, rather than the false sense of certainty which the phrase 'factor of safety' exuded.

After morning tea a preliminary draft of a booklet "Slope Stability in Urban Development" which is being prepared by the Geomechanics Society was circulated and discussed. The response of the meeting was generally very favourable and encouraging. One local body engineer said that he thought that individual councils might abstract portions particularly of the "Hints for Homeowners" type, and circulate these with the Rate Demands every two or three years. He pointed out that although in a bad winter there were often enough cases of urban land instability to make quite a bit of news, these represented only a very small proportion of house sites - or even of new house sites. The Society was doing the sensible thing therefore in keeping the style of the booklet well away from a code of practice or anything which could be 'adopted' by a council and thereby discourage the application of common sense. The booklet is to give broad indications of what constitutes good practice, and what sorts of action should be avoided, at the subdivision planning stage, during construction and in the long term, i.e. the "maintenance of slope stability".

GUIDELINES FOR PREPARING
ENGINEERING GEOLOGICAL REPORTS

The following report is reproduced from California Division of Mines and Geology Note Number 44, and was originally printed in California Geology, November 1974.

The guidelines are required for engineering geological reports submitted to the Department of Public Works, County of Ventura, California.

I. Geologic Mapping

A. Each report must be a product of independent geologic mapping of the subject area at an appropriate scale and in sufficient detail to yield a maximum return of pertinent data. In connection with this objective, it may be necessary for the geologist to extend his mapping into adjacent areas.

B. All mapping should be done on a base with satisfactory horizontal and vertical control - in general a detailed topographic map. The nature and source of the base map should be specifically indicated. For sub-divisions, the base map should be the same as that to be used for the tentative map or grading plan.

C. Mapping by the geologist should reflect careful attention to the lithology, structural elements, and three-dimensional distribution of the earth materials exposed or inferred within the area. In most hillside areas these materials will include both bedrock and surficial deposits. A clear distinction should be made between observed and inferred features and relationships.

D. A detailed large-scale map normally will be required for a report on a tract, as well as for a report on a smaller area in which the geologic relationships are not simple.

E. Where three-dimensional relationships are significant but cannot be described satisfactorily in words alone, the report should be accompanied by one or more appropriately positioned structure sections.

F. The locations of test holes and other specific sources of subsurface information should be indicated in the text of the report or, better, on the map and any sections that are submitted with the report.

II. General Information

Each report should include definite statements concerning the following matters:

A. Location and size of subject area, and its general setting with respect to major geographic and geologic features.

B. Who did the geologic mapping upon which the report is based, and when the mapping was done.

C. Any other kinds of investigations made by the geologist and, where pertinent, reasons for doing such work.

D. Topography and drainage in the subject area.

E. Abundance, distribution, and general nature of exposures of earth materials within the area.

F. Nature and source of available subsurface information. Suitable explanations should provide any technical reviewer with the means for assessing the probable reliability of such data. (Sub-surface relationships can be variously determined or inferred, for example, by projection of surface features from adjacent areas, by the use of test-hole logs, and by interpretation of geophysical data, and it is evident that different sources of such information can differ markedly from one another in degree of detail and reliability according to the method used.)

III. Geologic Descriptions

The report should contain brief but complete descriptions of all natural materials and structural features recognized or inferred within the subject area. Where interpretations are added to the recording of direct observations, the bases for such interpretations should be clearly stated.

The following check list may be useful as a general, though not necessarily complete, guide for descriptions:

- A. Bedrock - igneous, sedimentary, metamorphic types.
 1. Identification as to rock type (e.g. granite, silty sandstone, mica schist).
 2. Relative age, and, where possible, correlation with named formations (e.g. Rincon formation, Vaqueros sandstone.)
 3. Distribution.
 4. Dimension features (e.g. thickness, outcrop breadth, vertical extent).
 5. Physical characteristics (e.g. color, grain size, nature of stratification, foliation, or schistosity, hardness, coherence).
 6. Special physical or chemical features (e.g.: calcareous or siliceous cement, concretions, mineral deposits, alteration other than weathering).
 7. Distribution and extent of weather zones; significant differences between fresh and weathered rock.
 8. Response to natural surface and near-surface processes (e.g.: raveling, gullying, mass movement).

- B. Structural features - stratification, foliation, schistosity, folds, zones of contortion or crushing, joints, shear zones, faults, etc.
 1. Occurrence and distribution
 2. Dimensional characteristics
 3. Orientation, and shifts in orientation
 4. Relative ages (where pertinent)
 5. Special effects upon the bedrock.
(describe the conditions of planar surfaces.)
 6. Specific features of faults (e.g.; zones of gouge and breccia, nature of offsets, timing of movements ; are faults active in either the geological sense or the historical sense?

- C. Surficial (unconsolidated) deposits - artificial (manmade) fill, top-soil, stream-laid alluvium, beach sands and gravels, residual debris, lake and pond sediments, swamp accumulations, dune sands, marine and nonmarine terrace deposits, talus accumulations, creep and slopewash materials, various kinds of slump and slide debris, etc.
 1. Distribution, occurrence, and relative age; relationships with present topography.
 2. Identification of materials as to general type.
 3. Dimensional characteristics (e.g. thickness, variations in thickness, shape).
 4. Surface expression and correlation with features such as terraces, dunes, undrained depressions, anomalous protuberances.
 5. Physical or chemical features (e.g.; moisture content, mineral deposits, content of expansible clay minerals, alteration, cracks and fissures, fractures).
 6. Physical characteristics (e.g. color, grain size, hardness, compactness, coherence, cementation).
 7. Distribution and extent of weathered zones; significant differences between fresh and weathered material.
 8. Response to natural surface and near-surface processes (e.g. raveling, gullying, subsidence, creep, slope-washing, slumping and sliding).

- D. Drainage - surface water and ground water.
1. Distribution and occurrence (e.g. streams, ponds, swamps, springs, seeps, subsurface basins).
 2. Relations to topography.
 3. Relations to geologic features (e.g. previous strata, fractures, faults).
 4. Sources and permanence.
 5. Variations in amounts of water (e.g. intermittent springs and seeps, floods).
 6. Evidence for earlier occurrence of water at localities now dry (e.g. vegetation, mineral deposits, historic records).
 7. The effect of water on the properties of the in-place materials.
- E. Features of special significance (if not already included in foregoing descriptions).
1. Features representing accelerated erosion (e.g. cliff re-entrants, badlands, advancing gully heads).
 2. Features indicating subsidence of settlement (e.g. fissures, scarp-lets, offset reference features, historic records and measurements).
 3. Features indicating creep (e.g. fissures, scarplets, distinctive patterns of cracks and/or vegetation, topographic bulges, displaced or tilted reference features, historic records and measurements).
 4. Slump and slide masses in bedrock and/or surficial deposits; distribution, geometric characteristics, correlation with topographic and geologic features, age and rates of movement.
 5. Deposits related to recent floods (e.g. talus aprons, debris ridges, canyon-bottom trash).
 6. Active faults and their recent effects upon topography and drainage.

IV. The Bearing of Geologic Factors upon the Intended Land Use

Treatment of this general topic, whether presented as a separate section or integrated in some manner with the geologic descriptions, normally constitutes the principal contribution of the report. It involves both (1) the effects of geologic features upon the proposed grading, construction, and land use, and (2) the effects of these proposed modifications upon future geological processes in the area.

The following check list includes the topics that ordinarily should be considered in submitting discussion, conclusions, and recommendations in the geologic reports:

- A. General compatibility of natural features with proposed land use: Is it basically reasonable to develop the subject area?
1. Topography
 2. Lateral stability of earth materials.
 3. Problems of flood inundation, erosion, and deposition.
 4. Problems caused by features or conditions in adjacent properties.
 5. Other general problems.
- B. Proposed cuts
1. Prediction of what materials and structural features will be encountered.
 2. Prediction of stability based on geologic factors.
 3. Problems of excavation (e.g.; unusually hard or massive rock, excessive flow of groundwater).
 4. Recommendations for re-orientation or repositioning of cuts, reduction of cut slopes, development of compound cut slopes, special stripping above daylight lines, buttressing, protection against erosion, handling of seepage water, setbacks for structures above cuts etc.

- C. Proposed masses of fill.
 - 1. General evaluation of planning with respect to canyon-filling and sidehill masses of fill.
 - 2. Comment on suitability of existing natural materials for fill.
 - 3. Recommendations for positioning of fill masses, provision for underdrainage, buttressing, special protection against erosion.
- D. Recommendations for subsurface testing and exploration.
 - 1. Cuts and test holes needed for additional geologic information.
 - 2. Program of subsurface exploration and testing, based upon geologic considerations, that is most likely to provide data needed by the soils engineer.
- E. Special recommendations
 - 1. Areas to be left as natural ground.
 - 2. Removal or buttressing of existing slide masses.
 - 3. Flood protection
 - 4. Protection from wave erosion along shorelines
 - 5. Problems of groundwater circulation
 - 6. Position of structures with respect to active faults.

V. Seismic Considerations

The following published guidelines should be considered when preparing seismic information.

- 1. CDMG Note No.37, "Guidelines to Geologic/Seismic Reports".
- 2. CDMG Note No. 43, "Recommended Guidelines for Determining the Maximum Credible and the Maximum Probable Earthquakes".

VI. Documentation and Implementation

- A. The report should consider as the minimum requirement, Chapter 70, Uniform Building Code (1973). Refer to California Administration Code, Title 25, Section 1090. Excavation and Grading.
- B. All material in the report should be relevant to the purpose of the report.
- C. All statements should be documented by references or by accurate field observations.
- D. Aerialphotos (originals or suitable copies) should be included to document any discussion on landslides and faults.
- E. The method(s) of field analysis should be discussed in a lucid manner.

ACTIVITIES OF THE WELLINGTON SECTION OF THE
AUSTRALIAN INSTITUTE OF MINING AND METALLURGY

The Wellington Section of the Australasian Institute of Mining & Metallurgy has arranged to hold regular meetings throughout 1976 to stimulate interest among members. It is planned to combine relaxed socializing with interesting speakers on mining and related topics. On some occasions a small amount of institute business may be included.

"The Cellar", Dunbar Sloane Building, Waring-Taylor Street (between Lambton Quay & Featherston Street), has been booked this year on behalf of the Wellington Section on the first Tuesday of alternate months.

The format is that meetings will commence at 5 p.m. with refreshments (a variety); a buffet/smorgasbord meal will be served 6.00 - 6.15 p.m. on a pay as you eat basis. The period 7.00 to 9.00 p.m. is available for the guest speaker and general discussion.

The cost to each individual present will be his refreshments and a minimum charge of \$2.50 for the meal.

The following meetings have been arranged for the remainder of 1976:

- July 6th Mr C. Busck, who operates a concrete batching plant in the Whangarei area, will speak on dredging for marine aggregates.
- September 7th Mr A.G. Fricker, of the D.S.I.R., will review gold dredging in various parts of the world, following an overseas visit, and the application to N.Z. conditions.
- November 2nd Mr D. Kelly of AMOIL, who own and manage the Kanieri gold dredge, will speak on mining and the environment in N.Z. in relation to prospecting, mining and dredging.

The Wellington section of AIMM extend an invitation to members of the Geomechanics Society and friends to attend the meetings.

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 New Zealand 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).

I wish to affiliate to:

International Society for Soil Mechanics and Foundation Engineering
(ISSMFE) Yes/No

International Society for Rock Mechanics (ISRM) Yes/No

International Association of Engineering Geology (IAEG) Yes/No

Signature of Applicant _____

Date _____ 19__