N.Z. GEOMECHANICS NEWS

No. 14

JUNE 1977

A NEWSLETTER OF THE N.Z. GEOMECHANICS SOCIETY

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No.14, June 1977

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CONTENTS | Page

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 NOTES

CHAIRMAN'S REPORT

At the last meeting of the Management Committee, Mr D.K. Taylor, who has been our Chairman for the past three years, relinquished his post as he is required to do so under the Rules of the Society. Mr J.P. Blakeley was elected as incoming Chairman. Mr. Blakeley has expressed the aims and objectives of the Society in a report, which appears in this issue of Geomechanics News, to outline to members of the Society the planned activities in the coming year.

A vote of thanks is extended to Mr Taylor for the fine manner in which he has chaired the Management Committee over the past three years and the unflagging efforts he has made on behalf of the Society.

AUSTRALIAN GEOMECHANICS JOURNAL

The Society has been approached by the Australian Geomechanics Society asking if publicity could be given to the above journal and suggesting that it may be a suitable vehicle for articles of Geotechnical interest. At present the journal is published biannually but it is hoped to increase the frequency of publication to quarterly. Papers from New Zealand could help the Australian Society in their objectives.

Further information can be obtained from the Management Secretary.

INSTABILITY OF LAND

Instability of land, and the effects arising therefrom, form a considerable part of the copy of this issue of Geomechanics News. Articles submitted for publication cover topics ranging from a report on geological aspects of instability at Lower Hutt last December, to the subject of landslip insurance and statements by registered Engineers. It is encouraging to see so many members of the Society to the fore in these matters.

SECOND AUSTRALIA-NEW ZEALAND CONFERENCE ON SOIL MECHANICS PROCEEDINGS

The Society has been approached by Professor Nash, Secretary General of the I.S.S.M.F.E., who is keen to obtain a complete proceedings of the above Conference. Anyone - perhaps a retired engineer - who attended that conference and who no longer has any wish to keep the complete proceedings should contact the Management Secretary. Naturally, Professor Nash would be most happy to pay for the set of proceedings.

N.Z. GEOLOGICAL SURVEY INDUSTRIAL MAP SHEET - N42/6 - HOWICK

A further map has been published in this industrial series. Five maps in this series now cover part of the greater Auckland area, and one covers the Hamilton area. The Howick sheet covers an area from the Howick peninsula in the north-west to Beachlands and Maraetai in the north-east, and extends to Whitford in the south. The area covered is one where urban development is taking place and, hopefully, the map should be of interest to engineers and planners associated with future developments.

The geological map, at a scale of 1:25,000 has been presented on a photomosaic base map with a distinctive brown colouring which does tend to obscure some of the physiographic and cultural information. The map is essentially a lithological map, with conventional representation of structural features - bedding, folds and faults. The familiar formation names found on other geological maps of the Auckland area have been subdivided on the basis of hardness, using a scale which appears to confuse hardness with density and strength.

The map would have benefitted from explanation of terminology relating to engineering properties. Earthquake risk is confused with intensity of ground vibration resulting from earthquakes.

Despite these shortcomings the production of the map has resulted in publication of geological data at a useful scale for an area where there is a real need for such information by engineers. The Society would welcome the provision by D.S.I.R. of maps which give engineering characteristics of rocks and soils in urban areas in more detail.

GEOMECHANICS SOCIETY SYMPOSIUM, NOVEMBER 1977

Included in this issue is an article publicising the forthcoming Symposium on Tunnelling in New Zealand. Members are urged to attend the symposium and support the activities of the Society.

SUBSCRIPTION FEES, 1977

Due to increasing costs, caused to some extent by the increased activities of the Society and the opportunities which it makes available to its members, the Management Committee has been compelled to adjust the subscription fees. Members will be advised of the revised fees in the near future.

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 field 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/- New Zealand Geomechanics Society,
P.O. Box 12241, WELLINGTON.

I.M. Parton
EDITOR.

CHAIRMAN'S REPORT TO MEMBERS

The purpose of this report is to keep members informed of the aims and objectives of the N.Z. Geomechanics Society and its planned activities for 1977.

The Society is a technical group of the N.Z. Institution of Engineers, but as with other technical groups the membership covers a much wider range of occupational groups than the N.Z.I.E. Under the rules of the Society, membership is open to engineers, scientists and others with suitable qualifications or experience who are interested in the practice and application of soil mechanics, rock mechanics and engineering geology in engineering. The criterion for membership is an interest in the aims of the Society. In addition to civil engineers, our current membership includes geologists, engineering scientists, engineer's associates, engineering technicians, research students, mining engineers, surveyors, engineering contractors and drillers. Our current membership is around 270 people and climbing steadily.

The aims of the Society are:

* To advance the study of geomechanics (i.e. soil mechanics, rock mechanics and engineering geology) among engineers and scientists.
* To advance the practice and application of these disciplines in engineering.
* To implement the statutes of the respective International Societies insofar as they are applicable in New Zealand.

The Society is run by a management committee of ten people from around N.Z. who are representative of the various employment groups and disciplines within geomechanics. The committee meets three times a year in Wellington, generally in March, June and October, and a full day is spent on the business of the Society.

INTERNATIONAL AND AUSTRALIA-N.Z. REGIONAL ACTIVITIES

The Society is the official contact body in N.Z. with the three international societies (namely the International Society for Soil Mechanics and Foundation Engineering, the International Association of Engineering Geology and the International Society for Rock Mechanics). The Society distributes information received from the international societies to the membership, including details and dates of international conferences and other matters.

A member of the Society, Professor P.W. Taylor, is currently Vice President for Australia-N.Z. of the I.S.S.M.F.E. He has held this position since 1973 and hands it over to Mr Aubrey Hosking of Australia in July this year.

The Society submits papers prepared by New Zealanders for consideration for presentation at international conferences of these three societies. The Ninth I.S.S.M.F.E. Conference is to be held in Tokyo from 11 to 15 July 1977 and two papers from N.Z.have been accepted for the main sessions and three papers for the speciality sessions.

The Society is also responsible for organising regional Australia-N.Z. geomechanics conferences from time to time. The next one will be the Third Australia-N.Z. Geomechanics Conference to be held in Wellington in 1980. You will appreciate that a great deal of organisation must be put into the preparations for this conference and the management committee will be spending an increasing amount of time and effort on this over the next two years.

NEW ZEALAND ACTIVITIES

All members receive twice a year the publication "N.Z. Geomechanics News", generally in June and November. We hope it is providing the membership with useful information and keeping them informed about current events in geomechanics both locally and overseas.

About every three years the Society organises a symposium. The last one was the highly successful "Symposium on the Stability of Slopes in Natural Ground" which was held in Nelson in November 1974 (proceedings of this conference are still available at $15 to members of the Society and $18 to non-members). Our next symposium is to be held in Hamilton from 17 to 19 November this year and will be entitled "Tunnelling in New Zealand". Further information on this symposium will be included elsewhere in this issue. Previous symposia in this series have been

1965:	Roading Earthworks Symposium, Hamilton
1969:	Site Investigations Symposium, Christchurch
1972:	Using Geomechanics in Foundation Engineering, Wanganui
1974:	Slope Stability Symposium, Nelson.

The Society is also responsible for organising two or three technical sessions at each year's N.Z.I.E. Annual Conference. An invitation is extended to anyone who wishes to prepare a paper on any subject within the field of geomechanics to submit the paper to the Society for consideration for next year's N.Z.I.E. Conference.

The Society keeps a watching brief on geomechanics matters of public interest within N.Z. and produces publications as it considers appropriate. The most recent publication arose from our Nelson symposium and was published in January this year entitled "Slope Stability in Urban Development". Its publication was very timely, following the slips in Wellington which occurred in December 1976. This booklet was prepared by the Society but published in the D.S.I.R. Information Series (No.122) and is available from Government Bookshops for $2.00 per copy. A complimentary copy was sent to all members of the Society in February this year. Members may purchase additional copies for $1.50 from Dr B.W. Riddolls, P.O. Box 30368, Lower Hutt, cheques being made payable to the Society. The booklet is recommended to all technical persons involved in slope stability problems and is also written so as to be of interest and information to the general public. It is hoped that this booklet will be the subject of much study and discussion by various technical groups concerned with the future planning and development of N.Z.'s towns and cities.

The Society represents the N.Z.I.E. on various committees of the Standards Association of N.Z. (S.A.N.Z.) and plays an active part in preparation of new standards within the field of geomechanics. Current publications with which the Society is actively involved include NZS 4202P and 4205P (Foundations for Buildings Not Requiring and Requiring Specific Design), NZS 4402P (Mechanical Testing of Soil for Civil Engineering Purposes) and NZS 4431P (Code of Practice for Earthfill for Residential Development).

From time to time the Society organises lectures within N.Z. either by visiting people well known in geomechanics or by New Zealanders who have distinguished themselves in the field. The most recent lecture in this category was that by Professor G.G. Meyerhof of Canada which was presented in Auckland, Wellington and Christchurch in May-June this year.

Finally the Society encourages the activities of local geomechanics groups and provides them with limited finance for administration. At present there are active local groups working in Auckland, Wellington and Christchurch and the Society would be very pleased to encourage anyone interested in forming another local group elsewhere in N.Z.

We hope that members are satisfied with the current aims and activities of the Society but I will be very pleased to receive comments from any member who has suggestions regarding the way the Society should be run. To be successful, I hope the Society will continue to grow in numbers and all members are urged to persuade friends and acquaintances interested in the geomechanics field to join. For this purpose a membership application form is included at the back of this issue.

J.P. Blakeley
CHAIRMAN.

LOCAL ACTIVITIES

AUCKLAND GROUP

Pole House Foundation Symposium

The three papers presented at this highly successful symposium originally given in August 1976 and repeated in September 1976 have been published in the magazine "Building Progress" in the August-September 1976 issue. The papers are entitled -

"Foundations for Pole Framed Houses" by R.W. Melville-Smith

"Domestic Pole Frame Buildings" by E.B. Lapish

"N.Z. Pole Housing" by Peter Norton

Siltation Arising from Earthworks

A combined meeting of the N.Z.I.E. Auckland Branch and the Auckland Geomechanics Group was held on this topic on 20 April 1977. It attracted a large audience of over 70 people. A summary of the papers presented by the six speakers and the discussion which follows will be included elsewhere in the next issue of N.Z. Geomechanics News.

Symposium on the Geology of the Auckland Region

On 12 October 1976 a short symposium on the geology of Auckland City and Region was held at the University of Auckland School of Engineering from 4-7 p.m. The symposium was convened by Mr Warwick Prebble of the Geology Department of the University and a member of the committee of the Auckland Group. A half hour period was allowed for each of the five speakers to present his paper and for discussion on it.

Mr M.R. Gregory (Geology Department, University of Auckland) opened the meeting by giving a concise geological history of the Auckland region.

Professor M.P. Hochstein (Geology Department, University of Auckland) outlined results of his recent research into faulting within the Auckland region. He describes the structures present on the Hauraki Plains (Hauraki graben field) and the Drury fault and the Ardmore fault. He described a fault on the northern shore of the Manukau Harbour which is a secondary fault with up to 200 metres displacement. He said that along one fault it was estimated that a downward movement of 700 metres had occurred over a period of about 2 million years. He said that his research indicated that Auckland was not a seismic area as the tectonic movements are torsional and not transverse. However, he said that Auckland is not aseismic but torsional stresses lead to less energetic dip slip fault movements rather than more energetic strike slip fault movements.

Mr L.O. Kermode (N.Z. Geological Survey, Otara) discussed the need for urban geological mapping in the Auckland region. He posed the question as to what people want in a geological map. He quoted an example of a questionnaire listing 34 topics on which information would be wanted in choosing land for residential housing. In answering this questionnaire, real estate agents and builders listed geology in thirtieth place out of the 34 topics. Mr Kermode said that urban geology is called "environmental geology" in the U.S.A. Urban geology classifies rocks into lithologies, not into age groups. For most engineering purposes (and particularly for residential housing) only the top 20 ft below the ground surface is of particular interest. Mr Kermode said that the current programme of work in the Auckland region was firstly to complete the Industrial Series mapping over the region and then to revise these maps in a manuscript form.

Mr P.B. Riley (Beca Carter Hollings and Ferner Ltd., Auckland) discussed slope stability in the Auckland region. He emphasised that slope stability is totally dependent on the geology of the individual situation, both on the macro scale in terms of the rock and soil types, and in the structural geology of the individual site. He discussed slope stability problems in respect to five different rock and soil types found in the Auckland region. These were: Waitemata sandstone, which covers most of the area and has particular problems caused by weathering, and undercutting of cliffs by the sea; fine grained greywackes found in the Hunua Ranges and the foothills around Clevedon, which are reasonably strong when intact but are often deeply weathered and always traversed by many fractures and faults; Pleistocene deposits of South and West Auckland which have low permeabilities and cause problems when saturated; volcanic deposits, including the basalts of the Auckland isthmus which are very stable because of high rock joint strength, good drainage and general position in the bottom of valleys, but problems can arise with weathering of volcanic tuff deposits on top of clays weathered from Waitemata sandstone; and the Onerahi Chaos Breccia of Orewa, Silverdale and Dairy Flat, which are the most unstable geological formations in the Auckland Region with many shear planes traversing the formation with low shear strength, and failures on this material can occur at surprisingly low slope angles.

Mr Riley described geological factors at individual sites, including the weathering profile (which is a particularly important factor in Waitemata sandstones which have a firm desiccated clay layer near the surface, becoming softer and more silty with depth with permeability increasing below this in the sandy and broken rock zone above bedrock), geological structure including jointing and the attitude of bedding planes, and water conditions (water table levels can be related to weathering profile or geological stucture but are also influenced by the catchment behind the slope and potential drainage paths).

Finally Mr Riley described three types of common slope failure in the Auckland Region. These are: cliff failures (occurring in the steep sandstone cliffs around the Harbour and Gulf and usually consisting of slabbing off at the face or slides on bedding planes); infinite slope type failures where the failure plane is parallel to the ground surface (common in Waitemata sandstone and can start from creep-type motions accelerated by changes in conditions such as undercutting of the slope); and circular-type failure (although this type of analysis is commonly used, the clays around Auckland are not often deep enough to give a true circular failure but a circular failure analysis often approximates to the true answer).

Mr C.W. Firth (retired A.R.A. Director of Works) described the geological information obtained during a study carried out for the A.R.A. of bringing a water supply from the Waikato River to Auckland City. The particular area studied included the Mercer-Pokeno-Tuakau area for intake, off-river storage, tunnel and treatment plant sites; the Bombay-Ararimu-Ponga area for alternative storage sites; and the Tuakau-Pokeno to Redoubt Road (Manurewa) area for adequate pipeline and tunnel routes. The work included a determination of the depths of aggradation by the Waikato River in assessing dam foundations for off-river storage and a study of the Bombay and Pokeno fault systems and of the Bombay-Franklin volcanics and their relation to the underlying Puketoka and Waitemata beds (particularly for tunnel routes).

Mr R. High (M.W.D. Auckland District Laboratory) described the geological investigations which he had carried out in the South Manukau Lowlands with particular reference to the proposed Auckland Thermal No.1 power station near Waiau Pa on the southern shores on the Manukau Harbour.

The symposium was attended by about 30 people and appreciation was expressed to the authors for the information which they had presented in their papers.

THE SOCIETY'S PARTICIPATION AT N.Z.I.E. CONFERENCE
CHRISTCHURCH, FEBRUARY 1977

The Society filled two technical sessions in the afternoon of Wednesday, 16 February and held its A.G.M. at 5.00 p.m. on the same day.

Technical Session 1

The lecture theatre was filled for presentation and discussion of two papers.

The first by Mr R.G. Brickell on "Assessment of the Stability of slopes and batters in road construction" comprised a draft of Chapter 9 of Technical Recommendation No.1 "Geomechanics for New Zealand Roads" to be published by the Road Research Unit of the National Roads Board.

The stated objective of the chapter was "to present a digest of the state of the art of slope and batter profile assessment, and selection of methods for dealing with problem cases". The paper emphasises the crucial importance of informal observation and subsequent identification of likely modes of failure, and concludes with a survey of design methods and construction expedients for increasing batter and slope stability.

The second paper by Mr D.H. Bell, outlined the problems which arose primarily from the coastal devastation caused by cyclone Allison in March 1975. High intensity run off created erosion havoc with scouring and undermining in some places and stream aggradation in other places and increased mass movements of soil and debris which have become a long standing problem of the area. Geological and geotechnical investigations were undertaken to define the nature of the problem and seek means of stabilising the extensive soil mass movements.

Both papers aroused much discussion: nine speakers commented on Mr Brickell's paper and ten contributed to Mr Bell's paper. In most cases the discussion concerned matters of detail and the enlargement of ideas put forward by the authors.

Technical Session 2

This session comprised an informal discussion upon the Earthquake and War Damage Commission's proposal of 31 August 1976 to Local Bodies in connection with Landslip Insurance. A tape recording of a full and lively discussion was made and the meeting concluded with agreement that the Geomechanics Society should appoint a sub-committee to report and to maintain contact with a Municipal Association and Counties Association joint committee chaired by Mr J.B. Downer of Upper Hutt, and also to keep in touch with the E & W D Commission.

(Mr D.K. Taylor of Auckland has since been appointed Convener of the Sub-Committee.)

A separate report on this topic is included elsewhere in this issue.

Annual General Meeting

This was attended by 13 members and three visitors who are prospective members; the small attendance justifying the decision to hold a postal ballot which yielded more than 70 votes.

The minutes of the previous AGM, the Chairman's Report and Statement of Accounts which had been circulated to all members of the Society were adopted with little discussion and the election of Messrs Blakeley, Parton, Hughes, Riddolls, Northey, Hawley, Galloway and Olsen confirmed as a result of the postal ballot.

A suggestion was made that at local branch meetings an admission charge and a charge for papers could be made. Small charges of this sort are probably quite acceptable and preferrable to the alternative of more substantial increases in the basic subscription to the Society.

ENGINEERING GEOLOGICAL ASPECTS OF SLOPE INSTABILITY IN HUTT VALLEY AREA RESULTING FROM INTENSE RAINFALL OF DECEMBER 1976

B.W. Riddolls

N.Z. Geological Survey, Lower Hutt

The Rainstorm

The southern part of the Wellington region experienced intense rainfall on 20 December 1976, owing to the convergence of two moist air streams from the north and south. It caused widespread flooding and slope instability that resulted in many millions of dollars worth of property damage, and the loss of one life.

The heaviest rainfall (i.e. over 200 mm, most of which fell in a 12-hour period) occurred in a narrow (5 km) band extending from immediately east of Upper Hutt, to just south of Karori. Up to 300 mm may have fallen in a few places. The N.Z. Meteorological Service estimated (Technical Information Circular No.154) that a rainstorm of this intensity may have a return period for the affected area of over 100 years, and possibly over 500 years.

Slope Instability and its Effects

The following observations are based on a study of selected parts of the Hutt Valley area, particularly the Western Hills and Stokes Valley. The work benefitted from the availability of low-level vertical aerial photographs taken by N.Z. Geological Survey photographic staff.

Most of the instability in natural ground involved widely distributed superficial deposits of colluvium and loess, which are rarely more than 3 m thick. The colluvium, which was derived mostly from the adjacent bedrock, is commonly overlain by the loess, but the two materials are often not readily distinguishable owing to intermixing caused by earlier gradual downslope movement. Greywacke bedrock underlies the superficial deposits, and in many places has been weathered to a soil. Compared with the superficial deposits, there were few major failures involving bedrock slopes, road cuttings excavated too steeply in intensely weathered rock or alluvium being the main exception.

In the engineering sense, the superficial deposits that failed are mostly fine soils, comprising loosely compacted silts with varying amounts of weathered rock fragments. Locally, the rock fragments are sufficiently abundant to form gravelly silts. Generally there is an increase in particle size with depth.

A month after the storm, samples were collected from exposures at four sites where instability of superficial deposits had resulted in extensive property damage. The following results were obtained from classification tests performed on each sample by M.W.D. Central Laboratories, in accordance with NZS 4402P:

Lab. Sample No.	S.G.	As received w.c. (%)	Liquid Limit	Plastic Limit	Plasticity Index	Particle Size Distribution (%)			
						Clay	Silt	Sand	Gravel
1894A	2.70	18	43	23	20	31	62	7	-
1894B	2.68	20	50	26	24	33	61	6	-
1894C	2.68	27	38	25	13	19	41	24	16
1894D	2.67	17	46	25	21	29	53	14	4

In urban areas, the failure of saturated superficial deposits commonly caused damage or disruption to property where debris piled against or around houses, often up to window and even gutter level. In most cases of this kind, lateral support had been removed by excavation to form level areas, and topography, or inadequate artificial drainage, favoured the concentration of runoff. Slope failures along streams contributed significantly to the flood-deposited debris that caused widespread damage.

The most spectacular consequence of instability in the Hutt Valley and surrounding areas was the complete destruction of two adjacent houses in Stokes Valley, which were pushed off their foundations by the failure of superficial deposits up to 3 m thick. The original slope, which had been excavated to establish the sections, was about 25°. The surface of sliding was inclined at about 35°, partly on weathered bedrock, and partly within the superficial material. Hummocky ground upslope from the failure suggested that the ground had been unstable prior to development.

After the storm, the undeveloped hillsides in and adjacent to the urban areas showed extensive scarring due to slope instability. Vegetation on these slopes consists of grassland, scrub, and regenerating native bush. Most of the affected slopes are steeper than 25°, and many are over 35°. Instability commonly was localised in the heads of drainage depressions, where runoff collected, and superficial deposits were slightly thicker.

The extent of ground affected by mass movement is actually not as great as it looked initially, but it gave rise to mudflows which scoured lower slopes or collected and deposited more debris over larger areas. The large quantities of detritus that resulted from this instability were responsible for much of the damage from flood-deposited material in the lower reaches of many drainage courses.

Most of the slope failures in undeveloped ground can be regarded as normal geological erosion, accelerated in most places by the removal of the indigenous native forest. In many places however, man-made tracks appear to have contributed to failure by removal of natural support of the slopes, and by facilitating the concentrated movement of surface water. These conditions were common where many of the flatter slopes failed in undeveloped areas.

In many news reports on the storm, surprise was expressed that the undeveloped ground appeared to have been more affected by slope instability than the developed ground, particularly "cut-and-fill" areas. The latter may be partly explained by the facts that in many areas of massive earthworks, many potentially unstable superficial deposits will have been

Slope instability on Western Hills, Hutt Valley. Ground damage originated through mass movement locally, which gave rise to mudflows.

House pushed off foundations by slope failure, Stokes Valley.

removed, and also that effective drainage systems have been installed. However the major factor would seem to be slope steepness - on the whole, instability in natural ground occurred mostly on the steeper slopes. Indeed, but for man's interference with the flatter slopes, instability would probably have been limited almost entirely to the steeper slopes.

It should be appreciated, however, that this storm need not necessarily have fully "tested" the stability of all cut slopes in recently established subdivisions. If a comparable rainfall occurred in winter, when natural groundwater levels are higher, the effects could be very different. For instance, pore water pressures might become much greater in the widespread weathered greywacke cut slopes, resulting in many more failures in this material. Further, it is not yet possible to predict the long-term stability of these slopes, particularly whether progressive failure or seismicity might give rise to problems in the future.

Implications for the Future

Even allowing for the rarity of a storm of this kind, instability will continue to affect hillside subdivisions in Wellington and elsewhere so long as developers, builders, and house owners are permitted to excavate natural slopes and alter drainage without competent advice. The risk of instability could be considerably reduced if such advice were a prerequisite to any development or excavation.

The provisions and enforcement of regulations requiring competent engineering geological and soils engineering advice on slope stability in hillside subdivisions would, however, increase the cost of development, albeit marginally. Since only a relatively small proportion of properties is usually affected by events like the December rainstorm, perhaps it is up to the community to decide whether it will in future bear the costs incurred by the affected few and accept the risk of loss of life or whether it will accept the necessary regulations and additional costs to achieve higher standards of protection.

The need for regulations requiring professional assessment of the stability of slopes in urban areas should thus be evaluated not only on technical grounds, but on economic and social grounds as well. If such a study showed that all local authorities should have appropriate regulations controlling hillside development, particularly in relation to cut slopes, the larger authorities might need to engage an experienced engineering geologist on their staff to see that these regulations are implemented, just as they now employ building inspectors, town planners, and others to help administer existing regulations and by-laws. The engineering geologists so employed could also liaise with consultants and contractors involved with new developments, and with government departments such as N.Z. Geological Survey, Soil Bureau, and M.W.D. Water and Soils Division, who may have knowledge of particular local conditions.

DISCUSSION ON "SLOPE STABILITY IN URBAN DEVELOPMENT"

J.G. Hawley

This guide, produced by the Society and published by D.S.I.R. has been widely reviewed, in mostly favourable (if rather general) terms. The only correspondence of any substance so far has been a letter to the editor of Soil News. This letter, together with my reply is reprinted below:

Dear Sir,

Having just reviewed the same publication for another journal I was interested to read G.H. Neich's review of "Slope Stability in Urban Development" published in Soil News 25(2).

In the supplement to the Wellington section which covers the effects of the December 20, 1976 storm, Dr Hawley records his impressions that 'perhaps the most surprising thing (and a most important point) is that most cuts and fills on house sites gave no trouble' and 'it is remarkable how much more stable the developed areas (e.g. in Maungaraki and Kelson) were than surrounding grazed or bush-covered slopes'. Mr Neich's only comment on the Wellington section of the handbook is a paraphrase of the same point 'even under this extraordinary rainfall most cuts and fills on house sites gave no trouble and the developed areas proved to be generally more stable than the surrounding grazed or bush-covered slopes'.

These comments cannot remain unchallenged and allowed to become engrained in the literature, agreeable as that would be to local bodies and subdividers, because the impression that natural slopes failed in preference to cut and fill slopes during the December 20 storm is incorrect.

Two colleagues and I spent three weeks immediately after the storm mapping mass movements on natural slopes over the entire affected area, and on cut and fill slopes within Wellington City. A number of slips on natural slopes not discovered during the ground survey were later added from aerial photographs flown for the Wellington Regional Water Board.

Of the 550 slips south of the Newlands tip, only 160, or 30 percent were located on natural slopes. The limit of slipping corresponded with an isohyet of approximately 150 to 175 mm in the Meteorological Service (Tech. Inf. Circ. No.154) rainfall map. Of the total area south of Newlands enclosed by the 175 mm storm isohyet 30 percent is urbanised and contains cut and fill slopes. Thus 70 percent of the slips were located on 30 percent of the slopes, implying that 'cut and fill' slopes were worse affected than natural slopes.

Two other points are worth noting. The suburb of Kelson experienced very few slips because extensive earthworks have reduced almost all slopes to very gentle values - though material bulldozed across the edges of the flattened ridge contributed to slips along both the eastern bank of Speedy's Stream and the Wellington fault scarp. 'Cut' slopes which tended to fail were those containing relatively thick vegetation, on or above them, and which experienced critical shear stresses due largely to the saturated biomass. On the other hand bare rock cut slopes which experienced failures during the wet winter of 1974 such as those in the lower Ngaio Gorge, were stable, presumably because water during the intense summer storm did not have time to penetrate the joints and interstices of the rock and reduce its shear strength to the point of failure.

R.J. EYLES,
Geography Department,
Victoria University.

Reply from J.G. Hawley:

Dr Eyles has raised the very important and very 'political' question, "Does land become more stable or less stable when developed for housing?"

The statements of mine which he quotes, were true for the areas named and I accept that the statements he makes for areas south of the Newlands tip could well be true also. Both sets of observations are valid 'raw data' which were only beginnings to a study of the question. This situation illustrates beautifully the dangers of drawing conclusions from observations which are few in number and 'raw' in nature. The real lessons lie in why the areas south of the Newlands tip behaved differently from those north of the tip.

There are not just two types of area, developed and undeveloped; there are at least four.

A. Undeveloped land (which could be divided into further units according to steepness, vegetation cover, soil or rock type etc.).

B. The fully engineered (or 'over-engineered') modern subdivision such as Maungaraki and Kelson. These were engineered as entities with deep fills properly benched, adequately compacted and properly drained. The stripping of the softer surface materials (loess, weathered greywacke and colluvium) has tended to be fairly complete so that houses are founded on comparatively hard ground. Each area chosen for development was probably flatter than the surrounding areas in the first place, and the earthworks have made it flatter still. Most of the sizeable cuts remaining tend to be on the main access roads.

The houses on these areas are all fairly new with stormwater disposal systems not yet blocked or leaking, but discharging into newly-built stormwater mains (and thereby increasing the peak flows nearer the valley mouths).

Such areas, covered as they are with numerous umbrellas (house roofs) must be expected to be more stable than the natural slopes which they replace - and much more stable than the steeper unprotected slopes on their borders. Indeed, they proved to be so on December 20, 1976. Perhaps I should not have used the word "surprising" in the sentence quoted by Dr Eyles.

C. In the second type of subdivision earthworks have been made piecemeal, in some cases over many decades. Most of the subdivisions south of the Newlands tip and enclosed by the 175 mm storm isohyet would be of this type. Because they evolved piecemeal they did not acquire any general flattening of slope - rather the reverse! Furthermore, cuts are usually partially (and sometimes entirely) in the soft surface materials which remain because the area as a whole has never been stripped.

Many fills in these areas have been made by amateurs seeking a parking area and many are simply spoil pushed over a bank. In general they tend not to be properly benched, not adequately compacted and not properly drained. It would be very difficult in many of these areas to construct a proper fill on one site; access and working space for machinery are inadequate.

In the older areas, properties tend to be older! Gutters and downpipes and traps are often blocked or leaking and in many cases the stormwater drainage system has evolved in a piecemeal manner with amateur additions and subtractions here and there. In many instances no stormwater disposal systems exist at all for quite large sealed parking areas. In some older areas drains have become completely blocked by tree roots.

D. The third type of subdivision is the "ideal" modern subdivision with minimum earthworks and a fully preconceived drainage system. Perhaps the one proposed by Fletchers for the Kamahi area in Stokes Valley will be of this type.

In answer to the question posed above "Does land become more stable or less stable when developed for housing", I would generalise only so far as to rank them as follows:

1. Type 'B' above. (the most stable).

2. Type 'D' above. These, though on average probably not quite as stable as type 'B' would if properly and imaginatively engineered be 'acceptably' stable - and of course much more pleasant to live in than type 'B'.

3. Natural slopes, 'A' above. Slopes with different steepness, soil or rock type and vegetation cover would have different stability rankings but as a generalisation I place them all between ranks 1 and 2 above, and 4 and 5 below.

4. Suburbs with piecemeal but reasonably engineered earthworks. These usually have a mixture of old and newer houses on ground which varies from very flat to very steep.

5. Older subdivisions with improperly engineered cuts or fills, and/or with blocked or inadequate or non-existent drains. It is the steep areas which fail of course but the cause of failure can be the blocked drain on the old house on the flat ground above.

Stability is not of course the only thing which counts in a subdivision. The most stable class (Rank 1, i.e. type 'B' above) is the one I would least like to live in. They are bleak. Trees will never grow successfully in the areas where the hard rock is near the surface. Only if one were lucky enough to be on a well-built fill would gardening be a practical proposition.

There are strong arguments to be made against cut and fill subdivisions but lack of stability is not always one of them.

With regard to Dr Eyles' "Two other points ...", - I agree with the first which is in line with the ideas I have developed above (though I could not be as sure as he is about "due largely to the saturated biomass").

I would guess that the bare rock faces in Ngaio Gorge were stable on December 20, because the loosened and very recently weathered material had all been removed in the wet winter of 1974 and because it takes more than two and a half years for the action of tree roots and other agencies to bring the next lot of material to a condition of marginal stability. Water will of course penetrate open rock joints faster than it will penetrate soil. My guess is that few of the joints on the newly exposed faces are open yet.

J.G. HAWLEY
Water and Soil Division
Ministry of Works and Development

The compilers are giving some thought to the preparation of a second edition. This could include appendices on Whangarei, Hamilton and Dunedin, and perhaps also on Wanganui and New Plymouth. They are aware of the missing page reference (8) on page 54, the draughting error on the figure on page 18, and the fact that Tonkin and Taylor are erroneously referred to as a limited company in the acknowledgements. They would be interested to hear from readers about -

(a) any other misprints or ambiguities

(b) any ways in which the handbook might be improved

(c) any photos which might be considered for inclusion in the second edition.

LANDSLIP INSURANCE

AND STATEMENTS BY REGISTERED ENGINEERS

Since 1970 property insured under a contract for fire insurance has automatically been covered by insurance under the Earthquake and War Damage Act for damage caused by landslip. This insurance covers only the property which is insured against fire, that is the building and its contents. Damage to the land and other 'improvements' such as walls, paths, driveways is not covered.

The essence of the practical situation with regard to provision of landslip cover by the Earthquake and War Damage Commission is as follows:

(a) A local body approves a subdivision after having satisfied itself (as required by legislation) that, amongst other things, the land is stable.

(b) The owner of a piece of land in the subdivision applies for a permit to build premises to a specific design. The local body examines the proposals and, if satisfied, issues a building permit.

(c) The building is erected.

(d) The owner takes out Fire Insurance on the premises and Earthquake and War Damage Commission levy is automatically made on the premium.

(e) Once the premium is paid Earthquake and War Damage landslip cover is provided.

In the normal course of events, therefore, the Earthquake and War Damage Commission is not aware of the particular circumstances of the site unless:

(i) There has been a previous claim on its funds in respect of the same site;

(ii) The local body or somebody else draws its attention to particular circumstances; or

(iii) There is a slope failure and a claim is made upon the fund.

The Earthquake and War Damage Commission has been concerned by the amount of the claims which have been put to it, and with the cost of damage which has no insurance cover, which in many cases have arisen where building has gone on in areas of instability which were known, or should have been known about.

In August 1976 the Commission wrote to all Local Bodies in New Zealand expressing its concern, reminding them of their responsibility in this matter and suggesting a mechanism for ensuring that the stability of the land is adequately considered before subdivisions are approved and before building permits are issued.

This mechanism is described in the "Suggested Council Policy Re Land Stability" which is reproduced at the end of this article. The pro-forma statements A and B referred to were adopted by some Councils, and some members of the Geomechanics Society will have been asked to complete them for those Local Bodies. Copies of Statements A and B have not been included here because they are still under revision.

The Society's Management Committee is completely in agreement with the Commission objectives, but has some misgivings about the practicality of completing the Statements in their original form and about the legal implications for Engineers who sign them. These misgivings were shared by members of the Municipal and Counties Associations who have formed a joint subcommittee to review the matter.

The Society organised a discussion session at N.Z.I.E. Conference in February 1977 which produced much constructive comment from many Engineers from Local Bodies, and elsewhere. A sub-committee of the Society has since met in Auckland and has conveyed comments to the joint Counties Association and Municipal Association sub-committee which is in the process of producing revised formats for Statements of Engineers opinion upon land stability. The following is the suggested sequence of stability reports;

A Preliminary Land Stability map - and then where subdivision is proposed in an area previously defined as having known, suspected or potential land slip or foundation instability, reports at -

(1) Time of submission of a scheme plan for subdivision approved

(2) After engineering construction work on the subdivision

(3) In support of an application for a building permit.

The Society's main objection to the original forms (adopted by some Local Bodies) related to clauses 4 and 5.

Clause 4. "In my professional opinion the land together with any proposed excavation and/or filling, as shown on the drawings, is suitable for house construction and will be stable in all foreseeable and reasonable circumstances."

The last five words have implications of endless debate and litigation. Management Committee feels that they should be deleted and the statement should relate <u>only</u> to the specific proposals as described in the drawings and specifications (which may be referred back to their authors for amendment and amplification if necessary).

Clause 5. "The proposed measures to obtain land stability do not rely on the need for future maintenance, such as subdrainage measures which do not include appropriate filters."

The reference to subdrainage is reasonable enough, but there are many other measures which can and should be maintained (such as surface water disposal drains).

The revised formats under preparation remove these objections and make other desirable changes; they still require the Engineer to state that - "I am a Registered Engineer, experienced in the field of soils engineering and more particularly land slope stability". A Court of Law is likely to expect of an Engineer who signs such a statement more than "general practice" competence.

I would advise Members of the Society to consider very carefully the content of statements or opinions which they provide about land stability for Local Bodies and to modify pro-forma presented to them, as they think fit.

The Society's recent publication "Slope Stability in Urban Development"* provides guidance in the matter and also indicates the limitations upon what one can reasonably know about land stability in that situation.

D.K. Taylor.

* D.S.I.R. Information Series No.122 - 1977, available from Government Bookshops.

SUGGESTED COUNCIL POLICY RE LAND STABILITY

1. Council shall maintain a map of the Borough/City showing areas of known, suspected or potential land instability.

2. Council shall seek the advice of a civil engineer specialising in the field of soils engineering and more particularly land stability for the purpose of reviewing the above map and providing such additional guidelines (e.g. surface slope) as are necessary to help identify potential land instability problems.

3. When approvals for subdivisions are sought in any area of known, suspected or potential land instability or where indicated by the special guidelines, Council shall obtain Statement A herein prior to giving approval of a scheme plan.

4. Where special restrictions or requirements for building site preparation and/or foundations and/or site drainage which apply to individual site works are contained in a report, Council shall hold a copy of such report available for inspection by the public and shall ensure that the existence of such report is known to an engineer preparing Statement B for a building permit application.

5. Where building permit applications for new houses are sought in any area of known, suspected or potential land instability or where indicated by the special guidelines, Council shall obtain Statement B herein prior to the issue of the permit.

6. Where inspection by a professional engineer during construction is indicated, Council shall require such inspection to be carried out as a condition of the approval or permit.

(NOTE: - Any fees incurred for preparation of Statements under 3 and 4 and for professional inspection during construction under 6 payable by the applicant.)

N.Z. GEOMECHANICS SOCIETY

SYMPOSIUM, 1977

"TUNNELLING IN NEW ZEALAND"

The Society is sponsoring this symposium to be held in Hamilton at the University of Waikato from 17 to 19 November 1977. The aim of the symposium is to review and discuss the role of geomechanics in the investigation, design and construction of tunnels and underground excavations in New Zealand. There have been many varied experiences with tunnelling in this country over the years and, with the advent of new techniques in all aspects of this area of civil engineering, it seems appropriate to stage a symposium at this time.

The symposium will be open to all and, although not all prospective registrants may have had contact or experience with tunnelling, it is considered that there is wide interest in this subject. The organisers wish to encourage as many as possible to attend and have carefully chosen the date and venue with this in mind.

To ensure representation from all parties concerned with tunnelling in this country, papers have been accepted from contractors, consultants, local bodies and government departments. The papers will be published in their final form and issued to registrants at the beginning of November.

Each technical session at the symposium will consist of either two or three papers followed by a period of discussion. Registrants will be encouraged to submit written discussion. A further volume containing a summary of the discussions will be prepared after the symposium.

It is hoped to include on the programme for the afternoon of Saturday, 19 November a trip to a site of relevance to the theme of the symposium. Arrangements are also being made to entertain any accompanying wives of those attending.

Live-in accommodation in the form of single and double rooms at the University Halls of Residence will be arranged by the organising committee.

Registration forms will be mailed to all Society members when they are available. Meanwhile, further information can be obtained from:-

A.J. Olsen,
M.W.D. Central Laboratories,
P.O. Box 30-845,
LOWER HUTT.

TEACHING AND RESEARCH IN ENGINEERING GEOLOGY AT THE AUCKLAND UNIVERSITY

Warwick Prebble

Lecturer in Geology, University of Auckland

INTRODUCTION

Engineering Geology has been taught in undergraduate course-work for a number of years - as a part of applied geology at the Stage III level in the Department of Geology and as a full one-semester course at the second professional level in the School of Engineering. The latter course has, in fact, been an introduction to geology for Engineers and will continue to be taught as such. New courses in both the Geology Department and Engineering Faculty are planned for 1978 and graduate research in engineering geology has increased substantially.

UNDERGRADUATE TEACHING

In the School of Engineering, a one-semester course in "Introductory Geology for Engineers" will continue to be given as a core subject in Civil Engineering in the Second Professional year. The subject is oriented specifically towards civil engineering students but is otherwise an introductory geology course. Next year, for the first time, a course will be available - at the Third Professional level in Engineering Geology. The course is a one-semester elective, available to students who are interested in extending their knowledge of civil engineering into the field of engineering geology. The course will be practically oriented with examples from case histories, demonstrating the application of geology to civil engineering practice.

The Department of Geology has taught selected aspects of engineering geology for several years. This has been expanded to half a full course, given throughout the year at Stage III level in the Applied Geology paper. (Students taking this paper have a strong background from Stage II in structural geology, introductory rock mechanics, tectonics and field mapping techniques with also some introduction to engineering geology and geophysics).

The remainder of the Stage III Applied Geology paper includes applied geophysics, groundwater, photogrammetry and photogeology, advanced structural geology and a comprehensive course in field mapping and reporting.

GRADUATE COURSES

It is planned that a graduate course in Engineering Geology will be available at BSc (Hons) and MSc level.

Students who are especially interested in advancing in engineering geology are advised and directed to include in their degree not only the engineering geology and related course work in the Geology Department but also the full range of courses in Geomechanics which are taught in the Civil Engineering Department. Joint supervision of research projects between the two departments and joint teaching is an established practice.

RESEARCH PROJECTS

Current research projects which have engineering geology as a large part of their scope include the following three PhD thesis topics:

Stability of slopes in the Central North Island and East Coast fold belt. (W.M. Prebble)

Relationship of soil type, rock type and geologic structure to stability of slopes in the Elsthorpe Valley-Waimarama-Tukituki Valley area, Southern Hawkes Bay. (J.R. Pettinga)

The study of clay mineralogy associated with slope failures in the Central North Island. (R.C. Thompson)

Mr Pettinga's PhD study also forms a research contract with the National Water and Soil Conservation Organisation who have a direct involvement in catchment condition surveys in the Southern Hawkes Bay area.

Two further graduates, currently involved in papers for MSc work, are aiming to commence theses next year which include studies in coastal erosion and landsliding in the Auckland urban region and at Mahia Peninsula. The geology student interested in the latter project has some background in geomorphology and hydrology.

EQUIPMENT AND FACILITIES

Geomechanics laboratories are established in the School of Engineering and include such equipment as a direct shear machine, Hoek triaxial cells and compressive testing machines. Research in engineering geology in the Geology Department is utilising the extensive facilities for clay mineralogy. These include a sedimentology laboratory, differential thermal analysis, X-ray diffraction, X-ray fluorescene, electron microprobe and chemical laboratories. Geomechanics testing equipment is being acquired under a policy of complementing that which already exists in Civil Engineering laboratories and whenever possible with a view to portability and use in-situ, in the field. Hence the department has two portable field shear-vane testers, a penetrometer, and soil augers. Geophysical exploration equipment includes seismic reflection and refraction, resistivity, magnetic, gravity and a small trailer-mounted drilling rig. Geophysical investigations have been carried out for dam sites on the Rangitaiki River.

In conjunction with structural geology courses, a rock shear box is housed in the geology laboratories.

The current practice is to give Engineering Geology students a sound, progressive training in engineering geology, structural geology, tectonics, field mapping and applied geophysics on one hand and in geomechanics on the other. At the graduate level teaching and research will continue to develop jointly with the Civil Engineering Department. Research also continues separately in specialist topics to which the two respective departments' expertise and facilities are suited.

NEWS FROM THE MANAGEMENT SECRETARY

1. NEW MEMBERS

New members elected to the Society since the last list was published are:

R.A. Atkins, K.B. Blake, B.J.B. Brown, D.G. Bunting, R.H. Dewhurst, K.D. Doig, B.D. Field, I.S. McIntosh, S.D. Scott, M.D. Sinclair, Y. Thorp, M.A. Wesseldine, N.J. Withers, P.G. Young.

2. FORTHCOMING CONFERENCES AND SYMPOSIA

July 4 - 7	-	Conference on large ground movements and structures, Cardiff.
July 4 - 6	-	5th South-east Asian Conference on Soil Engineering, Bangkok, Thailand.
July 7 - 8	-	International Symposium on Soft Clay, Bangkok, Thailand.
July 11 - 15	-	9th ISSMFE International Conference, Tokyo.
Sept 5 - 7	-	5th Danube European Conference SMFE, Bratislava, (Czechoslavakia).
Sept 5 - 8	-	Rockstore 77, Sweden.
Sept 13 - 16	-	IAEG Landslide Symposium, Prague
Nov 17 - 19	-	New Zealand Geomechanics Society Tunnelling Symposium, Hamilton.
Nov 30 - Dec 4	-	New Zealand Geological Society Conference, Queenstown (includes "Geological aspects of energy resource development in N.Z." as a theme).

3. PROCEEDINGS OF THE NELSON SYMPOSIUM "STABILITY OF SLOPES IN NATURAL GROUND", Nov. 1974

The proceedings of the Nelson Symposium have been in such a demand both from New Zealand and overseas, that they are now out of print. Reprints will be available soon from the Secretary, NZIE, at a cost of $15.00 per member and $18.00 for non-members.

4. PROCEEDINGS OF THE 2ND ANZ CONFERENCE ON GEOMECHANICS HELD IN BRISBANE, July 1975

Copies of these proceedings are available from the Secretary, NZIE, at a cost of $25.00.

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.

STRESS PATH INTERPRETATION OF TRIAXIAL DATA

J.M.O. Hughes, P.R. Goldsmith
University of Auckland

INTRODUCTION

Many situations in soil mechanics do not call for special testing as often the experienced engineer can base his judgement on simple limit tests. However for situations such as the assessment of the stability of large embankments, cuts, or where unfamiliar materials are encountered, more sophisticated testing procedures are required.

To raise the sophistication of testing from simple limit tests on disturbed samples to say triaxial tests on "undisturbed" samples involves a significant increase in cost, thus every effort should be made to extract as much information as possible. This does not necessarily suggest that more testing is required but rather the data obtained is viewed in a different way.

It is conventional to view soil as if it were subject to two distinctly independent behavioural characteristics. This division is usually made between (a) the consolidation characteristics as determined on an Oedometer, and (b) the shear strength as determined from triaxial tests.

These phenomena are however not independent but are intricately linked. This is a fundamental factor which is often overlooked in interpreting triaxial data.

The authors consider that the technique outlined below will help to put the above behavioural characteristics in their true perspective.

THE TECHNIQUE

To illustrate the technique first consider the typical behaviour of an ideal clay. The Oedometer test would behave as indicated in Figure 1, where P_c corresponds to the maximum past pressure. Now if conventional undrained triaxial tests were conducted on samples which have been consolidated to various confining pressures such that the final conditions before shearing are given by points 1 2 3 and 4 on the consolidation plot of Figure 1, then the Mohr's circles for these undrained tests would be as shown in Figure 2. The line tangent to circles 3 and 4, which were from tests consolidated to pressures above the preconsolidation pressure, would probably go through the origin, i.e. A B C, whereas the tangent to tests 1 and 2 may well be slightly higher i.e. D B.* Results of tests carried out on "undisturbed" samples of Onerahi Chaos are shown plotted in Figure 3 in the same conventional manner as the ideal clay of Figure 2. The idealised behaviour of Figure 2 is to some extent illustrated, however the point B^1 (which corresponds to point B in Figure 2) is not precisely defined due to the relative scatter of the results. It is nevertheless clearly possible to determine a range of strength parameters appropriate to that soil. In many cases there may be little point in having more accurate results especially if the neighbouring soils are significantly different. Thus although the information contained in Figure 3

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* Because of the development of pore pressures during shearing the normal stress at point B does not usually have the same value as P_c.

is sufficient to obtain strength parameters it is not immediately obvious whether the tests have been performed at initial consolidation stresses above or below the preconsolidation pressure. The behaviour becomes much clearer when pore water pressure developing during the test is taken into account.

Figure 4 shows the pore pressure and shear stresses developed during shearing of the ideal clay during the undrained test discussed earlier. These results show that both the pore pressure change and the shear stress decrease with decreasing initial consolidation pressure i.e. test 4 through 1. If the conslidation pressures are low enough this change may in certain cases even go negative, as indicated by test 1. However other than noting that there is a clear distinction between tests 1 and 2 little further information can be obtained.

Probably the most valuable information about the clay is obtained from examination of the stress path the soil follows during shearing. For each of the consolidation pressures the stress paths will be different, except that major similarities depending on whether the soil is consolidated to a pressure above or below the preconsolidation pressure. This phenomenon is discussed later. Although it is a technique which has been employed for almost 20 years in research establishments, the concept of plotting stress paths is presently not widely used by consulting engineers.

The two approaches that have been developed are characterised by:-

(a) that of T.W. Lambe at MIT

and (b) that of K.H. Roscoe at Cambridge.

The difference between both methods is due to the use of slightly different parameters to describe the shear stress and effective pressure during shearing. These different parameters are indicated in Table 1.

	Shear Stress	Effective Pressure
Roscoe	$\sigma'_V - \sigma'_H$	$\frac{\sigma'_V + 2\sigma'_H}{3}$
Lambe	$\frac{\sigma'_V - \sigma_H'}{2}$	$\frac{\sigma'_V + \sigma'_H}{2}$

TABLE 1. PARAMETERS ADOPTED FOR SHEAR STRESS AND EFFECTIVE PRESSURE BY ROSCOE AND LAMBE.

In Table 1 σ'_V and σ'_H are the vertical and horizontal effective stresses acting on a triaxial sample.

Although there are various advantages of one system over the other the technique discussed applies equally to either system. The stress paths obtained for the ideal test shown in Figures 4a and 4b are plotted Figure 5 in p-q space, i.e. in terms of the Cambridge parameters. These stress paths are obtained by plotting the shear and effective stresses observed at each load increment during the test. From this figure there is a clear distinction between the stress paths followed by the two samples consolidated to pressures above the preconsolidation pressure i.e. tests 3 and 4 and

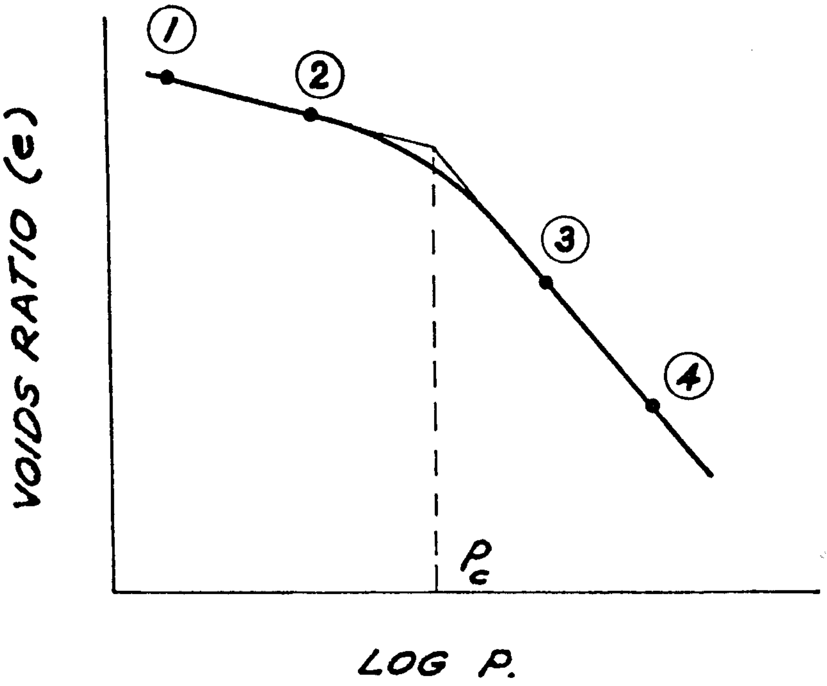

FIGURE (1) TYPICAL OEDOMETER TEST ON AN IDEAL CLAY

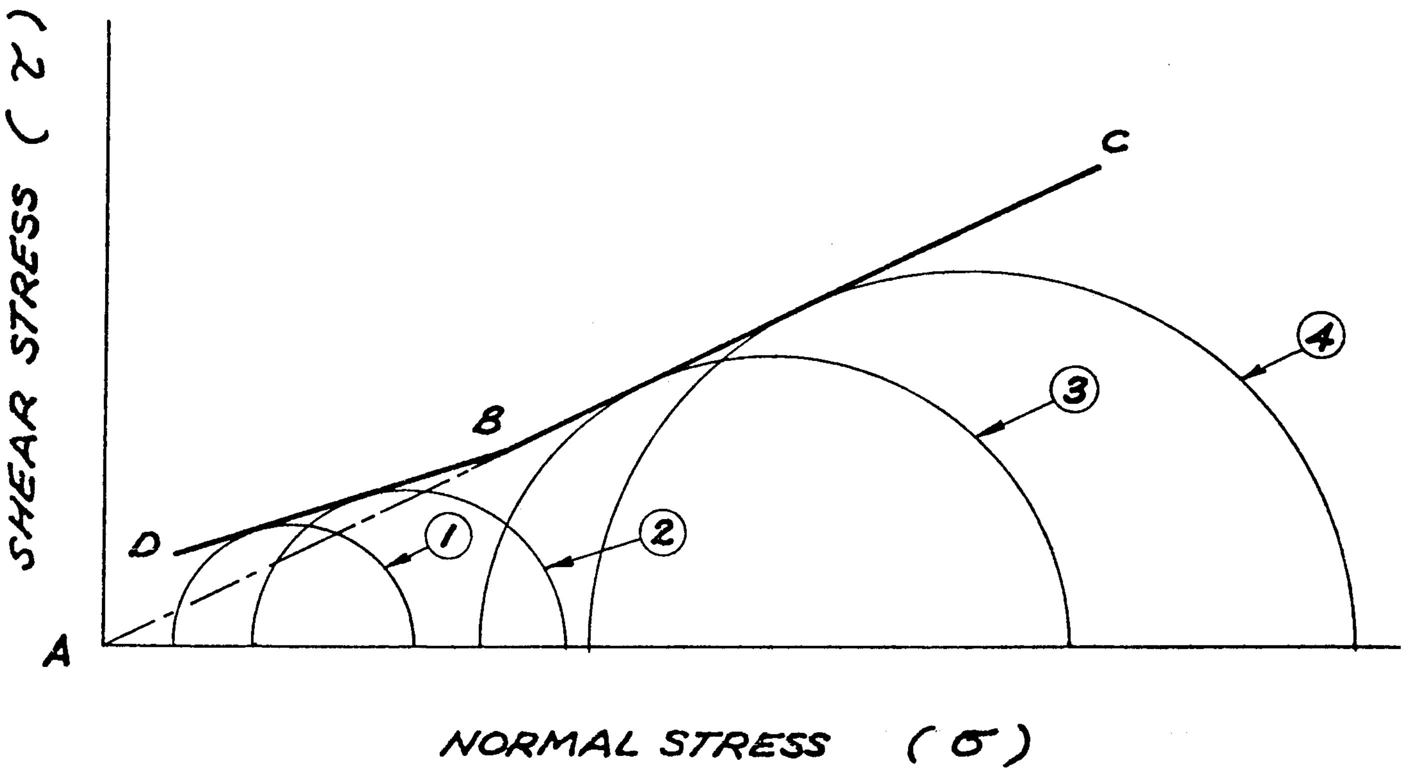

FIGURE (2) MOHR'S CIRCLES FOR AN IDEAL CLAY INITIALLY CONSOLIDATED TO THE STRESS STATES 1 2 3 AND 4 OF FIGURE (1)

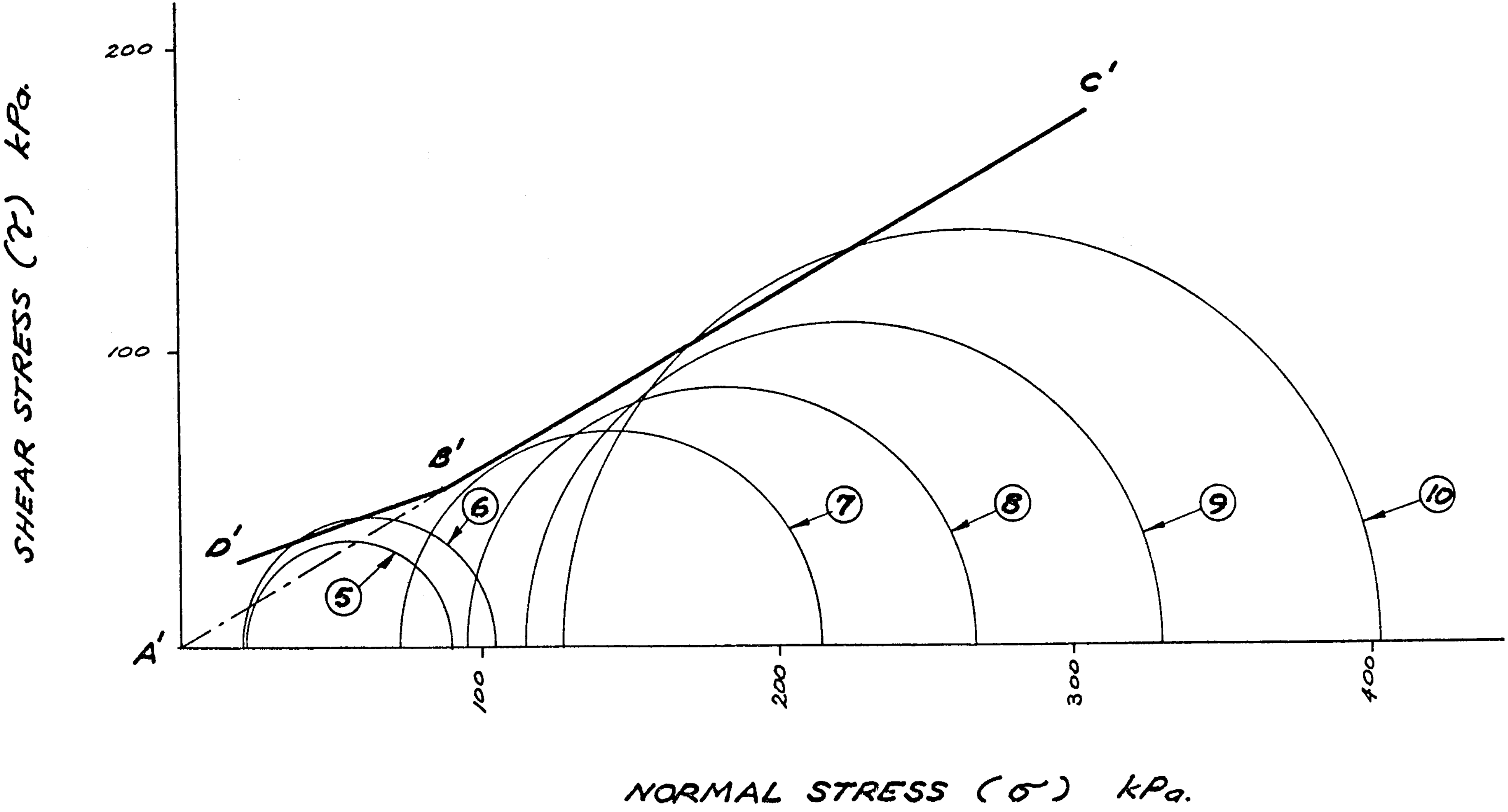

FIGURE (3) MOHR'S CIRCLES FOR WEATHERED ONERAHI CHAOS INITIALLY CONSOLIDATED TO DIFFERENT PRESSURES

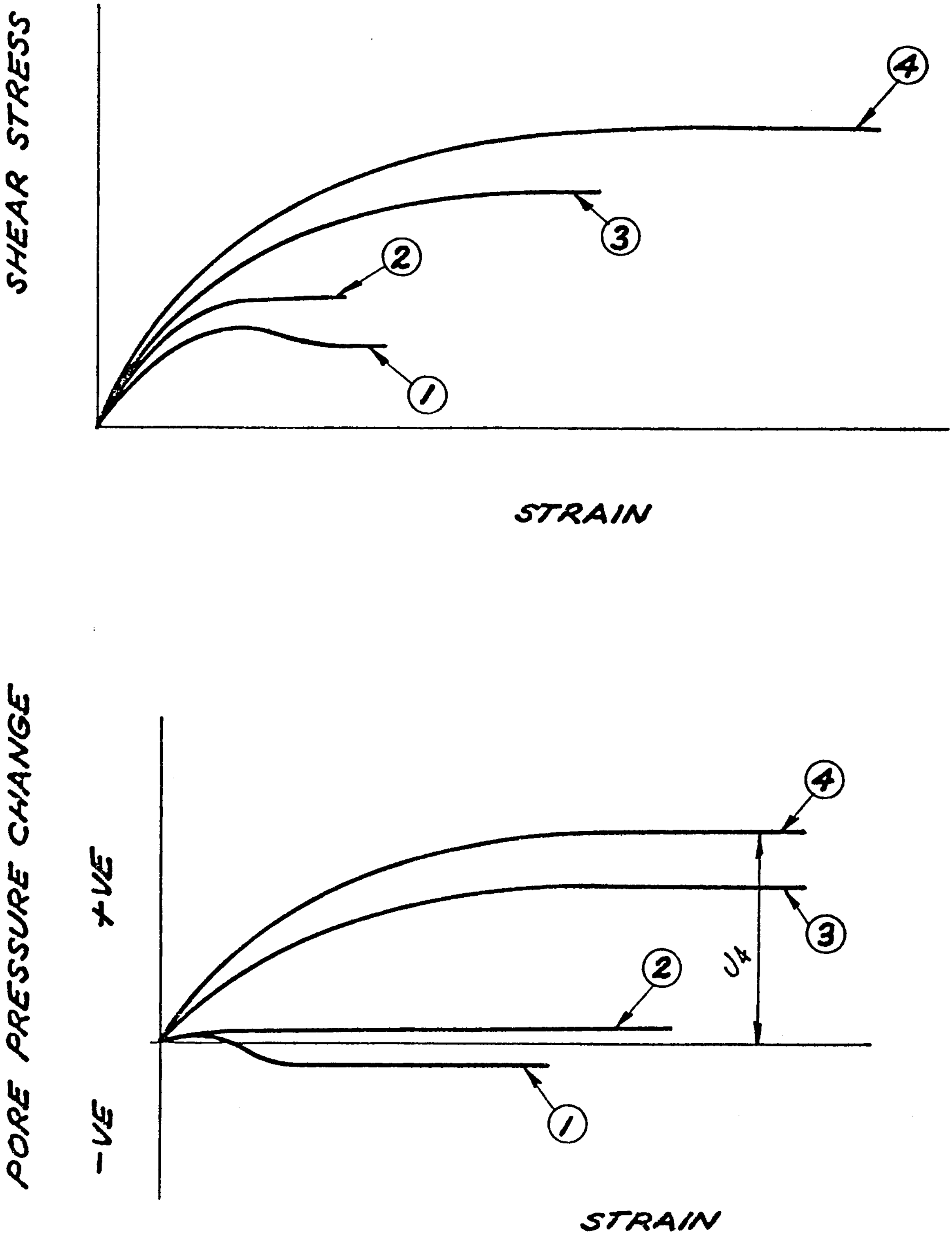

FIGURE (4) SHEAR STRESS AND PORE PRESSURE DEVELOPMENT DURING UNDRAINED SHEARING OF IDEALISED CLAY SHOWN IN FIGURE (1) AND (2) those for the samples consolidated to lower pressures, i.e. tests 1 and 2.

It should also be noted that the stress paths of tests 3 and 4 are geometrically similar and are distinctly different from those of tests 1 and 2.

The end point of each test (the stress level at which the samples fail) may be joined to give the lines D" B" below the preconsolidation pressure (P_c), and B" C" above P_c. Projected back B" C" passes through the origin A".

It is thus possible, from consideration of the shape of each stress path, to estimate the nature of the path that would be followed by a soil consolidated to the preconsolidation pressure at the commencement of the test. Such a stress path is shown by the broken line EB" in Figure 5.

If K_o, the ratio of the insitu horizontal and vertical effective stresses, (i.e. $K_o = \sigma'_H / \sigma'_V$) is able to be determined or estimated, then an indication of the insitu value of the preconsolidation pressure (P_c) may be obtained. For example, if K_o was unity i.e. $\sigma'_V = \sigma'_H$ the preconsolidation pressure P_c would be given by the value of P_c at point E in Figure 5. For any other value of K_o the stress state must be of a line such as A" K

$$\text{where} \quad \frac{q}{p} = \frac{3\ (1-K_o)}{1 + 2\ K_o}$$

The value of the stress at the intersection of the K_o line with the stress path B"E i.e. at point F, will give an indication of the preconsolidation pressure.

It should be noted that in adopting a stress path technique the slope of the line joining the end points of the paths of samples that have been normally consolidated, i.e. A" B" C" in Figure 5, does not give the effective friction angle ϕ' as is the case with the conventional plot of Figures 2 and 3. Rather ϕ' , using the Roscoe technique, is obtained from the slope of A" B" C" using the following relationship -

$$\text{Sin } \phi' = \frac{3\ q/p}{6 - q/p}$$

The plotting of a stress path is a relatively simple process. During an undrained triaxial test it is usual to record the applied axial load and the pore water pressures generated. The applied axial load is in fact a total stress which after allowance for pore water pressures generated during consolidation, yields the start point in q-p space of the stress path for that particular test - for example point G of test 4 for the ideal clay of Figure 5.

The total stress path followed during the test is given by GC" and is, from the geometry of the p-q stress space (and remembering that the total horizontal stress σ_H remains constant) always at a slope of 3 : 1 as indicated in Figure 5.

Thus it is a simple matter to enter the total stress path with the values of pore pressure and load observed at each stage of the test and simply scale back from the total stress path by an amount equal to the observed pore water pressure to obtain the associated point on the effective stress path. For example the pore water pressure for test 4 on the

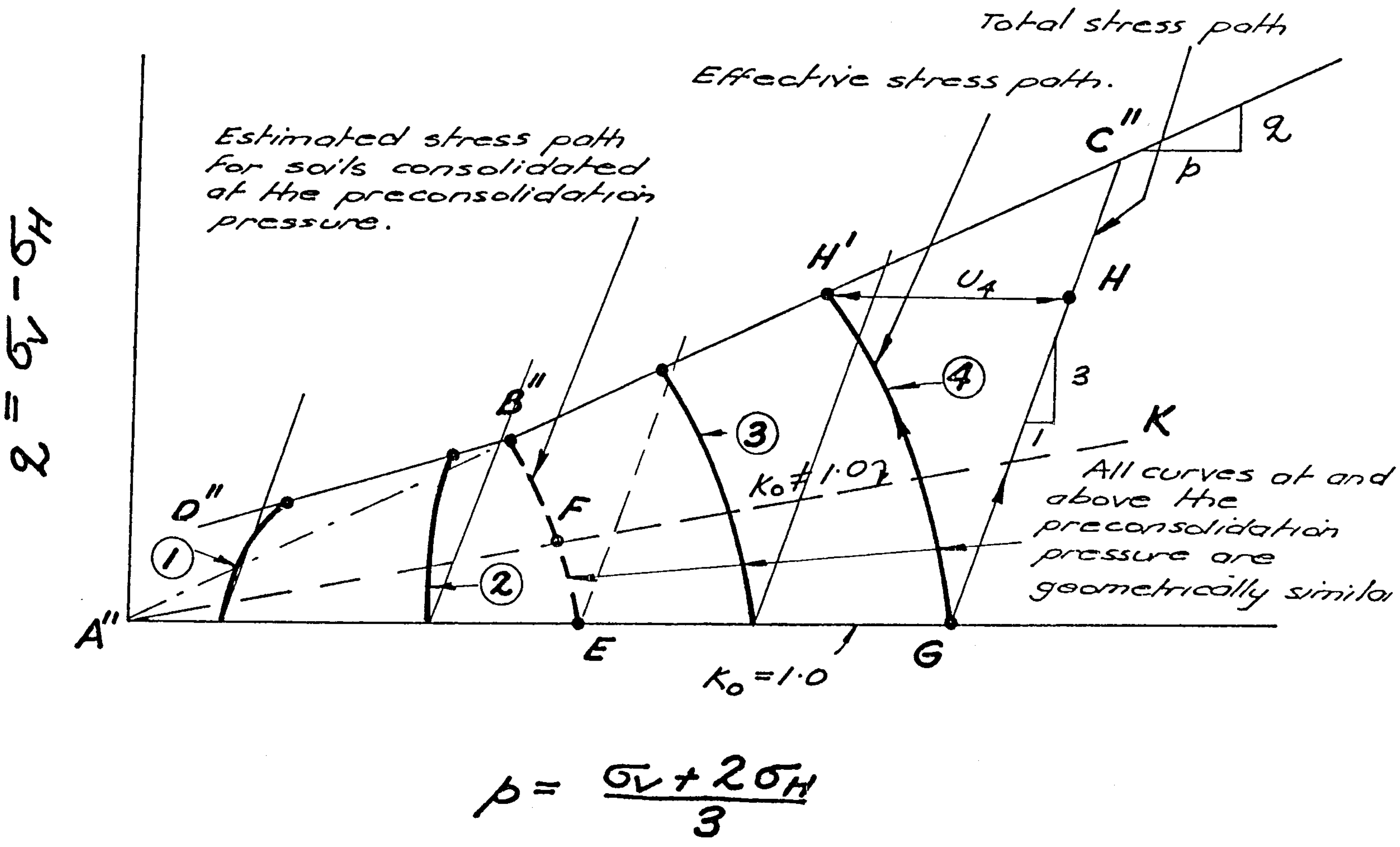

FIGURE (5) STRESS PATH FOR THE IDEALISED TESTS SHOWN ON FIGURE (2) AND (4) ideal clay of Figure 4 was equal to U_4 at failure. Thus on Figure 5 for the observed total stress given by point H, the associated point on the effective stress path is given by H'.

LABORATORY RESULTS ON ONERAHI CHAOS

The results of triaxial tests conducted on Onerahi Chaos which were presented conventionally in Figure 3 are shown as stress paths in Figure 6, plotted using the technique described. Clearly there is a distinct change in behaviour between tests 5 to 8 and 9 and 10. Hence it would seem reasonable to deduce that the transition zone between over-consolidated and normally consolidated states lies somewhere between tests 8 and 9. This would indicate a preconsolidation pressure of about 200 kPa, depending on the value of K_o. The associated value of ϕ' from the slope of A" B" C" is 30^{o}.

The stress path has another important function in that it enables an assessment of the build up of undrained shear strength as a soil is consolidated. For example if the all round insitu pressure (p) in the soil is estimated at initially 130 kPa say (i.e. equivalent to joint J on Figure 6) and the soil is then sheared, then no matter how the loads are applied (provided the shear stresses are always increasing) the stress path will tend to be unique in that it will follow along the path of test 7 until failure is reached at point E. Because of this behaviour it is possible, with the aid of triaxial tests interpreted using a stress path technique, to estimate what shear strength a soil would have if sheared from any initial stress state.

If the initial condition started at say F or H then the estimated stress paths would be FG and HI with failure at G or I respectively.

As a word of caution there is considerable evidence to suggest that much of the strength which lies above the failure line A'B' to B'D' in Figure 2 and 3 and A" B" to D" B" in Figures 5 and 6 is of a temporary nature and therefore cannot be relied on for any length of time. This may in part account for a number of failures in over-consolidated or lightly over-consolidated soils which occur some time (often years) after the initial earthworks.

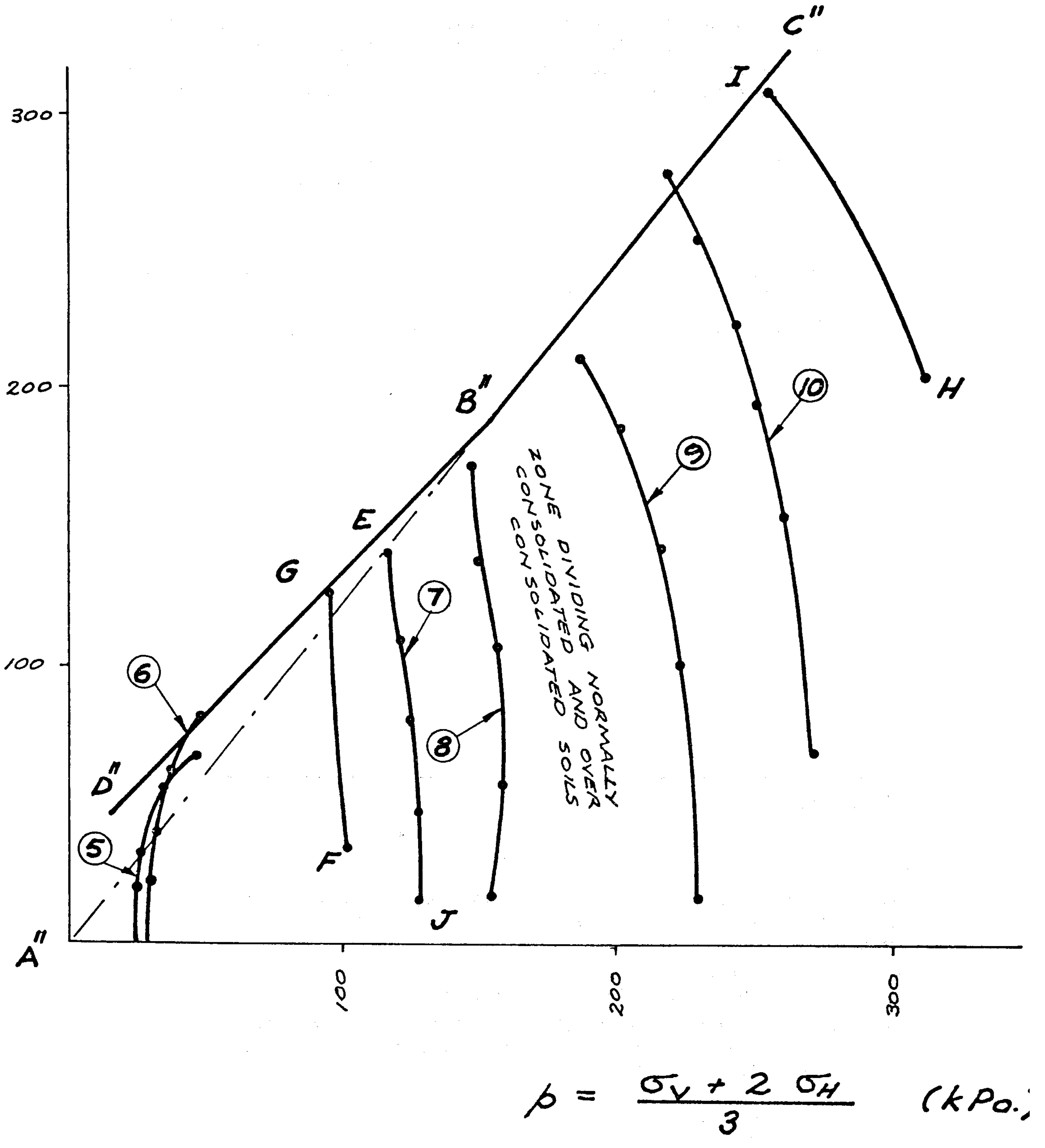

FIGURE (6) STRESS PATH FOR THE WEATHERED ONERAHI CHAOS SHOWN IN FIGURE (3)

SUMMARY

A technique has been presented which enables costly triaxial tests on "undisturbed" samples to be viewed such that more information may be obtained than is usual from a conventional interpretation of the same test data. This is done by viewing the complete test as it proceeds rather than just considering the end results.

The data is interpreted by recognising the intimate relationship between the shear strength and consolidation characteristics of the soil.

REFERENCES

Roscoe, K.H., Schofield, A.N., and Wroth, C.P. "On the Yielding of Soils", Geotechnique, Vol.8, p22-53, 1958.

Lambe, T.W. "Stress Path Method", Proc. A.S.C.E., Vol.93, SM6, Nov. 1967.

STOP PRESS

1978 NZIE ANNUAL CONFERENCE

CALL FOR PAPERS

A call is made for submission of papers of general Geomechanics interest for presentation at the NZIE Annual Conference to be held at Hamilton in February 1978.

Details of papers, including author, title and synopsis, should be forwarded to the address below by 31st July 1977 for selection and editing.

Authors submitting synopses should note that final drafts are required by 31st October 1977, and the acceptance of a synopsis denotes an obligation to submit a final draft by that date.

Synopses to: The Convener
39 Fernleigh Avenue
Epsom
Auckland 3.

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 Socièties: (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 ($2.25)

International Society for Rock Mechanics (ISRM) Yes/No ($6.20)

International Association of Engineering Geology (IAEG) Yes/No ($2;$6 with Bulletin)

Signature of Applicant ______________________________

Date ____________ 19 ___

N.B. Affiliation fees are in addition to the Geomechanics Society membership fee of $5.50.

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:

____

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Signature ____________________

Date ____________________