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THIRD WORLD CONFERENCE ON EARTHQUAKE ENGINEERING, NEW ZEALAND,

JANUARY 1965

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SUMMARY

Some seismological aspects of the Third World Conference on Earthquake Engineering and recent trends in methods of investigation of problems in the Territory of Papua and New Guinea are outlined.

Many overseas countries, including less affluent ones, have found that effective aseismic design requires the investigation of local problems, which cannot be covered by generalised building codes. The implementation of a programme of investigation in the Territory of Papua and New Guinea would be required to provide these data here, and the installation of a strong-motion accelerograph network is therefore recommended. Such a programme would consist of classifying the earthquake response characteristics of geological strata on which major towns and other important construction are sited, and classifying the important characteristics, from the standpoint of structural response, of earthquakes in different areas of the Territory of Papua and New Guinea. It is thought that a permanent committee, to deal with aspects of earthquake engineering in the Territory, would be valuable.

The work of seismologists and earthquake engineers in the New Zealand Department of Scientific and Industrial Research is briefly described.

1. INTRODUCTION

This record outlines an overseas visit by the author to attend the Third World Conference on Earthquake Engineering held in Auckland and Wellington, New Zealand, from January 22nd to February 1st 1965. The conference succeeded those in San Francisco (in 1956) and Tokyo (in 1960) but was the first to be held under the auspices of the International Association for Earthquake Engineering. Thirty countries were represented.

Five themes were covered in five sessions :

(I) Soil and foundation conditions relative to earthquake problems.

(II) Analysis of structural response and instruments.

(III) Seismicity and earthquake ground motion.

(IV) Earthquake resistant design, construction, and regulations.

(V) Recent strong motion earthquakes and resulting damage.

Proceedings will be published and recommendations that copies be purchased for BMR libraries have been made. Brief references are made in the following discussion to certain papers, but the reader is referred to the Conference Proceedings for more detailed information on material presented.

The author attended the conference in his capacity as Observer-in-Charge, Port Moresby Observatory, to present a paper in Session III, and because of the relevance of the conference to BMR responsibilities in the discipline of seismology, especially seismicity, in New Guinea. Most of the ensuing discussion is developed with this in mind.

Visits made to the Geophysics Division and the Physics and Engineering Laboratories of the New Zealand Department of Scientific and Industrial Research (D.S.I.R.) are briefly described.

The general impressions were :

(a) Much attention is now being given to the earthquake problem, especially in seismic countries with high population and construction densities. Research is being actively supported by governments and by UNESCO and most countries now enforce aseismic building codes, although the quality and complexity of these vary considerably.

(b) Problems of the vibration and behaviour of buildings under assumed conditions, which are being investigated using sophisticated mathematical and data processing techniques, can be distinguished from problems of determining actual ground response characteristics, which must be assumed for the former purpose. There is still a wide gap between theory and practice and the practising engineer and architect are often not yet able to translate the results of theoretical research for ready application to their needs.

(c) Ground response is still not adequately understood and the characteristics of strong ground motion have not yet been adequately recorded. Many theoretical calculations of structural behaviour are still being based on one Californian strong-motion recording made in 1940.

Despite a large increase in the number of strong-motion instruments installed throughout the world to record ground accelerations in the last few years there has not been a proportional increase in useful recorded data.

(d) The belief that a strong-motion recording programme in New Guinea would provide essential data for design purposes in the region was strengthened.

(e) New Zealand governmental research laboratories are well advanced in earthquake engineering research and in the application of results, so far as the practising engineer and architect are concerned.

2. CONFERENCE

General remarks

The author's interests were centred around seismicity studies, strong-motion recording and analysis, general differences in the behaviour of different geological foundations, and how New Guinea problems are related to these.

It is widely accepted that all aseismic design must be based on strong-motion acceleration records of large earthquakes, the characteristics of which may differ in different regions. Despite a very significant increase in the number of strong-motion instruments installed in many countries (e.g. India, Japan, USA, Mexico, New Zealand) there has not so far been a corresponding increase in required data. To overcome the high cost of commercial equipment, some countries have designed and built their own equipment to facilitate measurements of acceleration, and the most significant recent development here is in the work of the New Zealand Department of Scientific and Industrial Research.

Not enough is known yet about foundation behaviour and as this depends on location, recordings must be made in each country wherever the data are needed. This appears very relevant to New Guinea where, so far, no such measurements have been made.

A group of papers dealing with damage caused by recent notable earthquakes, e.g. in Alaska, Yugoslavia, and Japan, very clearly illustrated the current lack of understanding of the response of different kinds of foundation strata for different earthquakes according to magnitude, epicentral distance, and depth of focus, and also showed the unsatisfactory features of trying to utilise intensity estimations for engineering purposes.

There was strong argument that such standard earthquake parameters as magnitude and intensity, particularly the latter, have very little quantitative significance for the engineer as far as aseismic design information itself is concerned. On the other hand, it is recognised that many situations arise where intensity assessments comprise the only information available to engineers, and the importance of maintaining consistency in time of these data within each region was stressed. Generally speaking, the need for a greater appreciation and understanding, by seismologists on the one hand and engineers and architects on the other, of the application of commonly used parameters in each other's fields was realised, apart from a general cross-appreciation of problems.

The subject of earthquake insurance is certainly marginal to the geophysics of earthquakes, but the system adopted in New Zealand is probably unique and therefore worth mentioning here. It is undertaken only by the New Zealand Earthquake and War Damage Commission, which acquires funds by way of a levy or tax of 1/- per £100 of fire insurance on all policies written in New Zealand.

Seismicity

The basic method of displaying seismicity is the epicentre map and the most valid interpretation of this can be made through the use of extreme value theory to compute return periods for earthquakes of nominated magnitude within specific areas. This has been done in New Zealand by I. D. Dick, with quite close agreement with historical record, although the areas chosen seemed to me rather large ($2^{\circ} \times 3^{\circ}$) for results to be of greatest use. W. G. Milne and A. G. Davenport also have used extreme value theory to examine a sample area of Western Canada to calculate maximum expected magnitude and the maximum ground amplitude to be expected on Wood Anderson seismographs at selected points. It is a pilot study before attempting to analyse the seismicity of the whole of Canada.

A difference of opinion exists between New Zealand seismologists and geologists on the validity of seismically zoning New Zealand. The former regard the whole country as exposed to equal risk. This is not supported by earthquake statistics, but it is claimed that the period of observation is too short and the country is too small to rely even on extreme value studies as a basis for zoning seismic risk in view of heavy loss of life which may result in a lightly zoned area in the event of an earthquake of 'improbably' high magnitude. The alternative (geological) school of thought relies heavily on the association (questioned by the New Zealand seismologists) between earthquakes and faults, and a zoning system based largely on known fault distribution was presented at the conference.

In discussing earthquake intensities, G. A. Eiby stressed that although intensities cannot be quantitatively related to acceleration, velocity, or displacement for engineering or any other purpose, "estimates of intensity can be used for the investigation of differences in foundation conditions and characteristic and anomalous propogation of earthquake motion". There are strong reasons to support the development of intensity scales based on criteria suitable for particular regions or individual countries. This would ensure consistency within each region. He made these points :

1. Instrumental measurements can never remove the need for felt intensity observations.

2. Properly assessed felt intensities are objective measurements, independent of the observer.

3. Intensity measurements cannot be directly correlated with accelerations.

4. An international intensity scale is neither possible nor desirable.

5. Correlations with other physical quantities should not form part of the definition of an intensity scale.

6. Fault displacement is unrelated to intensity.

7. Abridged versions of intensity scales are undesirable.

8. Strong-motion seismographs, provided they have a proper time-base and do not merely measure maxima, will increase the value of existing intensity measurements.

His remarks are interesting because the commonly used Modified Mercalli scale is not satisfactory in its present form for application in New Guinea. It depends largely on observations of traditional European style architecture and is hard to apply in most parts of the Territory of Papua and New Guinea, where buildings of this type are uncommon. If only a restricted strong-motion instrumentation network is installed in the Territory an intensity scale using criteria specified to suit local circumstances is more likely to reveal differences in foundation conditions than is the standard Modified Mercalli scale in its present form - provided that an adequate number and even spatial distribution of observers can be assured.

Strong-motion recording

Characteristics of strong ground motion are recorded for engineering purposes by accelerographs - pendulum devices having a natural free period much smaller than that of the earthquake ground motion being investigated. Most accelerometers have free periods of one-tenth of a second or less. They are fitted with pendulum starting devices triggered by first motion and usually record for preset intervals of a few minutes.

Currently available accelerometers were listed, and performances summarised, by H. T. Halverson. While Japanese and USA equipment is priced at around $4,000, a new accelerometer developed by the D.S.I.R. is expected to be available soon for a considerably lower price. Its characteristics were described by P.C.J. Duflou and R.I. Skinner. Unusual features are :

(1) Omission of a relative time-base. It is claimed that the precision film drive renders this unnecessary.

(2) Use of a single light beam to obtain three traces. Reflecting mirrors on two of the three sensing pendulums are set at an angle of 45° to permit this.

Tape recording methods are not being adapted to accelerometers yet, and (largely for commerical reasons) are unlikely to be available for two years. Prices for such recorders are likely to be 25% higher than for existing types. It is understood that insufficient experimentation has yet been carried out to determine proper tape speeds to permit required resolution and economy of tape.

Installation of accelerographs has increased considerably in the last few years and several seismic countries now have extensive networks in operation. Apart from the USA and Japan, the Dominion Observatory of Canada has recently purchased eight such instruments. Both accelerometers and seismoscopes of the U.S.C.G.S. pattern are now being manufactured by the Fairey Aviation Co. in Canada. Mexico now has a network of about 40 accelerometers installed, including three-component instruments of their own design.

To avoid heavy expenditure on accelerographs, Indian authorities have designed a station instrumentation system consisting of six U.S.C.G.S. type seismoscopes, built locally, each of which covers different points on the response spectrum curve from 0.2 to 1.25 seconds and from

5 to 10% damping. One hundred stations are proposed within a 60,000-square-mile area of India. Complete specifications for seismoscope construction, a sample seismoscope, and specifications for station installation could be offered to the BMR if required. The work is under the direction of Professor Krishna, University of Roorkee.

In New Zealand, the Engineering Seismology Sub-section of the Physics and Engineering Laboratory of the D.S.I.R. is planning to install thirty accelerographs throughout New Zealand by the end of 1965.

A recent development in the USA may be mentioned here. By-laws to require the installation of accelerographs in new buildings of certain classification (mainly public) and size have only recently come into force. Retrospective ordinances are being considered to extend the requirement to existing large residential buildings. The object is to compare design forces with actual forces experienced throughout buildings during earthquakes so that the validity of design methods can be checked. It is not expected that the proposals will be fully effective for many years.

Strong-motion interpretation

As expected, earlier analogue techniques by which strong motion accelerograms were analysed have largely been replaced by digital computer programmes. These are extensively used in the USA, Japan, and by the D.S.I.R. in New Zealand. Programmes could easily be obtained, if required in Australia.

The most widely used approach still involves the reduction of the recording of acceleration as a function of time to a response spectrum (i.e. acceleration, velocity, or displacement) as a function of frequency of vibration, for different conditions of damping. E.g., for a single degree-of-freedom damped oscillatory system,

if y = displacement relative to ground,
a = ground acceleration,
w = undamped natural frequency, and
λ = damping ratio,

the equation of motion is

$$\ddot{y} + 2\lambda w\dot{y} + w^2 y = -a.$$

The free motion of the system (i.e. solution with $a = 0$) per unit initial velocity is

$$\frac{1}{w'} e^{-\lambda' w' t} \sin w't, \qquad (1)$$

where $w' = w(1-\lambda^2)^{\frac{1}{2}}$ and $\lambda' = \lambda(1-\lambda^2)^{-\frac{1}{2}}$.

The response of the system to an acceleration $a(t)$, where $a(t) = 0$ for $t \leqslant 0$, is therefore the convolution of (1) with $a(t)$, i.e.

$$y(t) = \frac{1}{w'} \int_0^t a(\tau) e^{-\lambda' w'(t-\tau)} \sin w'(t-\tau) d\tau.$$

(Hudson, 1956)

Digital programmes allow the analagous dynamic (elastic or inelastic) response of a wide range of many-storied multiple-degree-of-freedom structures, for several modes of vibration, provided the true dynamic properties of structures are known or can be (validly) assumed. It can be readily imagined that this field is complex and highly specialised. Although it is outside the direct interest of the seismologist it is important for seismologists, or geophysicists generally, who are involved with earthquake engineering problems, to become superficially acquainted with range and general nature of investigations which might be based on their recorded earthquake data. Readers are referred to the Conference Proceedings for further information, particularly the Session II opening and closing reports.

The applicability of results of accelerogram interpretations in engineering design is still very much restricted by a lack of adequate strong-motion records. The strongest accelerations recorded are still those (up to 0.3 g peak) from the El Centro earthquake in 1940 at 50 kilometres from the epicentre. No accelerometers were near the epicentres of the Chilean (1960), Buyin-Zahra (1962), Skopje (1963), or Anchorage (1964) earthquakes and the nearest instrument to the Niigata (1964) epicentre was 50 kilometres distant. In due course the widespread instrumentation in many countries will yield more adequate data on the nature of ground motion close to the epicentre for earthquakes of different size and focal depth and in different geological environments.

Meanwhile, studies are being conducted into methods of classifying recorded acceleration data according to earthquake magnitude, epicentral distance, focal depth, and region to ascertain the validity of extrapolation or interpolation from records of now-damaging earthquakes. A paper by Jenschke, Clough, and Penzien investigated three different methods of classification :

(a) Using the power spectral density function. This approach was found to be inadequate as the ground motions recorded are essentially non-stationary phenomena and the power spectral density could not be defined.

(b) Using Fourier spectra. Results were unsatisfactory, chiefly because the sine and cosine Fourier transforms exhibited highly irregular characteristics.

(c) Using response spectra. A significant correlation was found between peak spectral frequency and epicentral distance, but an inadequate variety of records precluded correlation with other parameters. A general conclusion was reached that construction of a 'regional probable spectrum' based on this kind of investigation would be feasible.

Such data would have important significance in New Guinea where large numbers of earthquakes of differing focal depth occurring over a wide magnitude range could influence structures in different ways. The data could be compiled during a shorter time than would be required in most other areas.

Penzien also provided data on the influence of appendages, e.g. radio towers, on the response of buildings.

A novel method of determining the natural frequency of vibration and damping characteristics of buildings was described by Kawasumi of the Tokyo Earthquake Research Institute. Power spectral density curves computed from seismograms of microtremors written in buildings clearly reveal the natural frequency of the structure. The seismographs (T_o = 2 seconds) involved were in standard use in Japan for microtremor recordings.

Okamoto (Japan) presented the results of a study of the behaviour of an earth dam 37 metres high, instrumented at different points by a total of eight accelerometers. Predominant frequencies were determined from small earthquakes and results were confirmed by data from the large Niigata earthquake 200 kilometres away. Amplification of accelerations was noted at the top of the weir.

Collectively, the papers by Kawasumi, Okamoto, and Penzien, gave encouraging support to the idea that accelerograms from small earthquakes are useful as a means of extrapolating values of parameters to be expected in major earthquakes.

Earthquake damage

Damage resulting from large earthquakes that have occurred since 1960 was reviewed in a separate group of papers. The following earthquakes were discussed :

(1) Acapulco, Mexico; earthquakes of May 11 and 19th 1962.
(2) Buyin-Zahra, Iran; September 1st 1962.
(3) Barce, Libya; February 21st 1963.
(4) Skopje, Yugoslavia; July 26th 1963.
(5) Anchorage, Alaska; March 28th 1964.
(6) Niigata, Japan; June 16th 1964.

Apart from the spectacular nature of some of the damage and the evidence of often-repeated earthquake damage, e.g. failure of structures of substandard materials, failure of 'inverted pendulum' architecture, poor construction practice, and construction supervision, the following major points emerged from the discussion :

(a) In developing countries that are also earthquake prone, the economic and practical problems of replacing traditional building materials (e.g. adobe) with more earthquake-resistant materials are very serious if not insurmountable. Methods of eliminating the worst features of construction, for example, by ensuring more desirable load and load distribution, integration and tying of structures, and prevention of capillary rise of ground water into the lower courses of walls, are being investigated.

(b) Evidence of selective damage, related, in part, to epicentral distance (75 miles), was given for the Anchorage earthquake, where, because long-period motion was predominant, tall structures were, in general, damaged more than small buildings.

(c) Damage at Niigata was also selective, but in a different way: it could be related to soil profile structure at depths of less than 15 metres. For buildings on pile foundations the damage depended on the depth of these in relation to the soil profile characteristics (particularly density) at the site. The region included marine sediments, sand, and river and lake deposits.
Vibrational damage to reinforced concrete and wooden buildings depended on the type of ground, and these structures were oppositely affected in some cases.

(d) Damage at both Anchorage and Skopje illustrated the inconsistencies associated with the estimation of Modified Mercalli intensities. In the opinion of one authority, however, the isoseismal pattern of the Skopje earthquake allowed an inference that the focal depth of the earthquake was much shallower than could be fixed by the instrumental records available.

(e) In general there was little evidence to indicate marked superiority of one construction material over another. Where this appeared to be so, the anomaly could frequently be traced to other causes such as construction or design malpractice.

(f) "The effects of soils under earthquake loading need much more study, particularly with respect to their relation to structures" (K. V. Steinbrugge - Anchorage earthquake structural report). Soil failure and 'liquefaction' were features of both the Anchorage and Niigata earthquakes.

If we are to learn from these experiences it is obvious that an urgent need exists in the Territory of Papua and New Guinea for instrumental strong-motion data in areas where damage is probable so that foundation conditions can be classified. One important example might be Lae, which is expanding very rapidly and yet which is sited in an area where unconsolidated sediments are characteristic. Ground response studies should help to identify areas which may respond to earthquake motion in such a way that no structural solution is possible, and which should therefore be avoided.

3. NEW ZEALAND DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

General structure (D.S.I.R. 1964a)

After the conference, special brief visits were made to two laboratories of the Geophysics Division of the D.S.I.R. The general structure of the D.S.I.R. is illustrated below with more details of the sections of most interest to the author.

Ross Dependency Research Committee — MINISTER OF SCIENCE — National Research Advisory Council

Director General
D.S.I.R.
Dr. N. M. Hamilton

- Assistant Director General L. W. Tiller
  - Biological
  - Zoological
  - Botanical
  - Agricultural
- Assistant Director General I. D. Dick
  - Mathematics
  - Industrial Development
  - Chemistry
  - *Physics & Engineering
  - Wheat Research
  - Various great aided research associations
- Assistant Director General Dr. E.I. Robertson
  - Antarctic Division
  - Geological Survey
  - ** Geophysics Division
  - Nuclear Sciences
  - Information
  - Oceanography
  - Scientific Liaison
- Assistant Director General V. A. Le Page
  - Finance
  - Accounts
  - Stores
  - Staff
  - Building Services
  - General Administration

*PHYSICS AND ENGINEERING LABORATORY

W. H. Ward

- Electrical — A.H. Allen
- General Physics — M.C. Probine
- Mechanical Engineering — S. Lattimore
  - Automation
  - Design
  - Industrial Liaison
  - Metrology
  - Optics
  - Engineering Seismology — R.I. Skinner
  - Workshops
- Upper Atmosphere Physics — G. McK. Allcock
- Field Station (Omaku, Central Otago) — R.S. Unwin

Engineering seismology

This work is undertaken by a subsection of the Mechanical Engineering Branch of the Physics and Engineering Laboratory of the D.S.I.R. The laboratory is located at Lower Hutt, about 10 miles from the centre of Wellington.

The subsection is concerned with :

(a) Research into methods of determining earthquake forces in buildings and the development of appropriate aseismic design techniques.

(b) The design and construction of prototype strong-motion equipment.

(c) Collection of ground response data throughout New Zealand by means of a strong-motion recording network.

(d) Analysis of ground response acceleration data, using both analogue and digital methods.

Perhaps the most significant recent work has been the design and construction of a new accelerometer, mentioned earlier. The sensing elements of the device are inverted pendulums with a natural frequency of 35 c/s; it produces records of three mutually perpendicular components. Five units were built in the laboratory and 25 additional units for installation throughout New Zealand are being built by a private instrument firm. One unit is being supplied to U.S.C.G.S. for testing and comparison with American equipment. The subsection has also designed and built a 20-c/s peak reading accelerometer, which produces a scratch plate record of very small size. This is normally interpreted under a microscope. This kind of record can be easily mutilated because it is so small, and because of this, R. I. Skinner considers that specialist personnel are unsatisfactory for servicing these instruments in the field. Impulse calibration testing benches and shaking tables are also part of the equipment of the laboratory.

The subsection plans to service accelerometers in the field after earthquakes and also at six-monthly intervals. They are being installed under locked covers.

R. I. Skinner believes that both the peak reading accelerometer and the more conventional Wilmot seismoscope designed by U.S.C.G.S. usefully supplement acceleration data. He believes these data are necessary from each seismic region to check the characteristics of the response spectrum before aseismic design can be commenced with confidence.

The laboratory has found that single storey buildings with a concrete base provide satisfactory accelerometer sites. On the other hand, because the primary function of the peak reading accelerometers and seismoscopes is to indicate differences in response of adjacent strata, special field sites often require preparation. Ideally, these should consist of a sunken concrete base just large enough for the instrument (about 12 inches high and 6 inches in diameter) and an external cylindrical or box-shaped weathertight cover to enclose, but not touch, the detecting installation.

Analysis of accelerograms has so far been handled by analogue machines designed and built by the subsection. Simple digital programmes have been written for early I.B.M. machines and, at present, Algol programmes are being compiled for a large Elliot computer currently being installed by the D.S.I.R.

Two analogue computers were seen. Briefly, the first of these is designed to compute the response spectrum diagram. The input is in the form of a transparent strip of photographic film, which carries an image of the accelerogram, wound around a drum. The speed of the drum simulates the frequency parameter. Light reflected in through the end of the drum provides the means of generating a photoelectric voltage proportional to ground acceleration. This is then applied to L-R-C resonator circuits (whose parameters may be varied) in the conventional manner to provide the required output. The peak voltage across the resonators is an earthquake response factor.

The response curves computed in the subsection display 'earthquake response factor' (Rm) against period, rather than velocity, displacement, or acceleration. Rm is defined as the ratio of the maximum displacement generated in a given simple resonator to the static displacement generated in that resonator by an acceleration equal to that of gravity.

The second analogue computer consisted of a bank of ten resonators providing an analogue of a ten-storey 'standard' building on which present actual aseismic design of tall buildings is based. This analogue was used in a first step to determine the basic shapes and approximate periods of the first three normal modes of vibration. These data provided the starting point for more refined digital analyses. The results, together with response diagrams, form the basis for aseismic design in New Zealand at the present time, and are conveniently displayed in the form of sets of 'standard diagrams' (Skinner, 1964). Until response spectra of future large New Zealand earthquakes become available, the standard response spectra used by Skinner have been computed as a weighted mean curve using eight of the largest accelerograms recorded in the USA.

Concomitantly with this research, the subsection has investigated actual building behaviour by instrumenting certain buildings in Wellington. This has already demonstrated the effect of coupling that can occur when frequencies of two modes of oscillation are very close together. These may be either frequencies of oscillation of the primary structure or, for example, one frequency each of the structure and any large appendage such as a radio tower.

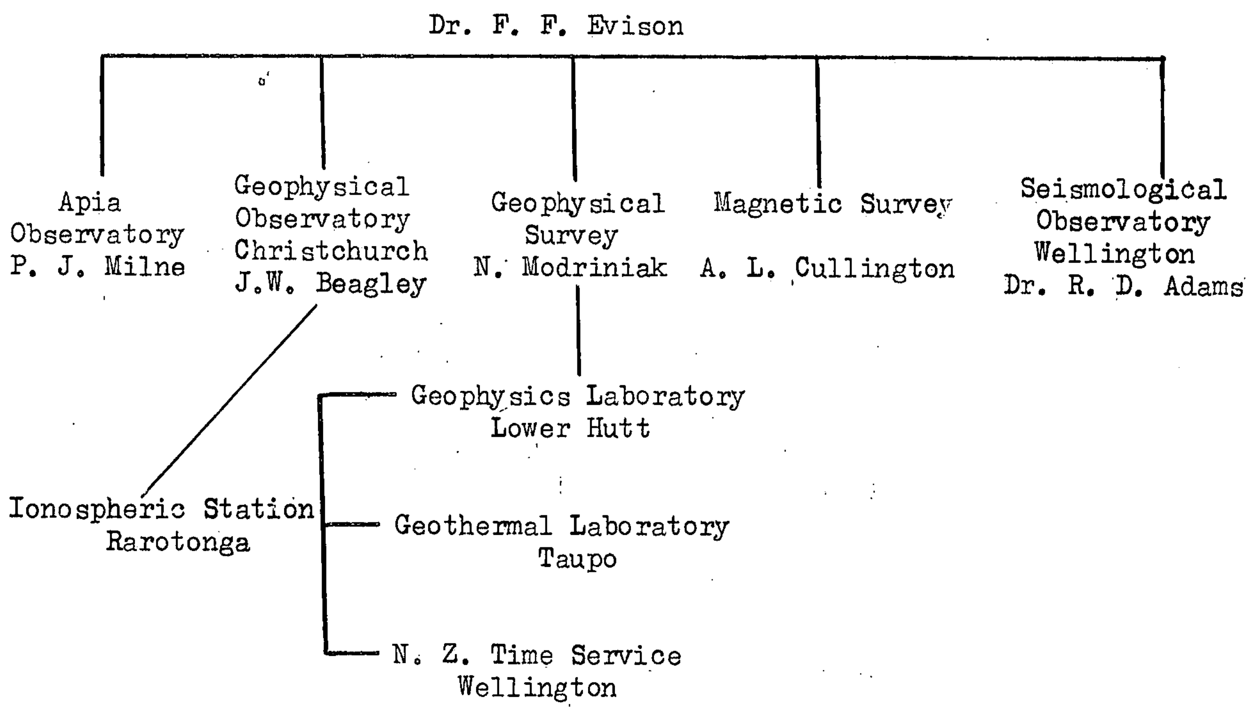
The D.S.I.R. physics and engineering laboratory would be willing to be consulted on any New Guinea strong-motion programme at any stage from project design to analysis. Although they would be very keen to analyse accelerograms of large earthquakes, their analysis facilities may be inadequate to cope with a large number of accelerograms from numerous small earthquakes which would be of less direct interest to them.

As far as construction of instruments is concerned, New Zealand Government policy is designed to encourage and support the local manufacturing industry, and for this reason it is unlikely that recording or peak reading accelerometer specifications could be released to enable construction outside of New Zealand.

<u>Seismological Observatory, Wellington</u> (D.S.I.R. 1964b)

The observatory is a major branch of the Geophysics Division.

**GEOPHYSICS DIVISION



It is responsible for the routine operation of all seismological stations in New Zealand and undertakes both fundamental and applied seismological research. The observatory has a professional staff of seven seismologists, and a sub-professional staff of seven technical and computational staff. Administrative work is minimal, being mostly carried out in the central office of the D.S.I.R. The professional staff and their respective fields of interest are :

Dr. R. D. Adams	Director	Deep earthquakes Earthquake mechanism Dispersion Core structure
Mr. G. A. Eiby	Seismologist	Seismicity Edits all routine data publications
Dr. R. M. Hamilton	Seismologist	Due to arrive from the USA before mid-1965 to take up a three-year appointment
Mr. M. G. Muir	Seismologist	Responsible for network operation Routine analysis (half-time)
Mr. A. A. Thomson	Seismologist	Crustal Structure (phase velocity project) Routine analysis (haf-time)
Mr. M. J. Randall	Mathematician	Theoretical aspects of earthquake mechanism At present completing Ph.D. at U.C.L.A.

Mr. R. M. Young	Mathematician	Earthquake mechanism At present on leave undertaking further study in Paris.

Technical Staff are :

Mr. M. A. Lowry	Technical Officer	Epicentre computation - his duties are mostly concerned with seismogram analysis
Mr. R. H. Orr	Technical Officer	Instruments
Mr. R. C. Martindale Mr. R. D. Maunder	Technicians	Network maintenance and installation
Miss. A. M. Crowther Miss C. M. Fisher Miss J. A. MacDonald	Technicians	Seismological record and data handling.

There are seventeen seismological stations in the North and South Islands of New Zealand at the present time. The most fully equipped of these is at Wellington (a World-wide Standard Station). The most commonly used seismometers throughout the network, except for Wellington, are Wood Anderson and Willmore instruments.

Routine

The basic routine programme is one of focal and magnitude determination for as many earthquakes as possible, as well as phase identifications. Uniform coverage is achieved for events of magnitude 4 and over, as well as all other earthquakes reported felt.

Data are supplied to the U.S.C.G.S. (Washington) and I.S.R.C. (Edinburgh) centres. All final analysis data from each station are card punched, including information required for I.S.R.C. which is then automatically selected and extracted from the New Zealand system cards and re-punched for that particular purpose. Local epicentre determinations are being continued to allow a lengthy overlap with similar data computed by I.S.R.C. The results of a comparison between the two sets of data will determine whether or not the local epicentre determination programme will continue.

Research

The Geophysics Division and especially the Seismological Observatory is very active in both fundamental and applied seismological research.

Much of this appears to have been stimulated and encouraged by Drs. Robertson and Evison, the latter being a very prominent seismologist of world repute. The most significant fundamental research is in the field of earthquake source mechanism. A representative shcool of thought in New Zealand (led chiefly by Dr. Evison) seriously questions the evidence quoted in support of the widely accepted belief that fault movements cause earthquakes. The alternative possibility that fault movement may be simply a gross form of earthquake damage has been canvassed. These views were summarised by Evison (1963) and have initiated investigations into the plausibility of polymorphic phase transitions accompanied by sudden volume changes as an alternative hypothesis (Randall, 1964 a & b).

Applied seismological research interests are very wide and are represented by many publications. The range includes structure of the inner and outer cores, crustal structure, velocity variations, and seismicity.

A crustal structure research project currently in the planning stage is similar to, but more comprehensive than, our own Papua-New Guinea phase velocity project. The New Zealand projects will also measure phase velocities across a tripartite network. Three-component long-period World-wide Standard installations will be used to allow analysis of both Love and Rayleigh waves. Equipment will be housed on specially cast piers within portable pre-fabricated plywood insulated huts (D.S.I.R. 1964b). The project is expected to be operational by June 1965.

4. CONCLUSIONS AND RECOMMENDATIONS

General awareness of people and authorities in the Territory of Papua and New Guinea to the earthquake problem is increasing. Acute awareness (as in New Zealand, a country of much lower seismicity) will be engendered only by the occurrence of a large damaging earthquake. The economic environment within which the country is developing poses many special problems for the Administration and the intrusion of the earthquake problem into this field, though unwelcome, is still a fact. No country, especially the Territory of Papua and New Guinea, can afford to repeat the obvious and costly planning and construction errors frequently exposed in recent large earthquakes. Given our existing knowledge of the distribution of large earthquakes in the past and the present state and rate of development of the art of aseismic design and site evaluation at such an early stage in the economic development of Papua-New Guinea, the proper application of our knowledge should avoid considerable economic wastage (perhaps millions of dollars) over the next few decades.

At the present time there is no branch or office of the Administration suited to the task of co-ordinating inspection, evaluating effects, and providing a general liaison and advisory service on matters relating to earthquake damage. Because expenditure on construction is becoming very considerable, it will become increasingly advantageous, as the country develops, for a proper account to be taken of advances in aseismic design techniques and the relation of building codes to damage that will be incurred in the course of time. It is not premature to suggest to the Administration the formation of a standing committee on Earthquake Engineering, which might serve the following purposes (inter alia) :

(1) To review periodically the aseismic building code (when one is finally enforced), which should reflect the latest trends and techniques.

(2) To organize properly constituted inspection teams to survey and evaluate the causes of structural damage and failure, especially in the light of the building code.

(3) To collaborate with town-planning authorities to ensure as far as possible that towns and cities do not spread into areas unsuited, for geological reasons, for construction.

(4) To recommend and advise on the desirability of special research or investigation to meet specific or general earthquake engineering problems.

(5) To represent the Territory of Papua and New Guinea at the International Association of Earthquake Engineering.

(6) Public liaison.

The belief that a strong-motion recording programme should be undertaken in the Territory of Papua and New Guinea was firmly reinforced at the Conference (see Appendix 2). Sooner or later, answers to fundamental questions bearing on soil and foundation response will be required and these are not the sort of questions that can be answered quickly or easily. World-wide experience already indicates that the length of time needed to record adequate data of this kind may be considerable, and thus, irrespective of the immediate demand in the Territory for this kind of information, there are good reasons for commencing a recording programme now.

The information presented at the Conference on the utility of small-earthquake spectra to characterise major events, while still far from conclusive, lends encouraging support to the idea that useful data should accrue from a study of the response spectra of the numerous small earthquakes in the Territory (viz. magnitudes between 4 and 6).

A strong-motion programme should be broad enough so that the characteristics of earthquakes in all regions would be evaluated. Secondly, a close network of peak-readings accelerographs and seismoscopes, or both, within the proposed areas of most important development, especially major towns, would provide information to guide town planning authorities and building boards.

A strong-motion programme can be divided into :

(a) Recording,
(b) Reduction of data,
(c) Application of results to design techniques.

Only (a) and (b) at the most could concern the BMR and even this has been questioned. One might ask what other Australian organization is better suited to undertake it. There seem to be only three possibilities :

(1) <u>The C.S.I.R.O.</u> Such a programme would relate to problems to industry and development and might, therefore, properly come within the ambit of C.S.I.R.O. On the other hand, as far as is known, it would constitute C.S.I.R.O.'s first excursion into the field of seismology. It seems reasonable to suppose, however, that C.S.I.R.O. would be a suitable organization to undertake (a), (b), and (c).

(2) The Snowy Mountains Authority. Although this organization undertakes or has undertaken routine seismological monitoring of earthquakes, this has not extended to a strong-motion programme as the earthquakes in eastern Australia are mostly too small to pose a significant construction hazard. Consequently, it seems unlikely that the Authority is well suited (by experience or facilities) to advise on the details of a New Guinea programme or undertake the work.

(3) Universities. A New Guinea strong-motion programme would appear to be beyond the interests or financial resources of any Department of Geology, Geophysics, or Engineering in Australia. Because the damand for this kind of training has not been made in Australia, the subject of structural dynamics has never been included in the curricula of Australian engineering schools. Australian engineers are therefore unlikely to be interested in this work. Because curricula are not so oriented, our university engineering departments are unlikely to include earthquake engineering research in post-graduate schools. It might be remarked though, that the dynamics of structures could form an important part of the curricula of future engineering schools in the Territory of Papua and New Guinea universities.

Sections (a) and (b) of a strong-motion programme would seem to be adequately covered by the fourth requirement of the BMR in the discharge of its functions (Department of National Development, 1962, p.17); (c) is not. At present all responsibility for "making basic investigations of seismology" in the Territory is being undertaken on behalf of the Australian Government by the BMR. A strong-motion earthquake recording programme certainly falls into this category. It would be unwise to suppose that, sooner or later, an important town or area in the Territory will not be seriously damaged and lives lost through earthquake activity. The later this does occur and the greater the damage, the more serious may be the implications of not having implemented a strong-motion accelerograph programme beforehand. The responsibility for making this requirement known rests with the BMR at the present time.

It is recommended, therefore :

(1) That the BMR formally advise the Administration of the Territory of Papua and New Guinea that, in its view, early action to implement a strong-motion earthquake recording programme is warranted. Such advice to be accompanied by a report prepared solely from a seismological standpoint, outlining the reasons for and advantages of undertaking the work in order that the data can be used later. Such a report should mention the need for post-earthquake inspection.

(2) That the BMR recommend that the Physics and Engineering Laboratory of D.S.I.R. be approached as consultants to advise (the BMR, the Administration of Papua and New Guinea, or the Australian Government) on the desirability of undertaking a strong-motion programme, and the best means of implementing any recommendations made.

(3) In view of the unusual nature of the problem in so far as Australia is concerned, and in view of United Nations activity in the field, an alternative or supplementary course of action is also worth considering, viz. that UNESCO be asked to investigate the desirability of undertaking a strong-motion programme in New Guinea, with special emphasis on the extent of any proposed investigation, the means of implementation, and the extent of United Nations financial assistance available, if and when called upon.

(4) That the BMR suggest to the Administration that it consider the formation of an Earthquake Engineering Committee as outlined above, in view of the special nature of the problems which overlap into so many fields. Such a suggestion would seem to be quite appropriate from the BMR in view of our responsibilities.

(5) That the Australian National Committee of Geodesy and Geophysics Sub-committee on Seismology be asked to consider an approach to the International Association for Earthquake Engineering, with a view to obtaining membership for either Australia or Papua-New Guinea, or both. It will be important to maintain formal contact with this field of investigation in future and this can best be ensured at Association level.

(6) That the task of drafting an observational earthquake intensity scale suited to the Territory of Papua and New Guinea be undertaken, and an adequate uniform system of reporting felt effects of future large earthquakes be established and maintained by an official organization within the BMR, so long as its responsibilities in the field of seismology extend to the Territory.

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APPENDIX 1

Conference programme

Session I – Soil and foundation conditions relative to earthquake problems

Reporter :	J. K. Minami (Japan)
Chairman :	K. Kanai (Japan)
J. K. Minami	Session report
Z. Bazant	Stability of saturated sand during earthquake
J. F. Fleming R. L. Kondner F. Screwvala	Foundation superstructure Interaction under earthquake motion
M. Hatanaka	An experimental study on the earthquake resistant property of breakwaters of the cylindrical shell type

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I. Herrera E. Rosenblueth	Response spectra on stratified soil
I. Herrera E. Rosenblueth O. A. Rascon	Earthquake spectrum prediction for the Valley of Mexico
R. L. Kondner	Characteristic periods of cohesive soil-foundation systems.
J. Krishna S. Prakash	Earth dams subjected to earthquakes
R. J. Krizek R. L. Kondner	Dynamic response of cohesive soils for earthquake consideration

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G. J. Lensen R. H. Clark R. R. Dibble H. E. Fyfe R. P. Suggate	Tectonic and earthquake risk zoning in New Zealand
H. Matuo S. Ohara	Dynamic pore water pressure acting on quay walls during earthquakes
N. Nasu	Ground investigations in city areas in Japan
R. Scott	Soil mechanics and foundation engineering aspects of the Alaskan earthquake of March 27th, 1964.

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T. Tajime S. Terada T. Mochizuki	Vibrational property and earthquake response of tall building supported with caisson or pile
J. Takeda H. Tachikawa	Mechanical properties of sand subjected to dynamic load by shallow footings
P. W. Taylor J. M. O. Hughes	Dynamic properties of foundation sub-soils as determined from laboratory tests
J. K. Minami	Summary report

<u>Session II</u> - <u>Analysis of structural response and instruments</u>

Reporter :	G. W. Housner (USA)
Chairman :	N. M. Newmark (USA)
Co-Chairman :	J. Krishna (India)
G. W. Housner	Session report
S. Balan M. Ifrim C. Pacoste	Direct determination of equivalence co-efficients of masses in the anti-seismic computation of structures
S. Cherry A. G. Brady	Determination of structural dynamic properties by statistical analysis of random vibrations
R. W. Clough K. L. Benuske E. L. Wilson	Inelastic earthquake response of tall buildings

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I. Funahashi K. Kinoshita	The vibrational analysis of the tower building (the vibration test and earthquake response of San-Ai Building)
H. G. Gôto K. Toki	Vibrational characteristics and aseismic design of submerged bridge piers
T. Hatano	Vibration of visco-elastic body
S. Hayashi N. Miyajima I. Yamashita	Horizontal resistance of steel piles under static and dynamic loads
T. Hisada K. Nagakawa M. Izumi	Earthquake response of idealised twenty-storey buildings having various elasto-plastic properties

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D. E. Hudson	Equivalent viscous friction for hysteretic systems with earthquake-like excitations
J. Ibanez	Displacement spectrum in the dynamic response of inelastic structures, for design purposes
P. C. Jennings	Response of yielding structures to statistically generated ground motion
K. Kanai	Some new problems of seismic vibrations of a structure

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C. Katsuta N. Mashizu	Earthquake isolation method of structure by a high-speed electrohydraulic servo-mechanism
H. Kawasumi E. Shima	Some applications of a correlator to engineering problems
H. Kobayashi	The deflection of a tall building due to earthquake
T. Kobori	Earthquake response of structural system under the effect of ground compliance

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S. Kotsubo	Seismic force effect on submerged bridge piers with elliptic cross-sections
K. Kubo	Response of a system of two-degree freedom
S. Kurata H. Arai T. Yokoi	On the earthquake resistance of anchored sheet-pile bulkheads
J. Penzien A. K. Chopra	Earthquake response of appendages on a multi-storey building
T. Naka T. Kato M. Yuasa	Dynamical analysis of steel structure by electronic analogy

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T. Odaka F. Horie	A study on the optimum value of a seismic coefficient
Y. Ohchi	Response analysis of framed structures
S. Okamoto M. Hakuno K. Kato F. Kawakami	On the dynamical behaviour of an earth dam during earthquake
Y. Osawa	Seismic analysis of core-wall buildings
J. M. J. Pereira	Behaviour of an elasto-plastic oscillator acted by random vibration

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H. Rosenfeld	Consideration of the rotation of the foundation in the analysis of a steel chimney 130m high, subject to seismic movement
M. F. Rubinstein	An engineering approach to computing the natural modes and frequencies of a tall building
W. E. Saul J. F. Fleming Seng-Lip Lee	Dynamic analysis of bilinear inelastic multiple-storey shear buildings
R. J. O'Driscoll R. Shepherd J. H. Wood	The determination of the normal mode properties of multi-storey rigid framed structures using an electrical analogy

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H. Shibata H. Sato T. Shigeta	Aseismic design of machine structures
R. I. Skinner D. W. C. Skilton D. A. Laws	Unbalanced buildings, and buildings with light towers, under earthquake forces
T. Shiga	Torsional vibration of multi-storied buildings
R. Szilard	Dynamic response of multi-level guyed towers to earthquake considering the non-linearity of the elastic supports

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H. Tajimi M. Ohmura T. Uchida K. Akino	Observed vibrations of a nuclear reactor building during some weak earthquakes
S. S. Tezcan	Earthquake analysis of space structures by digital computers
E. del Valle J. Prince	Analytical and experimental studies of vibration in two buildings
A. S. Veletsos N. M. Newmark C. V. Chelapati	Deformation spectra for elastic and elastoplastic systems subjected to ground shock and earthquake motions
G. R. Walker	Earthquake resistant design - The pulse method

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S. Watanabe Y. Kida M. Higuchi	The vibrational analysis of a steel structure (the vibrational test of Ohbayashi-Gumi building)
R. K. Wen J. G. Janssen	Dynamic analysis of elasto-inelastic frames
S. Yamamoto N. Suzuki	Experimental and Theoretical analysis of response against earthquakes of tower structures having non-uniform sections governed by rending vibrations
T. Yoshida K. Baba	Dynamic response of dams
G. W. Housner	Summary report

Session III - Seismicity and earthquake ground motion

Reporter :	D. E. Hudson (USA)
Chairman :	W. K. Cloud (USA)
Co-Chairman :	N. A. Mowbray (N.Z.)
D. E. Hudson	Session report
J. A. Brooks	Seismicity of the Territory of Papua and New Guinea
V. I. Bune	Seismic investigations in the Vaksh area of Tadzhik Republic relating to large dam construction projects
I. D. Dick	Extreme value theory and earthquakes

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P. C. J. Duflou R. I. Skinner	New strong-motion accelerographs
G. A. Eiby	The assessment of earthquake felt intensities
H. T. Halverson	The strong-motion accelerograph
G. W. Housner	Intensity of earthquake ground shaking near the causative fault
Hsu, Ming-Tung	Seismicity of Taiwan

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V. A. Jenschke R. W. Clough J. Penzien	Characteristics of strong ground motions
J. Krishna A. R. Chandrasekaran	Structural response recorders
D. A. Lacer	A simulation of earthquake amplification spectra for Southern California Sites
S. V. Medvedev	New seismic regionalisation of U.S.S.R. Territory
J. P. Rothe	Maps of seismicity for France

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W. G. Milne A. G. Davenport	Statistical parameters applied to seismic regionalisation
A. Ravara	Spectral analysis of seismic actions
I. A. Yershov G. A. Lyamzina V. V. Shteinberg	Methods of estimating the effect of superficial deposits on the intensity of seismic oscillations
F. F. Evison	Summary report

Session IV – Earthquake resistant design, construction and regulations

Reporter :	E. Rosenblueth (Mexico)
Chairman :	K. S. Zavriev (U.S.S.R.)
Co-Chairman :	J. F. Borges (Portugal)
E. Rosenblueth	Session report
J. R. Bennett	Earthquake insurance in New Zealand
J. Blake-Kelly	The effects of seismic engineering on architecture in New Zealand
J. A. Blume	Earthquake ground motion and engineering procedures for important installations near active faults

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J. F. Borges	Seismic design criteria for reinforced concrete buildings
J. Bouwkamp	Investigations for the earthquake resistant design of large-size welded and bolted girder to column connections
R. J. Burns	An approximate method of analysing coupled shear walls subject to triangular loading
J. I. Bustamante	Seismic shears and overturning moments in buildings
A. R. Chandrasekaran J. Krishna	Water towers in seismic zones

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C. C. Crawford	Earthquake design loadings for thin arch dams
J. Despeyroux	New French aseismic code
J. Despeyroux	The use of prestressed concrete in earthquake resistant design
S. U. Duzinkevich	On the problem of unification of basic requirements for the design of earthquake resistant structures
R. Flores	Design principles of earthquake resistant blast furnaces
I. L. Holmes	Concrete masonry buildings in New Zealand
Y. Ishii K. Fujita	Field test on the lateral resistance of large diameter steel pipe piles and its application to the aseismic design of pile bent-type pier
J. A. R. Johnston O. A. Clogau C. F. Candy G. F. McKenzie	Multi-storied state building design in New Zealand

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L. F. Kenna	Brickwork and earthquakes in New Zealand
I. Konishi Y. Yamada	Earthquakes response and earthquake resistant design of long span suspension bridges
J. Krishna B. Chandra	Strengthening of brick buildings against earthquake forces
K. Matsuchita M. Izumi	Some analyses on mechanism to decrease seismic force applied to buildings
S. V. Medvedev A. P. Sinitsym	Seismic effects on earth fill dams

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J. F. Meehan	State of California Office of Architecture and Construction Earthquake Research
P. O. Miller	Design of a 240-foot height reinforced concrete building in Wellington
A. A. Moinfar	Earthquake engineering trends in Iran
S. G. Napetvaridze	Research on earthquake resistance of dams in U.S.S.R.
V. J. Patel K. L. Arora	Existence of the critical surface in earth dams during earthquake

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S. V. Polyakov V. I. Konovodchenko	Earthquake resistant structures of residential and public buildings in the U.S.S.R.
W. M. Sutherland	Prestressed concrete earthquake resistant structures, development, performance and current research
K. Takeyama T. Ota Y. Nagata K. Atsumi	Anti-seismic design of a high-rise building in Djakarta
R. Tanabashi K. Kaneta N. Shinkai Y. Takemura	Earthquake-resistant design of Kyoto tower building

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Y. Tsuboi M. Kawaguchi	Earthquake and wind-resistant design of a suspension roof structure
H. Umemura Y. Osawa A. Shibata	Study of shearing forces in structures caused medium earthquakes recorded in Japan
F. Yokoyama M. Tomizawa A. Shibata	Aseismic structural design of a bending type building
E. Rosenblueth	Summary report

Session V - Recent strong-motion earthquakes and resulting damage

Reporter :	K. V. Steinbrugge (USA)
Chairman :	T. Hisada (Japan)
Co-Chairman :	N. N. Ambraseys (U.K.)
K. V. Steinbrugge	Session report
N. N. Ambraseys	An earthquake engineering study of the Buyin-Zahra earthquake of September 1st 1962
R. W. Binder	The Acapulco, Mexico, earthquakes of May 11th and 19th 1962
R. Cavallo F. Penta	Lessons drawn from the most recent earthquakes in Italy

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E. M. Fournier d'Albe	Summary of UNESCO activities in the field of earthquake engineering
J. Kodera	Some tendencies in the failures of bridges and their foundations during earthquakes
J. K. Minami	Relocation and reconstruction of the town of Barce, Cyrenaica, Libya, damaged by the earthquake of 21st February 1963
S. Omote K. Nakagawa H. Kobayashi S. Kawabata E. Nakaoka	A report on the Buyin earthquake (Iran) of September 1st 1962
K. V. Steinbrugge	Summary report

Special reports

G. V. Berg and others	Skopje
K. V. Steinbrugge and others	Anchorage

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K. V. Steinbrugge and others	Anchorage (continued) Niigata

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J. E. Rinne	Presidential closing address

APPENDIX 2

Excerpts from Presidential adress

Excerpts are given from the closing address to the Conference by the President of the International Association of Earthquake Engineering, John E. Rinne. The title of his address was "The Earthquake Challenge to the Structural Engineer". There are several areas that challenge the scientist.

"First, and most obvious, there is an urgent need for world-wide uniform instrumentation of ground motions. Some steps toward this end have already been taken under the sponsorship of United Nations Educational, Scientific, and Cultural Organization (UNESCO). In all probability, action will also be taken by IAEE in this Third World Conference on Earthquake Engineering. Instruments of several types are now available. The principal problem is to decide upon the desired instrument characteristics and the selection of instruments. The instruments need not be identical, but they should record comparable data, just like a pressure gauge will measure pressure uniformly around the world in convertible units.

"Second, and this may be considered to be corollary to the first, there is an equally urgent need for adequate instrumental coverage of the actively seismic areas of the world. A broad coverage should be obtained for basic ground motion instrumentation, and a selected and more detailed coverage should be provided for certain kinds of structures. There are times when all of us get "penny wise and pound foolish" and it is most unfortunate that despite fairly reasonable coverage of seismic areas in parts of the United States, there was not a single instrumental record of ground motion in Alaska in the March 27, 1964, major earthquake. Such instrumental records as obtained of the many lesser aftershocks are not a good substitute for the irretrievable record of the damaging major tremor.

"Third, there is need for more timely geological and geophysical evaluations of sites for the development of cities. Some such reports have been made in the past, but these warnings of potential hazards of landslides or subsidence have usually been much too late and have been duly filed, unheeded and unnoticed by the public. We are much more aware of the need for joint scientific and engineering evaluations of sites following earth movements in the Chilean Earthquake of 1960, and, more recently, in the Alaska and Niigata, Japan, earthquakes of 1964....

"Fifth, is the need for much better co-ordinated on-site, post-earthquake surveys. Local officials, understandably disturbed by the confusion following an earthquake of major proportions, must become thoroughly confused by survey teams of scientists and engineers - each group of specialists in its particular field. The public, however, is not usually aware of the distinctions and it reflects to the good of no one when enginneering questions are directed to the scientists, or vice versa, and are inaccurately or inconsistently answered. All of the needs of the scientists in such surveys cannot be covered by a single man; nor can those of engineers interested in the earthquake phenomenon. Hence, it would seem appropriate to have separate teams of scientists and of engineers, to make surveys from the standpoint of their respective interests. There are overlapping interests, so co-ordination between the groups is still needed very much.

"Sixth, the interests of seismologists and structural engineers seemingly have gone the route of diverging paths. More and more of the seismological literature of recent years has been directed to subjects which may ultimately have direct bearing on the work of the structural engineer but which at present lose the engineer almost before it starts. Like the need for a bridge between the mathematical analyst and the structural engineer, there is also a service to be performed by someone to build an interpretative bridge between the seismologist and the structural engineer....There is considerable evidence that too much reliance is being placed on the words in the code, without giving enough thought to creating a structure that can assuredly resist loads considerably in excess of those code-specified, without failure. There is merit in understanding and acknowledging that forces in major earthquake can exceed those specified. The problem and the challenge to the structural engineer is to provide reserve energy absorption capacity beyond that corresponding to design static forces to preclude failure. <u>There is some disconcerting evidence that some designers feel that their main obligation is to satisfy the word of the code, not the intent of the code</u>, nor the understanding of the more discerning to the complex problem.

"Seventh, a further outcome of the increasing complexity of codes is that they are primarily directed to the unusual structure. There is need for guidelines of much simpler form to provide good engineering practices to the construction of small buildings and structures for which professional engineering services cannot be available....

"The structural engineer, with the scientist and the soil mechanics engineer, must apply his best judgment as to the type of structure best suited to an area which may have potential large earth movements - assuming that the structure has to be built in such a location. There may be no good, assured solution to such problem structures. Economics may indicate that acceptance of the risks may be the only practical alternative to not building at all. In other cases, with a sound exploration of the subsurface conditions, it may be that pile or caisson foundations can avoid possible failure. This is understood to have been the case in Niigata, Japan. However, the question of whether all structures there, for example, justified pile foundations is very debatable, even with the large property losses that ensued with the earthquake of June 16, 1964. This is a challenge to the structural engineer as well as to the owner financing the structure. Much of the damage in Alaska and in Niigata, Japan, was attributable to large land movements - so large that there was really no practical structural solution by which the damage could have been avoided. This kind of damage must be distinguished from earthquake damage without landslides or land subsidence. The latter is within the province of the art of structural engineering; the former is connected to the site evaluation study in which the structural engineer's part is to support the views of the scientists and the soil mechanics engineers in calling attention to the hazards that are involved, and what, if anything, can be done structurally to <u>avoid these hazards</u>...."

(underscoring by J.A.B.)