EARTHQUAKE INSURANCE

By E. TILLOTSON

GENERALLY speaking, earthquake insurance is still only undertaken in very few cases and usually with reluctance by underwriters. This is understandable in that exact statistical evidence only exists in the majority of cases over a period of 40 ± 10 years, which is insufficient to make it possible to judge when another shock is likely to take place in any particular locality. Moreover, in the present state of knowledge, earthquakes cannot be predicted exactly by any other means. It is, however, possible to indicate which areas are more likely to experience earthquake shocks than others, and it should therefore be possible to initiate some sort of insurance against these natural calamities.

Further difficulties are, first, to envisage how much damage is likely to be done by a shock, and secondly, to build up sufficient reserves of capital to cover the losses. Given sufficient interest on the part of property owners in this type of insurance, mutual assistance by companies and perhaps initially Government aid to companies undertaking earthquake insurance, the question of reserves of capital could be solved and the companies could then proceed to formulate premium rates. One may suppose that these will be governed in any particular case by several factors such as expectancy of occurrence of shocks, type of building, amount of coverage, and an additional sum for expenses, profit and reserves.

The expectancy of occurrence of shocks varies according to the locality and can at best only be evaluated roughly. As example, it appears that in Japan there may be a severe shock every three or four years, whilst in the United States it has been estimated that there is a strong shock approximately every twenty-five years with a tendency for it to occur in the west rather than in the east. In Great Britain, scarcely any damage is done by earthquakes at all.

Buildings vary greatly from the steel-framed reinforced concrete buildings of low altitude such as those designed by Dr. Tachu Naito, of Tokyo, which suffer very little in any earthquake, to concrete block buildings and the native huts of tropical countries, which are often completely razed. Between these extremes, buildings offer various degrees of resistance to earthquake shocks, and it would not be difficult in the light of knowledge gained in previous shocks to classify buildings according to the extent to which they would be likely to be damaged should an earthquake of known intensity occur.

The type of ground on which a building rests also has an important effect on its resistance to earthquakes. Structures on unconsolidated sand or swamp suffer much more severely than those of similar design built on solid ground or rock. Also buildings over old faults are particularly liable to damage, as the faults nearly always renew their movement during an earthquake. For these reasons the advice of a geologist would be very valuable to any company undertaking earthquake insurance risks.

It is usual in all cases of insurance to calculate annual premiums from the formula

$$P = Cp,$$

where P is the annual premium, C the amount of covering and p the probability of occurrence of the disaster. It has been shown by Marchant that this formula may lead to

$$P = \int_A^U y\,x\,dx + U \int_U^V y\,dx,$$

where y is the probability factor that the sum of money involved in the accident be just x, V the total value of the goods and buildings involved in a possible accident, A the value of the goods not insured, and U the upper limit of payments guaranteed by the assurer. The difficulty in the case of insurance against earthquake hazards is to determine the form of y. Working purely on a statistical basis, he proceeds as follows: At any particular time in the given locality, let the total value of the insured goods be G, and during T years determine from statistics

n_1 years during which the earthquake damage was less than $G/10$;

n_2 years during which the earthquake damage was between $G/10$ and $2G/10$;

n_3 years during which the earthquake damage was between $2G/10$ and $3G/10$.

. . . .

n_{10} years during which the earthquake damage was between $9G/10$ and G.

The probabilities that the occurrences may fall into the above categories may be estimated as

$$p_1 = n_1/T = \int_0^{G/10} y\,dx\,; \quad p_2 = n_2/T = \int_{G/10}^{2G/10} y\,dx$$

$$p_3 = n_3/T = \int_{2G/10}^{3G/10} y\,dx$$

. . . .

$$p_{10} = n_{10}/T = \int_{9G/10}^{G} y\,dx\,;$$

from which we obtain by approximation,

$$\begin{array}{ll} \text{for } x = G/20 & y = 10p_1/G \\ \text{for } x = 3G/20 & y = 10p_2/G \\ \text{for } x = 5G/20 & y = 10p_3/G \\ \cdots & \cdots \\ \text{for } x = 19G/20 & y = 10p_{10}/G \end{array}$$

From these figures it is possible to construct a graph showing the form and variation of y with x. From the graph the premiums to be paid may be calculated after the values of A and U have been fixed by agreement. Thereafter adjustments would have to be made in the light of the considerations mentioned previously, it being assumed that the conditions will remain the same during the year.

In Switzerland, one of the foremost countries in dealing with insurance against all calamities caused by the forces of Nature, earthquake insurance is only undertaken by the Canton of Zurich, since the Swiss Re-insurance Union has advised against taking such risks on the grounds that it is impossible completely to predetermine the effects of an earthquake shock.

The "Fonds suisse" is, however, available in cases where insurance is impossible, and this now amounts approximately to two million francs. In New Zealand some earthquake insurance is undertaken by private companies, but the liability of these companies for payments under the Workers' Compensation for Accidents Act has been limited by the Government to £50,000 in a single earthquake or a series of earthquakes lasting seven days. In Great Britain certain companies undertake such insurance on request, but information is unavailable except from the companies concerned, there being apparently no clearing house for such information. In the United States, earthquake insurance is underwritten mostly by the mutual fire insurance companies, which state that the premiums need not be high if due attention is paid to earthquake-proof design in the buildings concerned.

CRYSTALLO-CHEMICAL ANALYSIS

THE BARKER INDEX AT OXFORD

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EVERY chemist is familiar with the well-developed crystals bounded by plane faces which are formed by chemical substances. That the angles between these faces are characteristic of the substance and can be measured accurately by the reflecting goniometer is also common knowledge.

Clearly it would be of advantage to the chemist were he able to make practical use of these characteristic angles for purposes of identification, as an alternative to the ordinary method of analysis. Only a very small amount of material would be required, for a crystal of the size of one cubic millimetre, or even less, can be accurately measured. Moreover, when the measurement is completed, the crystal remains intact. If an index were made which included all measured substances, arranged in the numerical order of their measured angles, any substance could be identified by measuring a crystal of it and seeking in the index the angular values obtained.

Why has the chemist hitherto been unable to make use of this method of identification?

The difficulty arises from the multiplicity of angles which can be measured on any given crystal and from the lack of guidance in the choice of the angles which are to be used as the basis of the index. It is clear that what is wanted is a set of rules which will ensure that two independent workers who have measured crystals of the same substance will choose, as characteristic of that substance, the same set of angles, by which it can be classified.

The number of chemical substances that have been measured considerably exceeds eight thousand, and the measurements of some seven thousand of these have been collected in the five large volumes of Groth's "Chemische Krystallographie", where they are arranged according to *chemical composition.* During the past thirty years, crystallographers have attempted to put this valuable material into such a form that it might be rapidly and successfully used in the identification of chemical substances. First among those to make such an attempt was Fedorov, the great Russian crystallographer. He devised a method of classification based on his theory of crystal structure and, with the help of his pupils, he produced his great index, "Das Krystallreich", which was published in 1920. It contained a list of all the crystals then measured, and by means of this index any of the substances could be identified by the measurement of its angles. The method employed in this remarkable work was, however, complicated, and the calculations required were lengthy and laborious.

The late Dr. T. V. Barker, of Oxford, who was Fedorov's pupil and enthusiastic collaborator, had hoped to make this method of practical use, but he gradually came to the conclusion that it was impossible to do so. After many years he devised a simpler method based, not as Fedorov's was, upon theories of crystal structure, but purely on geometrical form. His book "Systematic Crystallography" (Thomas Murby, London, 1930) describes a set of simple rules based on what he termed the "principle of simplest indices" (*op. cit.*, p. 2), which he proposed to make the foundation for a practical index of crystals. In this index, under each crystal system, a certain angle, chosen by these rules for each substance as the main classification angle, was to be incorporated in order of increasing magnitude. The rules ensured that no ambiguity could arise in the choice of the classification angles. Owing to pressure of other work, Dr. Barker published this short treatise "Systematic Crystallography" instead of a much larger and more ambitious work, the uncompleted manuscript of which is in the University Museum at Oxford. He hoped to begin work on the index in May 1931, but in April of the same year he was taken ill and died.

The possibility of compiling the Barker Index after the untimely death of its originator, and without his direction, was immediately discussed at Oxford by a number of crystallographers who were interested, and they decided to try out the method independently. At the end of a year, they unanimously concluded that the method was simple and workable. It was decided to proceed with the preparation of the Index and, with the kind permission of Prof. H. L. Bowman, to make its headquarters in the Mineralogical Department of the University Museum at Oxford.

In the initial stages of the work, certain unforeseen difficulties arose the solution of which involved time and labour. The first of these was that, in order to cover certain cases, it was found necessary to make minor modifications and additions in the rules drafted by Dr. Barker. The second difficulty was that considerable delay has been, and will continue to be, caused by the misprints and errors of computation found in the original descriptions. These have in all cases to be cleared up before the classification angles can be found. In order to guard against similar errors in the Barker Index itself, every calculation is being made independently by two workers and checked by a third before the results are typed on a card and filed in a card index.