EARTHQUAKE: THE UNIVERSAL MENACE

BY C.W.O. TURNER (1)

BSTRACT

Earthquake force applies itself to the works of man universally ıd relentlessly.

It is not sufficient that the work may have been conceived and esigned to the letter of an advanced code of practice or by the atest and most sophisticated methods of computation: it must be eveloped as an engineering structure, - by which is meant that the re of the experienced engineer must look over the whole and ensure ıat his art is applied competently and well. Notwithstanding all ıis unless the work is faithfully constructed these efforts may be ıllified when the time of testing comes.

There is a responsibility for earthquake engineers to ensure hat their brothers in other fields of the profession are made aware f the dangers of earthquakes. Particular reference is made to he field of electrical engineering and instrumentation. Moreover he small building remains a major challenge. While most of our esearch activities are aimed at producing safer better and cheaper igh-rise buildings very little is devoted to the small building, ore particularly to improving the safety of the dwellings of iddle Eastern peoples.

The paper makes reference to composite materials and suggests hat these may show a way towards solution of some of the special roblems confronting the earthquake engineer.

NTRODUCTION

The thoughtful and masterly paper presented by our President, r John R. Rinne at 3WCEE discussed "The Earthquake Challenge to he Structural Engineer". Mr Rinne emphasised the great need for an interpretative bridge" to help the engineer to understand the ork of his associate scientists, the geologists, the geophysicicists nd the seismologists. It is encouraging to note that this o-ordination is being advanced by the activity of UNESCO and the

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.) Charles Turner & Son, Consulting Engineers, Izard Road, Wellington 4, New Zealand.

Consultative Committee set up by that body as between IAEE and IASPEI. This is a major step forward. In New Zealand such intimate liaison is encouraged by having a seismologist, a soil physicist and a geologist nominated as permanent members of the National Committee for Earthquake Engineering.

Well co-ordinated and instructive reports of evidence recorded by disastrous earthquakes are being made available by investigation missions set up with the help of UNESCO, IAEE and National Committees.

Progress is also being made with the installation of strong motion instruments so that the important records of heavy earthquakes may not be irretrievably lost but become available to further our knowledge. Much still remains to be done but UNESCO is active in this field also, and IAEE delegates are continually pressing for action in their own countries.

The need for micro zoning studies for city and town developments and for important individual structures is realised, but such studies are sometimes difficult of implementation, and this work is making slow progress.

Development of the electronic computer has facilitated research and analytical work with the earthquake simulator and has given a tremendously powerful tool to the designer.

All these advances and contributions to science tend to give the earthquake engineer more data to assist him with a clearer conception of his problem, and better tools to help him to resolve it.

Notwithstanding all these scientific aids, the basic necessity for a sound earthquake resistant structure is - that it be conceived and designed and supervised during construction by an experienced engineer applying his art with the help of the tools which science has given him. The mere application of high powered mathematical analysis by an academician is not enough.

THE ART OF THE ENGINEER

Damaging earthquakes continue to bring to light the effect of poor overall conception or planning; buildings relying upon rigid cores eccentric in plan and without proper provision for the inevitable torsional forces; buildings with light peripheral and corner columns; - poor examples of our art. Moreover it is evident on examination of almost any report of damage to structures from earthquake that for a large part, - if we accept the inevitable damage due to major landslide or subsidence, it is due to the absence of sound structural detail and to the lack of that essential "tieing together" of the parts of the structure. A report just to hand(1) following the study of the Caracas earthquake indicates that much of the damage to concrete structures there was due to the lack of shear reinforcement, particularly in columns. The old and reprehensible practice of treating lateral column reinforcement as "column ties", placed according to arbitrary rule, still persists. The writer urges the desirability of deleting this anachronistic conception from building codes for earthquake resistant structures. He urges the importance of attention to detail.

ELECTRICAL ENGINEERING

The works of the electrical engineer in power projects, switchyards, etc., form an important part of the machinery of civilisation. A failure can be disastrous or at best inconvenient to many thousands of people. Nevertheless the necessity for designing against earthquake shock is still not appreciated to the full in this field of engineering. It is true that for a good many years in countries subject to earthquakes provision has been made that electrical equipment must be designed against earthquake to a seismic static design loading of perhaps 1/4g., and that transformers have been equipped with cramps or anchors to prevent them overturning under earthquake shock.

However, the materials which the electrical engineer has to use often have unsuitable characteristics for earthquake resistance. He has to use porcelain insulators for instance, and porcelain is a material which is very brittle and of low energy absorption capacity. As with other such materials, such as brick or even

(1) Bulletin 191, Department of Scientific and Industrial Research, New Zealand, Engineering Study of Caracas Earthquake, R. I. Skinner.

dried mud, an assembly might be designed to check satisfactorily for a static 1/4g., but in fact would fail dismally in an earthquake because of the high dynamic response of the structure. The provision therefore is quite inadequate in many cases.

Even though for reasons of insulation properties the electrical engineer is forced to use such brittle materials for structural parts of important equipment, once the problem is realised there are ways of dealing with it, either by shock insulation, by introduction of damping media or by post-stressing the porcelain elements into compression with tendons of fibreglass or some such material; or by a combination of these.

Without taking a specific example it is not possible to take this much further but it is hoped that even these few words will indicate the major nature of the problems confronting the electrical engineer and the necessity of expert help from earthquake engineers in the field of electrical engineering. Recent work by H. C. Hitchcock (1) in New Zealand in this field is interesting and informative; moreover some of the major manufacturing companies of electrical equipment are known to be designing circuit breakers and perhaps some other equipment from a dynamic approach to the problem. It is a field however to which the attention of earthquake engineers is directed. Likewise the field of instrumentation where, for example, the effect of earthquake vibration on instruments controlled by mercury type switches can cause serious breakdown.

SMALL BUILDINGS

Damage to small buildings in severe earthquakes sometimes accounts for more loss of life than any other kind of damage. Nevertheless the individual unit is small and apparently so simple that it hardly merits attention of the "high powered" earthquake engineer. Nothing could be further from the truth - it may be a highly complex problem.

When materials are not limited it should not be too difficult

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(1) H. C. Hitchcock, Electrical Equipment and Earthquakes, New Zealand Institution of Engineers. February 1969.

with the help of steel, aluminium, wood and concrete to produce an economic solution; but where one is limited by local materials it may be very difficult to find a satisfactory one. Certainly, one may hope that through patient and persistent education of indigenes in basic principles (such as one hopes may be conveyed through IAEE and its proposed Manual) and by help and advice (such as given through JNESCO to Iran in 1962 by Despeyroux and Lescuyer) conditions may improve. Such improvement should be feasible by symmetrical planning, igloo-type structures or domed roofs, by limiting window and door positions, etc.,- but absence of long-life fibres for tying or stressing may be restrictive;- and lack of money for importation of naterial for roofing, or even for material which might strengthen or reinforce roof structures,may make resistance to severe earthquake lifficult to achieve. Increasing industrialisation, by making funds vailable for purchase and transport of ancillary building materials, ay tend to relieve this problem. One would hope also that the work eing conducted by Krishna at Roorkee for UNESCO on the recommendation ay assist and conduce towards a solution of this and like problems, he magnitude of which merit continued research.

EW MATERIALS.

New materials and techniques are continually being developed. any of these materials are composite materials. One of the earliest f course was reinforced concrete which has been with us for many years. t is a material in which concrete, strong in compression but weak in ension, is allied with ductile steel, and it is a successful combination ecause the coefficients of expansion of both materials are alike. This erefore is a composite material which functions structurally within imits as a homogeneous material. Prestressed concrete is essentially fferent. It relies upon the adequate stressing by ductile elements steel or other material, to maintain compression in the concrete der all conditions of service. This comparatively new composite material s many advantages, but it brings new problems in respect of proper tailing of the parts of structures so that they will function well in sistance to earthquake.

The writer has mentioned the possibility of using prestressed tendons of fibreglass or such like material for certain electrical engineering applications; perhaps also there may be a prospect of developing and using fibre-composite materials; perhaps fibre-reinforced ceramics to assist in the solution of such applications. The field is one the importance of which demands the best efforts of the earthquake engineer in finding the most suitable and the most economic solutions.

Perhaps a word should be said to note briefly the progress in development of fibre-composite materials , most of which are essentially short fibres embedded in a matrix. One of the most important indeed is fibreglass which is known to us all, but many others are being developed. It is possible to develop enormous strengths with short fibres or "whiskers". Respective tensile strengths of such materials range from 3.5×10^6 psi for silica fibres; 2.2 for alumina whiskers; 1.9 for iron whiskers as compared with 0.35 for piano wire; 0.2 for fibreglass, etc. (all $\times 10^6$ psi). (1)

Certain of these materials when suitably embedded in a matrix may become very high strength elements. Some of them are at present applied by winding of the filaments on mandrels into such products as rocket motor cases (and many other parts for rockets), submarine hulls, etc., - and in the commercial and industrial field for railway tank cars, high voltage switchgears, rifle barrels, structural tubing, underground water pipes, etc., to mention only a few. Some of these materials are not cheap and not economically available to the earthquake engineer. However, this position may change and it may be that from this area may come new materials that will assist in solution of problems in the field of electrical engineering or nuclear engineering, and indeed it may not be too far fetched to hope that lastic high strength cordage may offer the means of strengthening the roof structures of middle Eastern homes.

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(1) Fiber Composite Materials, American Society for Metals, 1965.

CONCLUSION.

It is the writer's object to urge engineers continually to seek further advance towards perfection of their art : that they should consistently regard advances in scientific knowledge, results of research, analyses of existing structures, better methods of computation, etc.- as tools to advance their expertise in their art, - and by no means as a substitute for its application.
He urges continual education of labour in good construction practices and vigilant oversight of construction without which his fine efforts may be nullified.

He draws attention to the need for earthquake engineers to look beyond the field of structural engineering in the narrow sense, to the engineering of structures in the wider sense,- in all fields of man's endeavour. Only two or three of these fields have been mentioned; there are others. Certain of them, particularly electrical engineering offer a challenge, and an opportunity for the earthquake engineer, to exercise his skill and practise his art.

At the same time perhaps one should echo the warning of G. W. Housner(1):- "There is danger in trying to apply our extensive knowledge of the behaviour of ordinary buildings to these special structures. Attempts to transfer such knowledge may be quite hazardous."

Our dossier of knowledge, and our "tool-kit" for buildings will be of great value for other types of structure, but the tools may require some adjustment for the new conditions,- and some new tools, some special research, may be required.

The writer believes, nevertheless that the experienced earthquake engineer is basically equipped to attack and to solve the special problems, some of which have been mentioned.

There is a responsibility upon earthquake engineers to look around them, and see that their brother engineers in other fields are made aware of that universal menace - earthquake.

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(1) 3WCEE II Summary Report: Analyses of Structural Response and Instruments.