Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.V)

8-2-1

THE EXPERT SYSTEM AS AN AID IN EARTHQUAKE BUILDING DESIGN

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SUMMARY

The knowledge gained in the field of earthquake engineering over the last ten years has progressed considerably and has formed the basis for large-scale codification. This knowledge has been structured to such point that, combined with recent developements in microcomputers and inference engine technology, it can be considered as the foundation of an **E**arthquake **E**ngineering **E**xpert **S**ystem (E^3S). This paper attemps to present a methodology that an expert seismic structural engineer would adopt to communicate an extensive accumulated knowledge base that fully meets user requirements; opportunities for improvement of the tentative methodology are identified and discussed.

INTRODUCTION

In view of the current development of earthquake engineering, an expert system is more than a simple necessity: the specialist has a duty to transfer his knowledge to practicing engineers in an accessible form.

This approach is all the more justified since it is impossible to be cognizant of a comprehensive body of knowledge; a current modern-day phenomenon. Today, it is difficult to keep abreast of the full range of specialties outside conventional fields that are developed by earthquake engineers. We are obliged to constantly question the pertinence of such knowledge and to ask what is actually achieved in real terms once that knowledge is put into practice.

KNOWLEDGE

" knowledge is of two kinds: we know a subject ourselves, or we know where we can find information upon it " (Samuel Johnson, 1700).

Like all sciences, earthquake engineering is bounded by rules; the question is how we can discover Knowledge. One possible answer is that there is no answer: either Knowledge exists or it does not exist... and one cannot discover something that does not exist.

This argument is a little too trite, since the **E^3S** presents knowledge in its current state of existence and updates that base as and when new data are discovered. **E^3S** takes shape that we give it and therefore has not pretensions to being exhaustive. The system is open-ended, encompassing not only knowledge but know-how. At this stage in the development of **E^3S**, it is vital to describe in detail the structure and inter-relationship of our knowledge.

At this stage, too, the necessity for dual system of grading appears- a system designed to gauge the knowledge of earthquake engineering experts and the receptivity of the users. This can be likened to a system of meters, which will enable us to begin at the beginning: both meters must be set to zero.

The expert must work towards a cognitive science, a science that is concerned with the source of knowledge. This is a healthy development since it involves the analysis and the reconstitution of our thought processes, thus enabling us to improve them.

Users may ask themselves whether or not they should be aware of the problems of earthquake engineering. This is an erroneous question. Taking as a hypothesis the idea that designers, whether they be architects or engineers, and contractors have a solid grounding in the field of civil engineering, the use of **E^3S** should present no specific problems. Therefore, when a concept is acquired through the use of the E^3S, it is not problematical if the users has no knowledge whatsoever of that concept. Users must nevertheless follow the natural order of events: becoming aware of what is being done, analyzing what is being done and reaching the appropriate solution. **When we manage to grasps the essence of another person's experience, it is sometimes possible to discover the same experience ourselves through other channels.** (Samuel Papert, 1986).

METHODOLOGY OF KNOWLEDGE BASE

Knowledge acquisition or identification and encoding of knowledge - the first step in the development of an **E^3S** - is one of the most difficult and complicated development tasks. Even when adequate methods of knowledge representation have been developed, difficulties will still arise when experts are obliged to express their knowledge in set form.

This paper will attempt to present a "knowledge methodology" for the design of ordinary buildings in line with a new French earthquake regulation. Buildings having special characteristics (hospitals, industrial plants, etc.), buildings involving high inherant risk (e.g. chemical or nuclear facilities) or special structures (retaining walls, tanks, bridges, etc.) are outside the scope of this document.

The preparation of the knowledge base is a three-phase process:

1st step the preparation of the information network,
2nd step the organization of the facts in a decision tree,
3rd step the creation of the rules for each branch of the decision tree

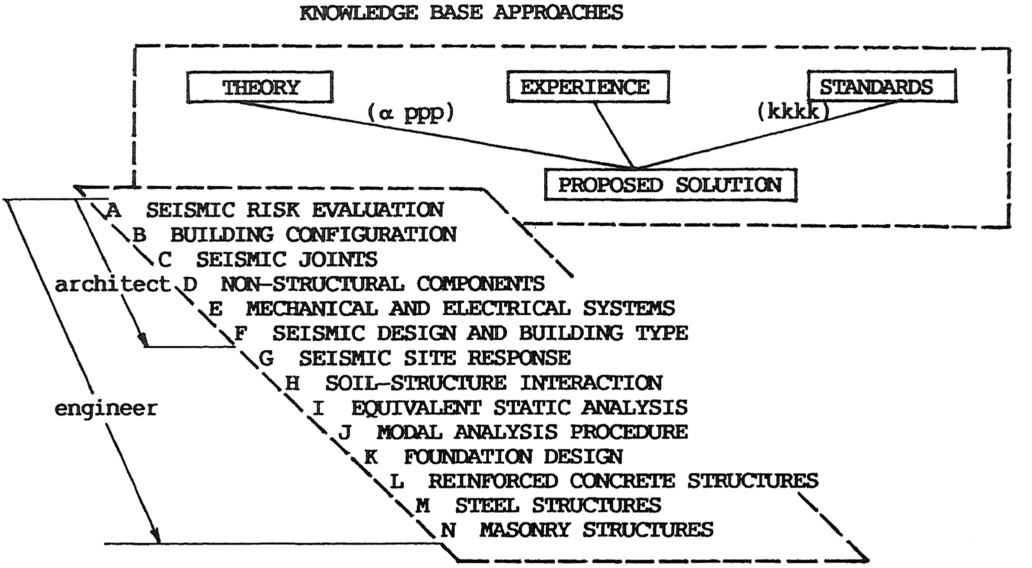
The proposed methodology divides the knowledge base information network (Fig.1) in three zones:

- theory of dynamics and seismic response → **theory**
- experimental information network: → **experience**
  * building performance during past earthquakes
  * seismic test on shaking table
  * case studies, etc.
- code requirements network: → **standards**
  * calculation of seismic forces
  * structural analysis
  * design requirements, etc.

These sources form the basis of the **E^3S.** → **proposed solution**

The inevitable distortions produced by the interaction of the **Theory,** the **Experience,** the **Standards** and the **Proposed Solution** sections epitomize the very notion of knowledge acquisition.

Fig. 1 Knowledge-Base Information Network



The primary function of the methodology is to provide an explicit datum of attributes occuring in the **semantic networks**. Each data item was assigned a unique label of eight or fewer characters, of the form **α ppp kkkk** where:

α is the chapter alphabetical character,

ppp is an arbitrary number to distinguish the different data items within the chapter,

kkkk is the earthquake regulation section number.

The development of the **E³S** requires the use of technical documents, research reports, specialized press articles...and what can be called "expert" knowledge. The experience acquired during tests with a shaking table or gained from previous earthquakes is another vital data source; all this data will be classified under the reference **ppp**. This section of the system is universally applicable. Earthquake regulations - the second section of the **E³S** - are classified under the reference **kkkk**. This section of the system is modular and can be adapted to the specific regulations of each country.

Two separate approaches have been adopted for the formalization of the methodology:

a) to provide overall coverage of the subject and to remain as general as possible, while bearing in mind the inevitable limitations that result from creation of a semantic network: this is theoretical and experiential aspect of the system;

b) to provide a more precise vision, based on earthquake regulations, which attempts to give those regulations a form that is sufficiently clear to be act as a foundation for a rule base: this is the regulatory aspect of the system.

These two approaches are inextricably linked and the exclusion of either one would lead to serious misunderstandings or inaccuracies.

The proposed method is original since it not only involves the approach of the expert to the cognitivist, but also develops a rule base that makes it possible to identify and categorize information from two sources: theory and experience on the one hand, and earthquake regulations on the other.

This modular concept means that the E³S can be designed using all types of country-specific regulations, e.g., UBC Sec 2312 (USA), Eurocode N° 8 (EC).

The arborescently-structured semantic networks allow for a value-added representation of the knowledge contained within the system. The graphs highlight the interconnections between significant components (i.e., semantics). In our study, the semantic network will be displayed as an assembly of memory registers (Figs. 2 & 3); each register is identified by an alphanumeric character and is inter-related to a number of other registers. This inter-relationship can be made explicit by defining the ingredients (α, ppp, kkkk) of each datum, i.e., the list of all data items that may be necessary to construct the methodology.

The proposed data chain result from systematic application of earthquake engineering technology. By following the semantic networks proposed in Figures 2 and 3, it is possible to understand the approach of the project team (evaluation of seismic risk, building configuration and the associated interfaces, examination of the problems linked to the foundation soil, the computations resulting from these parameters and construction details).

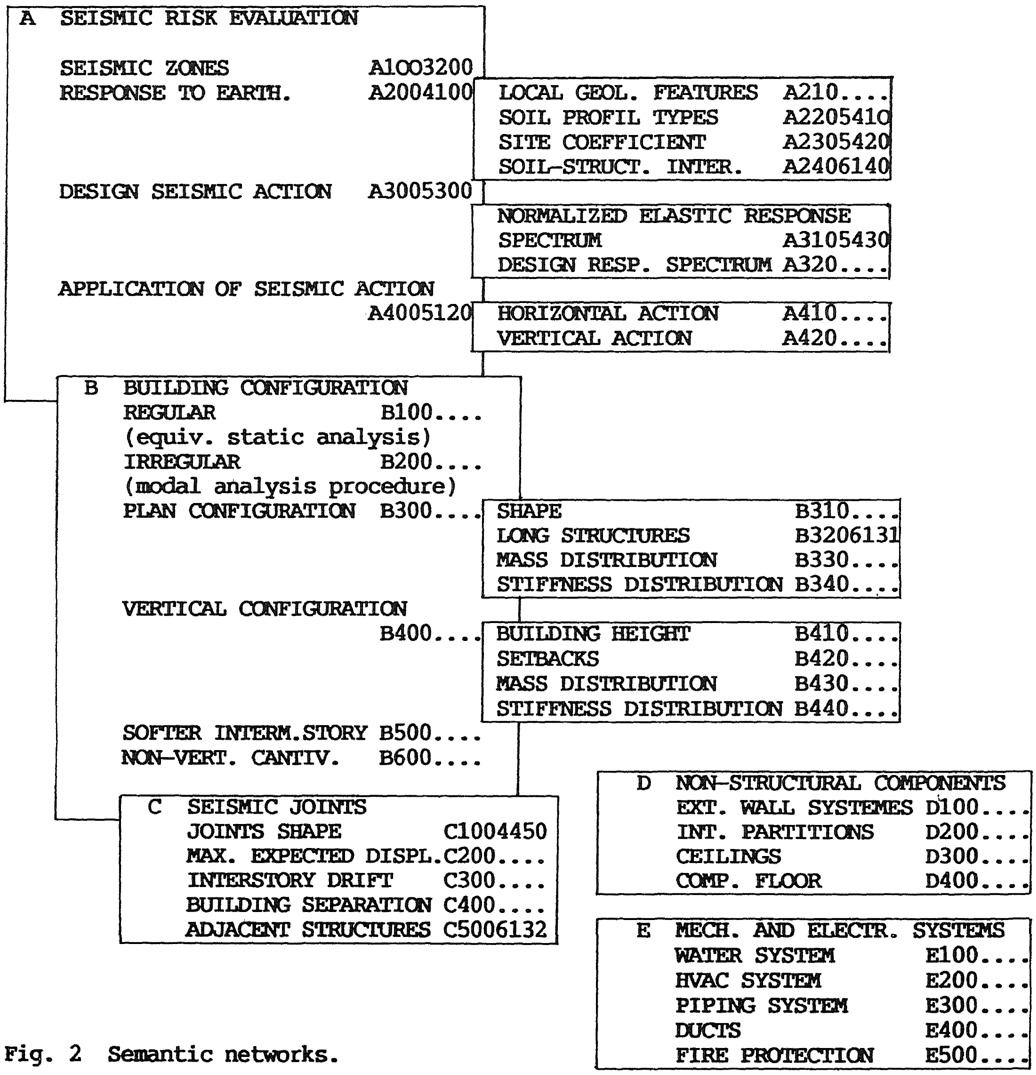


Fig. 2 Semantic networks.

F	SEISMIC DESIGN AND BUILDING TYPE
DWELLINGS SINGLE STORY	F100....
RESIDENTIAL	F200....
HOTELS	F300....
OFFICES	F400....
EDUCATIONAL	F500....
MEDICAL FACILITY	F600....
COMMERCIAL	F700....

LOW-RISE	
MEDIUM-RISE	
HIGH-RISE	

G	SEISMIC SITE RESPONSE
SITE INVESTIGATIONS	G1004200
LIQUEFACTION	G2009100
DYNAMIC RESPONSE PARAMETERS	G300....

FAULT MOVEMENTS	G1104110
LANDSLIDES	G1204122
SOIL LAYERS DEPTH	G1304332
DEPTH TO BEDROCK	G1404333
SETTLEMENT	G150....

SHEAR MODULUS	G310....
DAMPING	G320....
DENSITY	G330....
FUNDAMENTAL SOIL PERIODE	G340....

H	SOIL-STRUCTURE INTERACTION
DESIGN PROVISION	H1006142
SLOPING BEDROCK INFLUENCE	H200....
SURFACE WAVES	H3005510
FOUNDATION EMBEDEMENT	H400....

I	EQUIVALENT STATIC ANALYSIS
FUNDAMENTAL PERIOD	I1006624
HORIZONTAL DESIGN FORCES	I2006623
TORSIONAL EFFECTS	I300....
INTERSTORY DRIFT	I400....
LIMIT DEFORMATION	I500....

J	MODAL ANALYSIS PROCEDURE
DAMPING	J1006234
SOIL-STRUC. DAMPING	J200....
MODES SELECTION	J300....
COMBINATION OF MODAL RESPONSES	J4006613
BASE MAT LIFTING-OFF	J500....
INTERSTORY DRIFT	J600....
LIMIT DEFORMATION	J700....

Fig. 3 Semantic networks.

CONCLUSIONS

The E^3S is designed to bring precise theoretical and practical responses to problems encountered by users. In the future, the E^3S should bring users to re-examine their own knowledge insofar as they have been able to identify and to maximize their potential.

At a later stage, the methodology should be analyzed to determine whether the information is clear and consistent. The principal benefit of this prototype is to raise questions when problems are detected that might indicate a lack of clarity or comprehensiveness.

Thinking about one's thought is an epistemological exercise - one enters into the realms of the critical study of one's own reflections. The whole process may be reminiscent of improvisation, but the attitude of "making do with what we've got" sums up the whole learning process.

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