

of contacts with a wide variety of sources of expertise and data. The former are found to be divided on a number of key issues and the latter is far from complete at any one source. The settling of differences and filling of gaps is envisaged to take a considerable period of time. For example cost data is traditionally held as 'Tender data' together with some cost/design information. We feel - although not everyone agrees with us - that what we really need is 'Final Account cost data' and more complete information on cost/design factors. A further factor is the difficulty in obtaining final costs for buildings. These are regarded as confidential by many professionals and clients. While understanding the ethical motive behind this, there is the suspicion that the secrecy is also used to cover up the fact that the final cost exceeded the tender amount and therefore what the client fondly assumed was the budget.

#### REFERENCES

1. Richard Forsyth, Expert Systems - Principles and Case Studies (Chapman and Hall, London and New York, 1984)
2. Building Cost Information Service, Building cost/design data published for subscribers by BCIS Management Committee under the aegis of the The Royal Institution of Chartered Surveyors, London.

#### Anti-Seismic Design Support Expert System

A. Miyamura, M. Murata, and S. Kato

School of Architecture  
MEIJO University  
Tempaku, Nagoya, JAPAN 468

#### KEYWORDS

Artificial Intelligence, Anti-seismic Design, Expert System, Earthquake Resistant Elements, Structural Design

#### ABSTRACT

Historically strong earthquakes attacked Japan necessary to construct buildings on soft alluvium with dense population. Despite the recent development of structural designs and construction techniques strong earthquakes provide even heavy damages, almost all of which are lower and medium sized designed by smaller structural design offices. They cannot sufficiently provide appropriate engineering advice at the early stage of architectural design. Mutually contradictory requirements must be solved by junior engineers. The expert system on structural design problem can support them. Herein, the expert system of optimal layout of earthquake resistant elements in frames is discussed. SIM-system is added to ISI-system which provides general structural design tools. PSI-machine contributes to provide the software operating system called SIMPOS in ESP language based on the logical KLO. Thus the knowledge base on the subject includes; A) consistency with the relevant codes, B) consistency with architectural and environmental design requirements, and C) structural design requirements in terms of the grades such as CF, membership level of fuzzy sets, the level factor by MEM.

Appui du plan anti-sismique Expert system

A. Miyamura, M. Murata and S. Kato

School of Architecture  
MEIJO University  
Tempaku, Nagoya, JAPAN 468

Mots Clés

Intelligence Artificielle, Plan anti-sismique, Expert System, Éléments résistants aux tremblements de terre, Plan structural

Sommaire

Historiquement les séismes lourds attaquent le Japon qui est nécessaire de construire des bâtiments sur la plaine alluviale peu solide avec population dense. Malgré le développement nouveau du plan structural et de la technique de construction, les séismes lourds entraînent même de grands maux aux bâtiments, presque totalité de qui sont bas et millieux de dimension, sont fait le plan par des bureaux au plan structural plus petits et plus faibles. Ils ne peuvent pas suffisamment fournir des conseils juste au premier stade du plan architectural. Les exigences contradictoires mutuellement doivent être satisfait par des ingénieurs débutants. L'expert system sur le problème du plan structural leur peut donner son appui. Ici, l'expert system sur l'arrangement idéal des éléments résistants aux tremblements de terre des charpentes des bâtiments est discuté. On joint SIM-system à ISI-system qui fournit les outils du plan structural général. PSI machine fournit le software operating system qui s'appelle SIMPOS dans la langue ESP qui se base sur la logique, KLO. Par conséquent le knowledge base sur la titre contient; A) la cohérence avec les règles relatives, B) la cohérence avec les réclamations du dessin architectural et ambiant, C) les réclamations du plan structural écrit comme CF, membership level des ensembles flous, le facteur level par MEM.

1. INTRODUCTION

In Japan the structural design of buildings is necessarily accomplished under the severe restrictions due to natural disasters, such as strong earthquakes, and the dense urban area. Actually almost medium or low-rise framed buildings have been designed largely by the smaller structural engineering offices in collaboration with architects. Additionally the short job term and lower job fee oppress the situation of structural engineer. To improve such situation we developed the ISI-structural design support system consisted of the data input, the structural design (the prediction of ultimate resistance load capacity, elastic plastic vibration analysis, coupled vibration analysis of building and soil, artificial ground motion and wind), the estimation, the designed drawings output, the job progress management, and the accounting management systems on the 32-bit super mini-computer (Mitsubishi MELCOM 70/MX 3000 with Unix). Thus, the ISI-system has the following characteristics;

- 1) Systematized structural design tools make each engineer evaluate sufficiently his own structural design concept and engineering judgement.
- 2) Option of the automatic structural design system or the man-machine interface system.
- 3) Large reduction of input data based on individual default data file.
- 4) Cost comparison of structural frameworks by the estimation system.

However, there rises the problems after two years performance of this system;

- 1) Because of the heterogeneity of density between application programs junior engineers demand the criteria of the best selection from a large number of softwares available.
- 2) The influence of input error from excessive design information is not negligible on the design results.
- 3) Versatile technique applicable to the design modification—The more rigorous parameter survey by computer needs the much computer time. To improve these problems PSI (Personal Sequential Inference Machine), which is one of the ICOT-machines, is added to the already installed ISI-system as a front processor to provide the strong expert ability. Hence, the design decision making and engineering judgement can be attained in the early stage of the structural design by the expert system.

2. OPTIMAL LAYOUT OF EARTHQUAKE RESISTANT ELEMENTS

In the present paper the optimal layout of earthquake resistant elements in framed structures is discussed in view of the expert system. In Japan the structural design stands by not only the strict requirements of occupancy and site shape from excessive dense urban area but also the architectural and environmental engineering demands. The typical multi-story framed buildings have earthquake resistant elements, such as shear walls and braces, arranged in frames. Recently the computer can analyze even elastic plastic response of building subjected to the ground motion when modeled appropriately. However smaller structural engineering offices in Japan have accomplished the structural design by rather daring analytical model too simplified from the economics of computer time and



job payment. As a result excessively safe or unsafe buildings were built in some cases. The optimal layout of earthquake resistant elements are closely related to factors such as frame dimensions, effect of perpendicular frames, mass and stiffness distribution along the frame height, eccentricity between gravity and rigidity centers and others, each of which becomes difficult to be rigorously analyzed. The expert system can support the decision making and engineering judgement on the subject. When the abundant knowledge from expert engineers are rule-based, junior engineers can easily access them, which also indicate the optimal choice of softwares from ISI-system.

### 3. ABSTRACT OF SIM-SYSTEM

Fig.1 shows the total system configuration. It consists of the ISI-structural design support system (including the set of softwares related to the usual structural analysis and design) and SIM-system (Sequential Inference Machine). The SIM-system contributed to the realization of expert system. The ISI-system was discussed elsewhere(1). As an expert system the SIM-system should realize not only the effective programming environment as to software system easily handling but also the sufficient memory area and implementation ability as to the hardware. Thus it is similar to DEC-10 Prolog on DEC 2060 hardware. It is necessarily, furthermore, a super personal computer with a superior man-machine interface as follows.

The SIM-hardware consists of the fundamental hardware and extended hardware. The former corresponds to the PSI (Personal Sequential Inference Machine) and LAN-INI, whose architecture provide the tug architecture (32+8 bits), micro-program control, hardware stack mechanism, multi-process support, VO bus and LAN. It has: implementation speed-approximately 30k LIPS, micro-program memory device-64 bits 16 words, machine cycle time- 200ns, memory capacity-40 bits 16 Mwords, cash memory-40 bits 4 kw 2 sets and device technology-TTL, NMOS. The latter means a high speed processor system as a backend hardware processor of PSI machine. It also includes the graphic and image I/O devices.

The whole SIM-softwares system called SIMPOS (SIM Programming Operating System) is one of the latest personal operating systems additionally with high power functions, that is, the realization of an innovative operating system similar to a super personal LISP-machine. Thus, this operating system is written by powerful ESP (Extended Self-contained Prolog) with its size approximately 90 k steps based on the logical KLO (Kernel Language 0). SIMPOS has five fundamental features; System design based on the homogeneous framework-the framework based upon only Prolog logic programming language can support all of machine architecture, language system, operating system and programming system, personal dialogue system, database function, multi-window function and Japanese language.

ESP, OS and PS is discussed in the following.

Description language--ESP is the machine language of PSI. Almost all function of KLO can be directly expressed by ESP. It has also logic programming language function, such as parameters delivery by means of unification and search mechanism of AND-OR trees by backtracking. The

programs described by EPS are compiled into KLO.

Operation system--The operating system of SIMPOS has the three categories; Kernel can manage hardware resources interacted the PSI hardware with supervisor. Supervisor provides the implementation functions such as the object accumulation area, process communication, implementation environment and others. It contains the pool (object area of any class, list, array), directory (pool of object, tree), and stream (object into pipe, used as the message communication between processes). I/O media system has the subsystems to control the interface to external world (window subsystem supports the man-machine interface of the SIM system, configuration of hierarchy, and pointing device. File subsystem stores data and objects. Network subsystem provides three kinds of interface with MX 3000 programming system).

The programming system of SIMPOS--is the set of expert process, which means the process with the independent communication window (e-window) and makes special implementation to user demands. Thus, users can access and control the expert process through the e-window. It is not necessary to search complicated process trees.

Coordinator--is the process to manage expert set to send key commands by user through windows, to support communication by means of white board. The white board support communication channels to write and read mutual messages.

Debugger--interprets programs to provide information on implementation by means of multi-window.

Editor and transducer--Text expression as nest structure manipulate the general structured text. The editor of SIM called Edips facilitates the compilation of ESP program and customization by macro definition.

Library subsystem--manages all classes and predicatives on SIM. It registers class, loads program files, makes compilation and controls class object by succession analysis.

Exception and help subsystem--Zero divide by hardware, I/O error, error by software, help function to users.

### 4. THE PRESENT EXPERT SYSTEM

Fig.2 shows the present expert system of the optimal layout of earthquake resistant elements based on the SIM-system. In general there are the three design support expert systems; to check and propose unsatisfactory requirement, to provide guidance to cross over some threshold of design, to supplement the deficit of design in sequence.

The expert system by SIM-system is of production rules, whose implementation process consists of recognition and matching to the working memory, selection of target rule, implement the righthand side of selected rule, and conduct deeper inference by repetition. There are the following essential features; to approach the expert knowledge easily for non-expert end users in dialogue, consistent knowledge acquisition from expert engineers, and to construct the knowledge base. KE (Knowledge Engineer) can accomplish the knowledge acquisition.

It is necessary to accumulate not only the technique of earthquake engineering but also the very concrete and abundant knowledge. Thus, the



present knowledge base includes;

A) Consistency with the relevant codes—Japan has rather severe codes and regulations governing the building design because of the heavy density and disasters. They are severely revised after occurrence of a large disaster. Under these restriction it becomes more difficult to accomplish enlargement or reconstruction of existing buildings. Furthermore the practical interpretations of regulations on earthquake resistant design are different in each region individually. The consistency between them can be effectively supported by the expert system.

B) Consistency with architectural and environmental design requirements—Layout of earthquake resistant elements, especially shear walls, is largely restricted under these requirements. At structural design the geometrical allotment of frame and the elements is determined by architects in advance. Thus there is possibility of claims on modification of layout from the requirements by the client due to the loose evaluation of designed layout by the lack of expert knowledge.

C) Factors of structural design on the layout—There are numerous factors contributed to the resistance capacity of frames and earthquake resistant elements. These factors can be classified into nine categories with five evaluation levels as in Fig.2.

C1) Construction—The survey of past damages shows the inadequate concrete formwork, deficit coverage, insufficient shear reinforcement, inadequate fixity, bad fastening of braces and others. Necessarily check field process sheets.

C2) Terrain and foundation—Unequal settlement of foundation reduces the resistance capacity. Adequate choice of foundation system against the liquefaction. Soft soil layers suffer large displacement by ground motion. Resonance of duration between building and ground. Excessive vibration at the top and bottom of hill.

C3) Form—Irregular shape of building suffers large damages due to distortion. Eccentric layout of the elements demands increase of heavy reinforcement.

C4) Deformation capacity and ductility—Usual earthquake resistant elements show the lack of ductility after the elastic limit. Thus, propose the structural details to attain adequate ductility in plastic region. Limitation of relative story drift. Distribution of rigidity ratio  $R_s$  should be less than 0.6. If not so, show the corresponding story and propose alternative dimensions.

C4) Strength—To predict the distribution ratio of horizontal force between the frame and the elements, especially in elastic plastic region. Eccentricity provides distortion to increase reinforcements. If the eccentricity ratio  $R_e$  becomes larger than 0.15, check the horizontal resistance strength by the plastic analysis.

C5) Stiffness—to show the natural frequencies and modes by the deformation distribution method. Elastic buckling load.

C5) Secondary members—Effects on deformation and strength behavior of frame with the elements. Additional wall elements.

C5) Deterioration due to aging, environmental condition—Removal of the elements, especially steel brace.

## 5. CONCLUDING REMARKS

Recent economic situation in Japan motivates necessity of development of the computer-used structural design, especially on the earthquake resistant design. However, junior engineers tend to make abuse of computer time. This demands deployment of the expert systems to support the special subjects of structural design. In the present paper the discussion of the expert system of optimal layout of earthquake resistant elements in frames is made, where the most important objective of the system is how to build the knowledge base. It needs the consistent, rather heuristic expert experience by expert engineers. Furthermore, to attain the experienced target it is necessary to add the appropriate hierarchy in terms of assignment of the grades such as CF (Certainty Factor), membership level of fuzzy sets, the level factor derived from MEM (Maximum Entropy Method) and others. SIM-system can support this knowledge base and provide the expert system of the optimal layout of earthquake resistant elements in frames to junior engineers.

## REFERENCE

1. T. Iijima, A. Miyamura and M. Murata, "Structural design supporting system by micro-computer in engineering office," Proc. EPMESC, pp. 43-52 (1985)
2. S. H. Iyengar and J. E. Goldberg, "Elastic analysis and design," Monograph on Planning and Design of Tall Buildings, SB, pp. 33-61 (1979)
3. K. Murakami, T. Tsunoda and R. Onai, "The parallel machine and the knowledge base machine," Science and Technology in Japan, 232, pp. 28-40 (1985).
4. S. Uchida and T. Yokoi, "Proposal of programming environment of logic language," Science and Technology in Japan, 232, pp. 56-66 (1985).
5. L. Brownston, R. Farrell, E. Kant and N. Martin, Programming expert systems in OPS5 (Addison Wesley, London, 1985), Chap. 1, pp. 5-29.
6. F. Hayes-Roth, D. A. Waterman and D. B. Lenat, Building expert systems, (Addison Wesley, London, 1983), Part V, pp. 349-370.
7. B. M. McNamee and L. W. Lu, "Inelastic multistory frame buckling," J. the Structural Division, ASCE, 9062, pp. 1613-1620 (1972)
8. J. C. Anderson and V. V. Bertero, "Seismic behavior of multistory frame designed by different philosophies," Report EERC 69-11, Univ. of Calif. (1969)

FIGURE 1 Total system

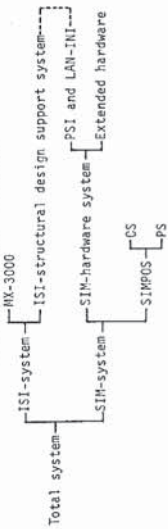
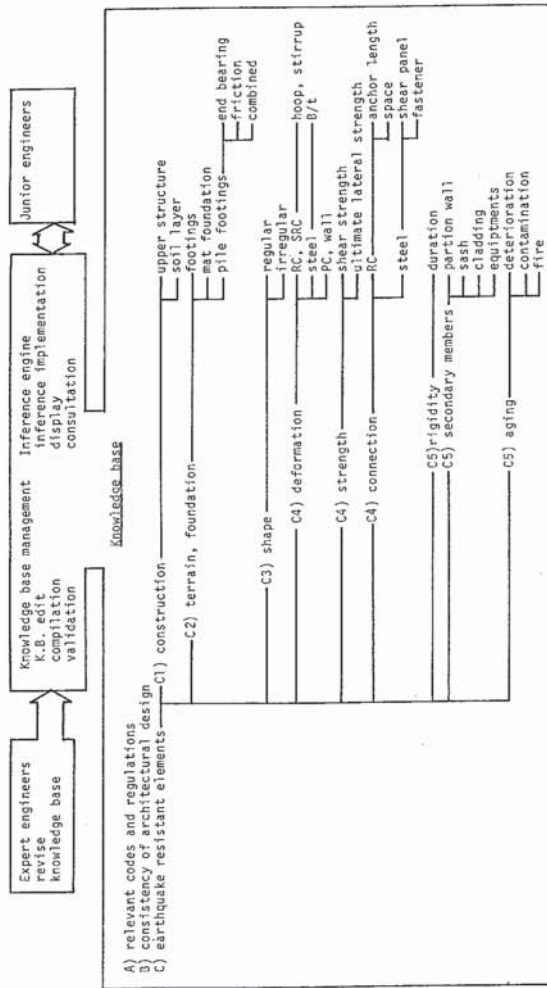


FIGURE 2 Expert system



South Bank Polytechnic  
Wandsworth Road  
London SW8 2JZ  
United Kingdom

KEYWORDS

Expert System, Houses, Learning, Market Information, Market-research Medium, Physically-Handicapped People.

ABSTRACT

The authors have developed a learning tool for house designers and house-sales staff. The system is available for housing developments of all kinds. The paper focusses particularly on housing for physically-handicapped people. The system is organised as a market research medium. Market information is gathered as and when potential purchasers use the system for assistance in relating their requirements to the house builder's houses on offer. There was a problem to know the reasons when potential housebuyers did not proceed to a purchase. The potential purchaser's inputs enable the house builder to assemble and monitor the reasons why sales are achieved and also why they are not. The system is being developed with especially written programs. There is a core program which may be extended to suit the requirements of the developer who purchases the system.