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ASEISMIC CODE FOR BUILDINGS AS A KNOWLEDGE BASE OF AN EXPERT SYSTEM

Janez DUHOVNIK

Institute of Structural and Earthquake Engineering
Department of Civil Engineering, EK University in Ljublj.:na,
Slovenia, Yugoslavia

SUMMARY

The reasons which stimulate the development of expert systems in the field of civil engineering and, particularly, in the field of technical provisions and design codes are explained. The process of the creation of the knowledge base, using the Yugoslavian aseismic code for buildings as a specific field of experience is described. The use of the discussed knowledge base in the connection of an experimental expert system shell working on IBM PC XT/AT compatible micro-computers is presented.

INTRODUCTION

Expert systems are one of the possibilities for the more intensive use of the computers in the everyday work of civil engineers. Regarding the fact that a greater part of the professional knowledge in civil engineering originates from experience and only a smaller part of the knowledge is of such a kind that one can translate it into different algorithms, it is possible to conclude that the use of the computers in civil engineering will be much more intensive and also more effective, if suitable expert systems are developed.

Design codes are a very important resource and guidance in the work of civil engineers. The essential property of the design codes is that they involve a lot of knowledge, which is based on long term experiences. This knowledge is incorporated into many determinations and requirements in the codes. Rosenman and Gero [1] state that this knowledge is usually widespread and ill-structured. Consequently, finding and interpreting the necessary information is often difficult and time-consuming. This is not valid only for designers but also for other participants in the process from the idea to the construction of a building, its maintenance and demolition. It may be concluded that any systematic process should result in the reduction of errors or inconsistent decisions with resultant general benefits.

THE YUGOSLAVIAN ASEISMIC CODE FOR BUILDING AS A KNOWLEDGE BASE

The Yugoslavian code of technical regulations for the design and construction of buildings in seismic regions [2] comprises eighteen sections. The first section involves general determinations and explanations of symbols. The second section involves the classification of buildings. The third section involves the determination of seismicity and seismic parameters. The fourth section deals with local ground conditions. The fifth section determines the methods of calculation, permissible stresses and displacements. The sixth section deals with the calculations of seismic loads and involves chapters which discuss the fundamental principles of calculation, the equivalent static load method and the dynamic analysis method. The seventh section deals with testing of structures. The eighth section involves general determinations for the design of earthquake-resistant structures, and the sections nine to sixteen provide the principles for the design of structures made of different materials.The seventeenth section determines the procedure in the case of reconstruction and adaptation of existent buildings. The eighteenth section involves final provisions.

As usually, the code comprises knowledge in the shape of different requirements and determinations, which can be expressed in the knowledge base of an expert system in a different way. One of the possible and recommended ways [1] for the representation of such a knowledge are production systems.

We intend to build an expert system, which will be able to select the appropriate articles of the design codes on the base of the data of a real designed or existent building. As an expert system shell we dispose of an experimental expert system shell Micro-Expert [3] which can run on the personal computers IBM XT/AT and compatibles. The inference mechanism used in Micro expert is backward chaining.

The aseismic code for buildings in seismic regions is composed of articles, which are gathered in separate chapters dealing with a specified field, i.e. the calculation of seismic forces, the experimental testing of structures, complete local conditions of soil, etc. Each chapter should deal with a complete theme, but it is not always so. The data about the maximum permitted shifting are in several chapters, the data about construction are not gathered in one place and similar.

The preparation of the knowledge base flows in two steps. The first step in this process is the organisation of the facts in the decision tree. In the second step one writes down the rules for each branch of the decision tree that ends with a conclusion.

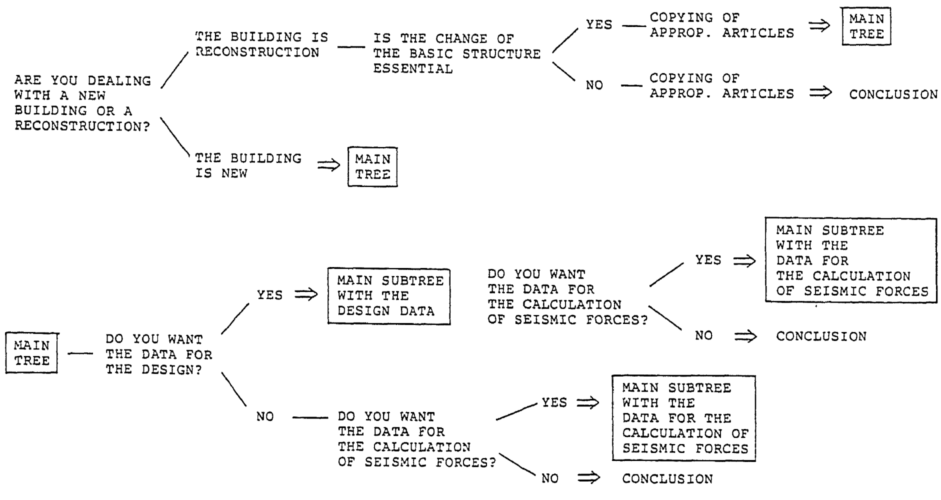

Fig. 1 Decision tree of the aseismic code

The contents of the code can be divided into two main parts. The first one deals with the calculation of seismic forces and the second one with the design requirements. Similarly, the decision tree is composed having two main subtrees (Figure 1). Each of these two main subtrees is also divided into subtrees. Some of the subtrees appear in the decision tree several times. The first branching of the decision tree exists because the building can be a new building or a reconstruction. If the reconstruction is involved, it is possible that an essential change of the existent basic structure is foreseen or not. If an essential change is not foreseen, the corresponding part of the article, which involves the requirements about reconstruction, is copied out followed by the end of the consultation. In case that the foreseen change of the basic structure in reconstruction is essential or if the treated case is a new building, the tree continues with the main tree.

```
1
if building is reconstruction
and change is no
then name is procedure display ('name.dat')
and article is procedure display ('art116a.dat')
and z *** is 1 ***
and design is finished ***
and calculation is finished ***
.
2
if building is reconstruction
and change is yes
then name is procedure display ('name.dat')
and article is procedure display ('art116b.dat')
and z *** is 1 ***
.
3
if building is new
then name is procedure display ('name.dat')
and z *** is 1 ***
```

Fig. 2 Some rules which follow from the part of decision tree, shown in Fig. 1

The main tree branches out after the question if the design data are needed or not. In the point where they are needed, the main subtree with design data is connected to the main tree. The question if the data for the calculation of seismic forces is needed, is included into the decision tree twice. Such a shape of decision tree enables that all parts of the code can be reached in one consultation. Some rules, which follow from this part of decision tree, are shown in Figure 2.

The design subtree starts with the copying out of the articles giving the general information. Then the branching because the different structure material follows (Figure 3). The possible kinds of materials are: reinforced concrete, prestressed concrete, steel or masonry. If the material is reinforced concrete, the tree branches out after the question if the structure is monolithic or prefabricated. The branch of the monolithic structures divides in three branches: for frame structures, shear-wall structures and frame systems with added shear walls or cores. The lower level of branching includes the branches of special design requirements, joints, beams, columns, infill panels and reinforcement. The similar branching is used if the structure is prefabricated. If the material of the structure is prestressed concrete, the decision tree branches out regarding the amount of the mild-steel reinforcement. In the case when the building has masonry structure the decision tree branches out for ordinary, plain-masonry structures, masonry structures with vertical, reinforced concrete tie-beams and reinforced-masonry structures. As in the case of reinforced concrete structures, all three last branches divide in the additional branches of special design requirements, allowed number of stories and the sort of mortar. The branch for the allowed number of stories is divided furtherly in the branches of different seismicity.

The tree of the calculation of seismic forces begins with the question of the kind of the building (Figure 4). Then the category of the building is determined. Branching because of different seismicity follows. Some of the branches end here, but the majority of them branch out at first at the selection of the method of calculation, then regarding soil conditions, determining the type of structure concerning ductility, ascertaining if the structure has

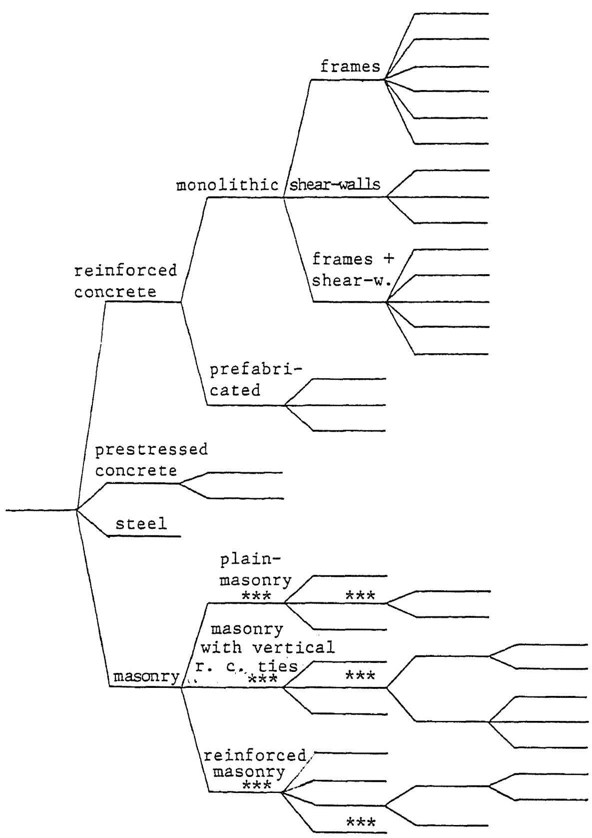

Fig. 3 The structure of the design subtree

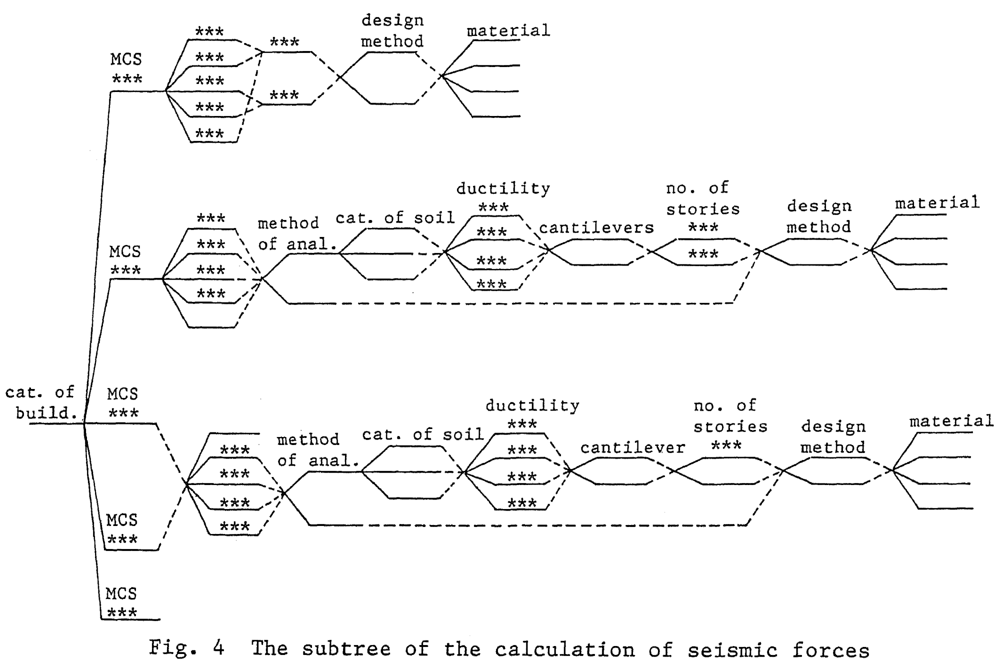

Fig. 4 The subtree of the calculation of seismic forces

cantilever parts, establishing the number of stories, choosing the method of the analysis and finally selecting the sort of material.

The code involves 37 typed A4 pages and contains 118 articles and 6 tables. 99 rules are needed to comprise the whole code, 26 prompts to put questions and 18 translations to elucidate some attributes, which are used in the rules.

USING KNOWLEDGE BASE

Using Micro-Expert, the knowledge base described above and the files where the appropriate articles are written down are needed. While constructing the knowledge base it became obvious that many articles should be copied out completely. However, the system Micro-Expert in its basic version does not enable this as well as the recording in the file. Because of this fact the program was completed by the procedure for copying out any text on the screen and in the file.

The copy procedure can be used only in the conclusion part of the rule. When the system comes across this procedure, it looks for the appropriate file and copies it out simultaneously on the screen of the computer and in the file with the results. When the consultation is finished, the copy is arranged by pages and is equiped by the appropriate front page.

At the start of the work of the Micro-Expert the system asks: What is the final goal for this consultation? Among the possible goals the program quotes many attributes. It is possible to choose only those, which are not denoted with three asterisks. The last serve as the connections between the decision subtrees or they denote the files for output. The goal, which guides the user through the whole code, is CODE. The appropriate articles are written down in the file CODE.DAT. The system operates satisfactorily, regarding the simplicity of the inference mechanism and the simple method of the knowledge base preparation. The response time is strongly dependent upon the computer type.

CONCLUSIONS

The preparation of the knowledge base with the Yugoslavian aseismic code for buildings as a specific field of experience and work with Micro-Expert using this knowledge base shows again that the use of the expert systems in the field of the design codes is possible. The working of the system can be more successful if some changes in the preparation of knowledge base, inference mechanism and user interface are made.

The production system for the representation of knowledge is well understood, the rules are simple to be written down. In Micro-Expert only the operator AND can be used. If the operator OR is available, the work on the preparation of rules will be much more simple and effective. This change will be possible under condition, if inference mechanism also changes. Now, some parts of the rules repeat for several times. With the reduction of the rule numbers, the response time will be shorter. An automatic system for the decision tree design will be an indispensable tool in the future.

The inference mechanism has to be completed with forward chaining. Now it enables backward chaining only. At the start of a consultation, the process of finding the goal begins at the lowest level. But the user usually knows the information at higher level and he does not need to answer elementary questions. Designers are often interested for one datum only. The inference mechanism must enable the jump on the single branch which corresponds to the decided information.

The system must provide the orders for saving the determined facts and conclusions to enable the use of these results in a future consultation.

The input of the prescribed goals through the keyboard is very clumsy. The answer must be exactly the same as prescribed in the rules. It seems that the input with mouse will be more appropriate.

Although the expert system with code as the knowledge base can be used independently of the programs for the analysis of structures and CAD in general, its main benefit will be evident when the connections between these programs and expert systems will be realized.

A specific problem is the language in which the dialogue between a man and a computer flows now. In our work, a mixture of the "English" language which Micro-Expert understands, and the Slovene language is used. The attempt to translate the dialogue completely into the Slovene language decays in the consequence of different syntax.

The work in the development of design codes as the expert systems can have a retroactive effect on the preparation of the codes. In the future each new code can be prepared as a knowledge base in advance.

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