Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 13 (1988)

Artikel: Expert systems for the concrete industry

Autor: Serén, Karl-Johan

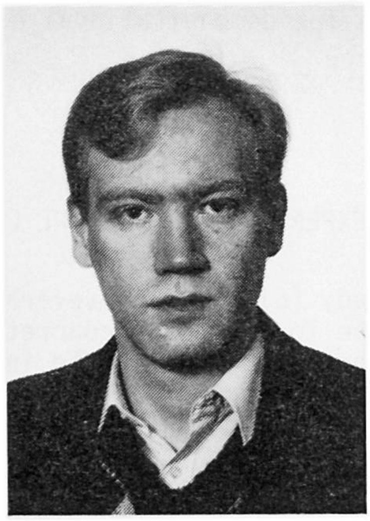
DOI: https://doi.org/10.5169/seals-13000

Expert Systems for the Concrete Industry

Systèmes experts dans l'industrie du béton

Expertensysteme für die Betonindustrie

Karl-Johan SERÉN
Research Scientist
Techn. Res. Centre of Finland,
Espoo, Finland



Karl-Johan Serén, born 1958, received his MScTech degree in mechanical engineering at Helsinki University of Technology. For three years he has been involved in research projects concerning automation in the concrete industry, with special interest in application of advanced electronic data processing techniques, such as knowledge engineering.

SUMMARY
In this paper, potential applications of knowledge based expert systems in the concrete industry are discussed. Moreover, two expert system applications for building sites concerning concrete and concrete structures are presented. The first expert system assists in choosing ready-mix concrete. The second system is an expert system for the repair of concrete balconies. Both systems are prototypes and they run on microcomputers.

RÉSUMÉ
L'article présente les réalisations possibles des systèmes experts dans l'industrie du béton, dont deux se rapportent particulièrement aux chantiers de construction en béton. Le premier système facilite le choix du béton prêt à emploi, et le second à la réparation des balcons en béton. Les deux systèmes sont des prototypes fonctionnant sur des micro-ordinateurs.

ZUSAMMENFASSUNG
Dieser Vortrag behandelt potentielle Anwendungsbereiche von Expertensystemen in der Betonindustrie. Ferner werden zwei für Baustellen mit Betonverarbeitung konzipierte Expertensysteme vorgestellt. Das erste Expertensystem dient der Wahl von Transportbeton. Das zweite Expertensystem ist bei den Reparaturen von Betonbalkons behilflich. Beide Systeme sind Prototypen und funktionieren auf Mikrocomputern.

1. INTRODUCTION

Knowledge based expert systems offer a new way of solving various problems related to concrete. A wide variety of potential knowledge engineering applications can be found in the precast concrete industry as well as on site in concrete construction. In Finland the research activities in the field of artificial intelligence in building construction have mainly focused on the practical aspects, i.e. what expert system techniques offer in the way of problem solving and decision support; what knowledge engineering applications from other branches of industry can be used; the state of art of software tools; building small expert system prototypes for demonstrational purposes to prove the feasibility of the technique etc.

2. POTENTIAL APPLICATIONS OF EXPERT SYSTEMS IN THE CONCRETE INDUSTRY

The conclusion of a brief study [6] was that several potential applications for knowledge based systems can be found in the concrete industry. One aspect to consider are the differences between the concrete industry branches, especially in view of automation level and type of production. The concrete industry branches can be divided into three categories [1]: 1) ready mix concrete plants, 2) concrete product factories and some of the precast element factories with large production lot sizes and 3) precast element factories with small production lot sizes consisting of individually shaped concrete elements.

2.1 Design and its impact on the manufacturing process

Several expert systems assisting the design process have been reported. As an example one could mention the work done in Sheffield Polytechnic in conjunction with Ove Arup and Partners to develop an expert system written in Prolog which relates to reinforced concrete beams design [7]. The expert systems relating to architectural and structural design do not usually deal with the constraints of the manufacturing process and the need for such systems is obvious. An expert system of this kind should be able to consider the constraints set by the mould and casting equipment, make the selection of materials and check the dimensions of the elements (depending on the precast concrete factory manufacturing the elements) as well as check the design in relation to the national building codes and structural aspects.

2.2 The manufacturing operations

The use of expert systems for the control of manufacturing equipment and machinery obviously requires a high level of automation. The implication of this is that, in the short term, application areas for manufacturing operations expert systems can be found mainly in ready mix concrete plants and in concrete product factories manufacturing mass-produced articles. In ready mix concrete plants expert systems can be used to automatically choose the appropriate mix proportion according to the structure to be cast. Another application would be monitoring the mixing process and interpreting the signals from various probes and sensors. In the future knowledge based systems can be used in various robotic applications, for instance in the control systems of autonomous mobile robots [8].

2.3 Production planning and control

Production planning and control seems to offer the highest application potential in the short-term for expert systems in the manufacturing process of precast concrete factories. The optimization of production is difficult due to the great amount of information. It is often difficult to form production lots from different orders even though these may contain similar elements. The detailed scheduling is also difficult because of the great amount of possible control parameters. An additional difficulty is that the element factory does not have the final manufacturing drawings, the order in which the elements will be erected or the erection schedule at its disposal when the production planning is done. For a human being, such a dynamic environment is hard to master, and conventional computerized production planning systems are too inflexible. Expert systems could be used for the production management in cases such as the one described above, for instance, to generate acquisition proposals, production schedules and work descriptions. In other branches of industry expert systems have been developed for this purpose. One example of such a system is Isis [3].

2.4 Quality control

Automated quality control is a potential application area for knowledge based systems. Advanced sensors, such as machine vision systems, laser gauges [5] and ultrasonic pulse systems [4], are being developed to perform repetitive inspection tasks (for instance dimensional measurements and defect detection) more economically and more accurately. Knowledge based systems can be used to interpret the signals and to make a statistical analysis of the production output to minimize product error and downtime with automatic correction control of the manufacturing machinery.

2.5 Maintenance

The maintenance of a complex item of machinery involves a diagnostic procedure incorporating many rules as well as judgment decisions by the maintenance mechanic. Expert systems can be utilized to assist maintenance personnel by presenting menu-driven instruction guides for the diagnostic task. Many examples of such systems have been reported [5].

3. EXPERT SYSTEMS FOR CONCRETE CONSTRUCTION

3.1 An expert system for choosing the type of ready mix concrete

This expert system is intended to be utilized as a decision support system for the building site personnel in choosing the type of fresh concrete to be ordered from the ready mix concrete plant. At present the system is a demonstration prototype and it can't be used in production as such due to its somewhat limited knowledge base (the knowledge base does not contain any information about special cases). It can be used for educational purposes though. The system runs on IBM PC/XT/AT and compatible microcomputers. The software tool used for developing the system is a commercially available expert system shell called Insight 2+. The knowledge is presented in the form of productions (IF-THEN-ELSE -

rules), which are formed of statements or facts bound together by logical operators (AND, OR and NOT). The inference system is mainly goal-driven (backward-chaining). The knowledge bases are developed by writing the source code in the knowledge representation language and by thereafter compiling the knowledge bases into an inner representation form, which the inference system can use during a consultation. The inference system automatically generates menu-type queries when it finds a statement with an unknown value during the search through the rules. Textual information can be attached to the facts to give a more finished appearance to the user interface.

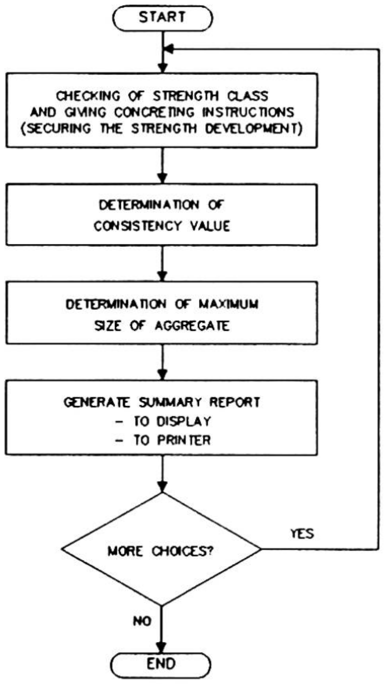


Fig. 1 The general outline of the expert system for choosing ready-mix concrete.

In Finland the building site personnel has to inform the ready mix plant about the following properties when ordering fresh concrete:

1. The compressive strength class (defined by the designer), taking into consideration appropriate concreting techniques.
2. The consistency value of the fresh concrete (usually defined as VeBe-time or sVB).
3. The maximum size of aggregate.

The domain is therefore divided into three sub-problems or contexts, each of which is a typical classification problem, i.e. the system has to choose from a number of pre-defined solutions. Weiss & Kulikowski [9] have stated that a production system is a natural way of solving problems like this. The production systems have one major drawback [2]: the search space easily grows very large and the system becomes inefficient. The general outline of the knowledge base and the course of inference is shown in fig. 1.

The first context contains knowledge about the compressive strength class and about appropriate concreting techniques. First the system checks the required minimum value for the strength class and compares it to the strength class defined by the designer. If the strength class given by the designer is too low the system gives a warning about this. The system queries following fact values from the user for this purpose:
- environment class,
- water impermeability requirements,
- frost proof requirements,
- corrosion proof requirements and type of corrosive environment and
- the compressive strength class given by the designer.

Secondly the system gives recommendations about appropriate concreting techniques, such as curing, heating and heat treatment; increasing the strength class for the ordered fresh concrete in some cases; some general information about the use of admixtures. The fact values queried from the user for this purpose are
- the outdoor temperature at the building site and
- the desired production cycle time (form stripping time).

The second context contains knowledge about the consistency value of the fresh concrete. The system deduces the suitable consistency value using following fact values queried from the user:
- structure: the type of structure, the thickness of the structure and the spacing between the reinforcement bars,
- production equipment: the compaction method and the transport method for fresh concrete used on the building site.

The third context contains knowledge about the maximum size of aggregate. The facts influencing the choice of maximum aggregate size are
- structure: the type of structure, the thickness of the structure, the spacing between the reinforcement bars and the desired quality of the concrete surface
- environmental requirements: water impermeability requirements
- production equipment: the compaction method and the type of form (number of joints in the formwork and the sealing of the joints).

It may be noticed that some of the facts mentioned above have been queried in the previous contexts. The results from each context are shown on the display as the inference proceeds. The results from the strength class checking and concreting recommendations are shown as textual displays and the results of the determination of the consistency value and maximum size of aggregate are shown as bar-charts, where the suitability of each alternative is given by the length of the bar.

3.2 An expert system for the repair of concrete structures

The expert system for the repair of concrete structures is intended to be used as aid in preparing the repair planning documents, but it may also be used by the contractor to aid in preparing the working plans. At present only a small subset of the final knowledge base is implemented. The implemented part of the knowledge base contains knowledge about repairing concrete balconies. The software tool used to develop this system is an expert system shell called Xi Plus. The system runs on IBM PC/XT/AT and compatible microcomputers. Like Insight 2+, Xi Plus is a rule-based shell.

The knowledge base contains information about the repair of concrete balconies. The domain consists of two main damage types: surface damages and cracking. The knowledge base is divided into three separate knowledge bases: a small main knowledge base, from which one of the two sub-knowledge bases for the different damage types are loaded. This divided knowledge base structure is chosen to maintain the efficiency of the system and to make it easier to add new parts to the knowledge base.

Each sub-knowledge base has two contexts. First the system makes a diagnosis of the damage. It queries from the user a number of properties related to the damaged concrete and concludes from these the possible causes of the damage. Secondly the system determines the level of damage based on some facts queried from the user, after which it gives recommendations about repair methods.

4. CONCLUSIONS

The experiences show that it is quite possible to build feasible microcomputer based expert systems with the software tools available at present. There are some restrictions: the problem domain should be very small and clearly defined. If possible, the knowledge bases should be divided into separate smaller knowledge bases to maintain a reasonable performance of the systems. The first of the described expert systems is presently being modified for educational purposes. It will, however, take some time before systems like these will be taken into production use on building sites.

At present a major project for developing an automated real time manufacturing process control system for precast concrete factories is under planning at The Technical Research Centre of Finland. This system will consist of modules for measurement and control of various manufacturing parameters, such as moisture of the concrete aggregate, workability of the fresh concrete, compaction parameters, curing and heat treatment and control of the strength development. The system is planned to include knowledge based expert system modules for the handling of uncertain and incomplete feed-back information.

REFERENCES

1. ALASALMI, M. & RATVIO, J. Development of production automation of the concrete industry. Preliminary study (in Finnish). Technical Research Centre of Finland, Research Reports 271. Espoo 1984. 104 p. + app. 41 p.

2. APPLEGATE, L. M. et al. Decision support for management systems. Decision Support Systems 2(1986)1, p. 81 - 91.

3. BOURNE, D. A. & FOX, M. S. Autonomous manufacturing: Automating the job-shop. Computer 17(1984)9, p. 76 - 86.

4. HILLGER, W. & NEISECKE, J. Ultrasonic pulse technique for automatic non-destructive quality control of precast concrete components, part 2. Beton-werk + Fertigteil-Technik 51(1985)3, p. 165 - 169.

5. MILLER, R. K. Artificial intelligence applications for manufacturing. SEAI Technical Publications. Madison, GA 1985. 202 p.

6. SERÉN, K.-J. The concrete industry and expert systems (in Finnish). Technical Research Centre of Finland, Research Notes 571. Espoo 1986. 24 p. + app. 32 p.

7. WAGER, D. M. Expert systems and the construction industry. CICA. Cambridge 1984. 128 p.

8. WEISBIN, C. et al. Self-controlled. A real-time expert system for an autonomous mobile robot. Computers in Mechanical Engineering 5(1986)2, p. 12 - 19.

9. WEISS, S. M. & KULIKOWSKI, C. A. A practical guide to building expert systems. Chapman and Hall. London 1984. 174 p.