Development of knowledge-based system for cofferdams

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Développement d'un système à base de connaissance pour les barrages de palplanches

Entwicklung eines wissensbasierten Systems für Fangedämme

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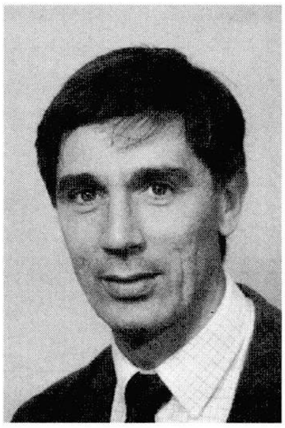

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SUMMARY
The use of expert systems is currently limited to banking and insurance companies. Apart from experiments, no operational systems for the construction industry are described in the consulted literature. This paper discusses the development of a knowledge-based design system for construction pits, emphasising the system development process instead of describing the system itself. After the realisation of a prototype, it was concluded that knowledge-based systems are very promising tools for construction engineering.

RÉSUMÉ
L'utilisation de systèmes experts est actuellement limitée aux banques et compagnies d'assurance. Dans le génie civil, on en est encore au stade de l'expérimentation; il n'y a en tous cas aucun système opérationnel décrit dans la littérature. Le cas particulier d'un système à base de connaissance pour les barrages de palplanches permet de décrire le processus d'évolution du système, plus que le système lui-même. La réalisation d'un prototype permet d'envisager des applications prometteuses en génie civil.

ZUSAMMENFASSUNG
Expertensysteme sind zur Zeit auf Banken und Versicherungen beschränkt. Für das Bauwesen stehen sie noch im Experimentierstadium, zumindest ist in der Literatur kein operables System beschrieben. Am Beispiel eines wissensbasierten Entwurfssystems für Fangedämme wird weniger das System selbst als vielmehr der Entwicklungsprozess beschrieben. Nach der Entwicklung eines Prototyps lässt sich sagen, dass solche Systeme im Bauingenieurwesen mächtige Werkzeuge darstellen.

1. INTRODUCTION

Delta Marine Consultants (DMC) designs civil engineering structures. As a subsidiary of the Dutch general contractor HBG, one of the activities DMC is involved in is the design of temporary works such as construction pits, often used to enable the construction of basements and shallow foundations. Optimizing this design requires experience of the engineer as well as many tedious calculations, growing in complexity with the implementation of new design codes, while the available time to create designs, especially in tender phases, is reducing. Moreover, the industry faces a loss of experience due to early retirements and increased holiday periods.

DMC decided to investigate the possibility to create a Knowledge Based Design System to take over all engineering and estimating activities that can be defined in straightforward set of knowledge rules.
In this paper the approach and the results of the project are reported.

2. DEVELOPMENT TOOLS

The key development tool used is Design^{++}, a Unix based product of Design Power Inc. (Finland). This is an object oriented knowledge based reasoning shell, based on product modelling that can contain 3-D geometric data of objects. To represent the geometric data, Design^{++} is linked to a common CAD-system (AutoCAD). A second link is made to Oracle, merely to retrieve product information.

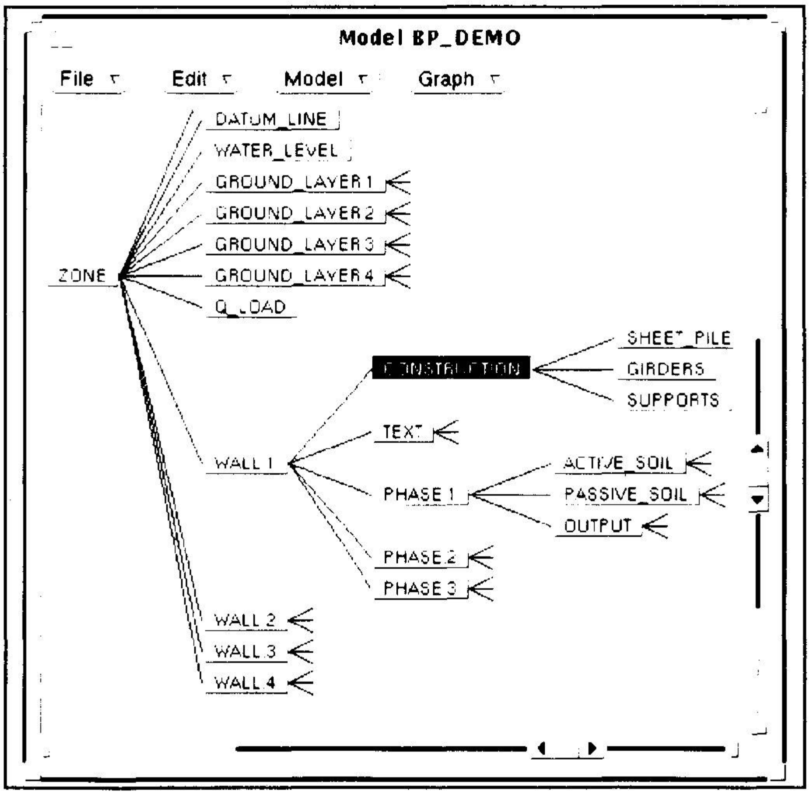

Fig. 1 Partial product model of construction pit

Design^{++} is suited to build configuration systems which link components from the database in order to create installations, structures, etc. according to the knowledge rules. Key element of each Design^{++} application is a product model that consists of all objects which may occur in the structures covered by this product model and knowledge rules describing the relations between these objects. The Design^{++} (forward) reasoning system is determined by these knowledge rules in Lisp, containing information to calculate and select values for attributes of objects such as selecting products from the database, determining which objects are relevant for the present design task and creating input files for external computer programs.

If the reasoning system lacks information, it will ask the user for input to proceed. This enables interactive operation of the system. Figure 1. shows an example of a part of the product model. The reasoning system needs the constraints given by the user as input to generate the structure within the limits of the Design++ model. It is the task of software developers to create the product model and to describe knowledge rules. This paper discusses the development of the product model for construction pits, named Pit Design++.

3. APPLICATION AREA

3.1 Objectives of Pit Design++

The application area is subject to the goals of the system, being:
- *reducing design time.* Use of the system will lead to a considerable time saving of 50 % or more, used not only to reduce costs but also to take more time to look into design alternatives or sensitivity analyses of different parameters. This will lead to improved and more optimized design solutions.
- *improving quality.* Use of a knowledge based system for a design task will not only standardize the creative design process but also ensure a proper use of design codes and company rules. The latter may be one's own interpretation of codes and rules dealing with the constructability of the design solution, in view of economy, safety and environmental impact.

3.2 Process covered

In order to develop an efficient system, an IDEF-0 analysis has been carried out (as illustrated in figure 2), concerning the process of:
1. choosing typical solutions;
2. elaborating the design;
3. estimating detailed design;
4. detailing design;
5. constructing sheet piled excavations.

Phases 1, 2 and 3 are required for both tender design and detailed designs. They will consequently be used for all design projects. Phase 1 was excluded from the program since it was found impossible to provide reliable knowledge rules. This phase will only occur for projects in progress and needs a high level of variable detail. It was therefore decided that Pit Design++ should cover phase 2 and 3 of the process only. This means elaboration of the chosen typical solution to the level of tender-design, including a calculation report for the client, drawings and a bill of materials priced with standard prices.

3.3 Products covered

Besides the process, the product range needed to be limited. It was decided that the area, which should be covered by the system, would cover 80 % of all possible construction pits. This means that apart from some exceptions all design tasks had to be dealt with by the knowledge system. Since designs have to be conform the design codes, these have been used as a guideline for the development of the system. Since DMC has an international working area both the German EAU\EAB and the Dutch CUR 166 Codes had to be implemented.

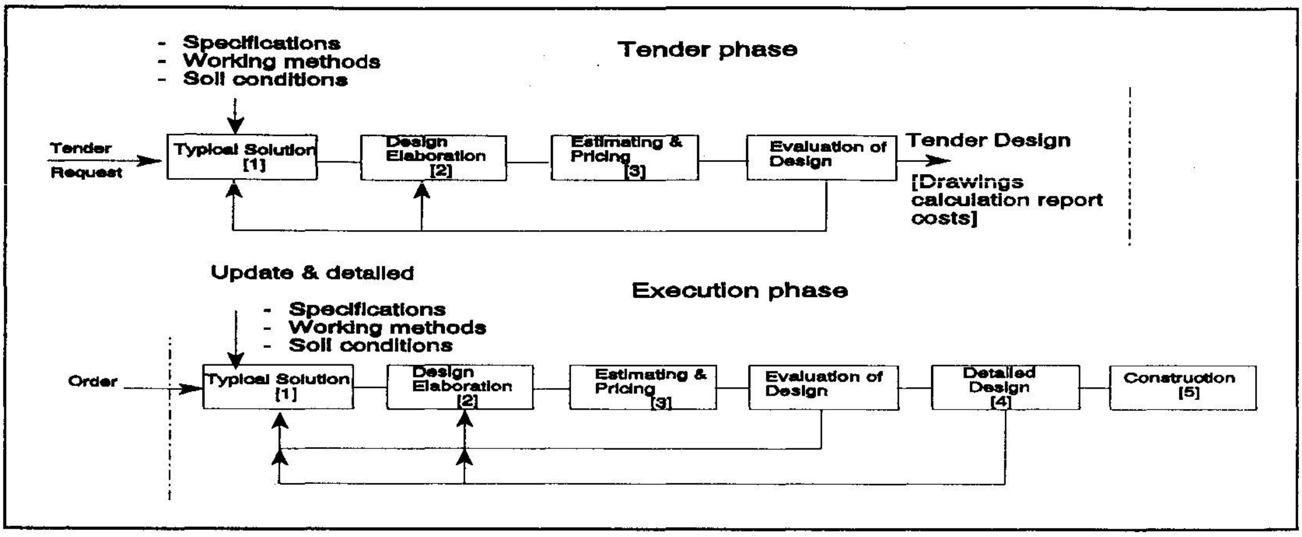

Fig. 2 Process scheme of the design of a cofferdam for a construction pit

4. APPROACH

4.1 Development method

Pit Design++ is basically developed in discrete project steps. The following project phases are used: (1) proto-typing (2) defining system specifications (3) technical design, (4) programming and (5) implementation.

Proto-typing consists of elaborating a simple Design++ model for a construction pit, containing all typical problems that may occur in the final version of the program. The development of the prototype learned that no serious problems were to be expected. Besides the realization it provided a large amount of information on the required effort to realize the final system and made it possible to quantify the running time reduction for construction pit designs. The prototype turned out to be a very useful tool to convince the organisation of the benefits of the project.

4.2 Specifications

Section 3.2 stated that 80% of the design tasks had to be covered by the system. This requirement led to the following main specifications:
- no limitations to construction pit lay-out
- six typical solutions to cross-section of the construction pit walls to be elaborated (see figure 3)
- computerized design of a sheetpile wall, anchors, anchor screen and supporting frame including computerized optimization
- different types of walls (combi-wall, sheetpiles, Peiner-wall, diaphragm wall, etc.)
- schematic presentation of standard details
- all other design tasks that can reasonably and practically be computerized will be programmed.

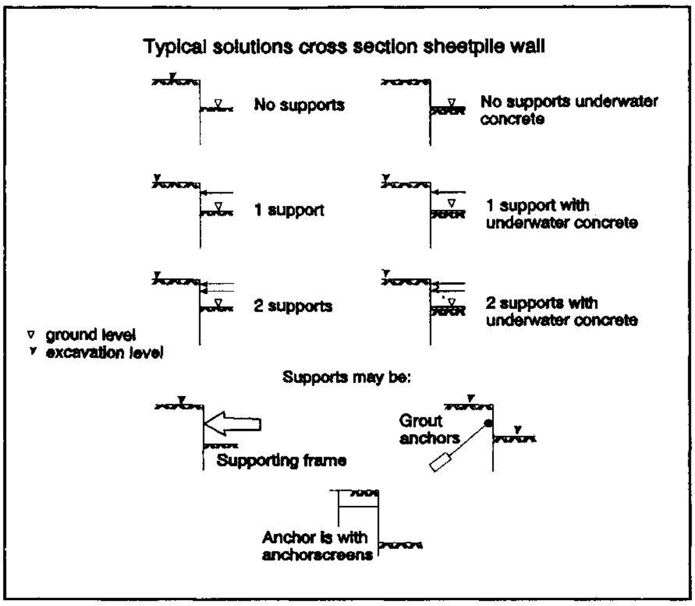

Fig. 3 Typical sheetpile walls as selected

4.3 Knowledge acquisition

Designers and estimators needed to be involved to supply the information to establish knowledge rules. In eight sessions with six specialists consisting of both designers and estimators it was decided which design checks had to be included in the system and the sequence of the design steps. It appeared that on various subjects the engineers had different opinions where the design process was concerned. The consensus reached on a standard design process, reported in a 300 page report on knowledge rules, was already an important result of the project.

It appeared that none of the specialists involved was reluctant to give his knowledge. They considered that the system would take over the boring design tasks so that they would have more time to do creative tasks.

5. LESSONS LEARNED

5.1 Design system

In Section 2 it was stated that Design^{++} can be used as a configuration system. During the project it appeared, however, that the design of a sheetpile wall for a construction pit is very complex since all the objects of the structure such as sheetpile wall, girders, support beams, anchors have many interdependent relations. This means that the reasoning system must execute a complex iterative solution process, making it difficult for the developer to guarantee the integrity of the data of the product model in each stage of the design process.

5.2 Development costs

The development of Pit Design^{++}, which cost several man years, confirms previous experience that high costs are involved in the developement of multi purpose engineering software within DMC.

5.3 Use of knowledge based design systems

It seems that in the construction industry only very few knowledge based systems are presently in use and that only few are under development.
Recent research within the industry has not led to similar cases of applied knowledge based technology in production environments. The experience with Pit Design^{++} shows, however, the possibility to build powerful systems leading to a considerable increase in productivity and quality if the application area is well chosen and a scenario for implementation is clearly defined.

6. LITERATURE

CLIVE L. DYM & RAYMOND E. LEVITT; Knowledge based systems in engineering; McGraw-Hill, Inc.; 1991