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## **Impact of CAD/CAM Systems on the Construction Industry**

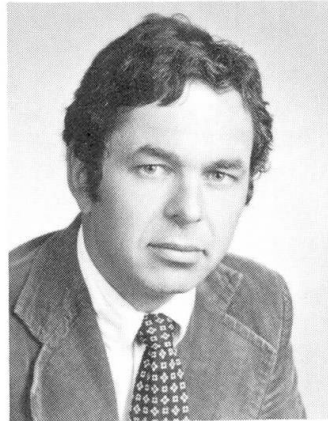
Implications de la CAO/FAO dans l'industrie de la construction

Erfahrungen bei der Einführung von CAD/CAM-Systemen in der Bauindustrie

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### **SUMMARY**

Although CAD-systems have been used increasingly by designers and structural engineers in the design stage, there exists little experience about the application of CAD/CAM-systems in the construction phase by contractors. The paper describes results and conclusions obtained by the application of such a system by contractors to a major construction project.

### **RESUME**

Les systèmes de CAO (Conception assistée par ordinateur) sont de plus en plus fréquemment introduits dans la phase d'élaboration de projets de construction. Par contre, il existe peu d'expériences sur la mise en place, dans les entreprises, de système de CFAO, qui interviendraient au niveau de l'organisation et de la réalisation des travaux, (Conception et fabrication assistée par ordinateur). Ce rapport fait état de résultats et de recommandations tirés de l'application d'un tel système dans le cadre d'un projet important.

### **ZUSAMMENFASSUNG**

CAD-Systeme werden in zunehmendem Umfang für den Gebäudeentwurf eingesetzt. Dagegen existieren nur wenige Erfahrungen über den Einsatz von CAD/CAM-Systemen für die Bauplanung und Bauwerkserstellung durch Bauunternehmungen. Der vorliegende Bericht beschreibt Ergebnisse und Schlussfolgerungen, die beim Einsatz eines derartigen Systems für ein Grossbauvorhaben gewonnen werden.



## 1. INTRODUCTION

CAD-systems are increasingly used by designers and structural engineers in the design stage. Various reports [1], [2], [3] describe the programs, applications and the market. In the English speaking countries, this trend towards CAD-systems is more marked than in the German speaking countries.

This situation is in a remarkable contrast to the rather few applications of CAD/CAM systems by construction companies especially during the construction phase. This is certainly due to the fact that the program developing institutions have stressed their efforts on the design problems of buildings and paid less attention on manufacturing problem. However, if the complete information of a building is stored in a data base, these information can be exploited in many ways, to produce drawings and lists which enable the contractor to rationalize the construction site.

## 2. PRINCIPLES OF MODELLING

The project to which the CAD/CAM system is applied consisted mostly of prefabricated concrete members. Cast in place concrete is rarely used. The following sections of the paper refer only to the structural elements (hollow core planks, girders and columns) of the project.

For the modelling of the building, a volume orientied 3D-system [4] is used. The principles of the modelling of the shape of the building are shown in Fig. 1.

The lowest modelling level is the level of geometric primitives, i. e. cubes, prisms, cylinders. In the second level, these geometric primitives are assembled to combinations of geometric primitives to model for example different haunch types. In the first level, the structural members are modelled as geometric primitives and assemblies of geometric primitives. In the building level, the structural elements are located in the building. From this pattern we see that three levels (level 1 - 3) are used to model the structural members, and one level, the building level, to locate the structural members inside the building.

In Fig. 2 the complete information, stored in the different levels is shown. Since the location of any structural member can be given in relation to a rectangular regular construction grid; the information needed, to locate a structural member is basically information about the grid axis together with the pointer to the corresponding structural element.

In the first level, the information about the shapes of the structural elements is stored as pointers to combinations of geometric primitives and to geometric primitives together with pointers to the corresponding reinforcement units in level 2 and to the corresponding embedded items in level 3. In addition the different amounts of labour which are needed for different fabrication steps of the prefabricated members are stored in this level.

In level 2, combinations of geometric primitives are stored as pointers to geometric primitives together with units of reinforcement as pointers to reinforcement primitives and in level 3, the geometric primitives are stored together with the reinforcement primitives and the embedded items.

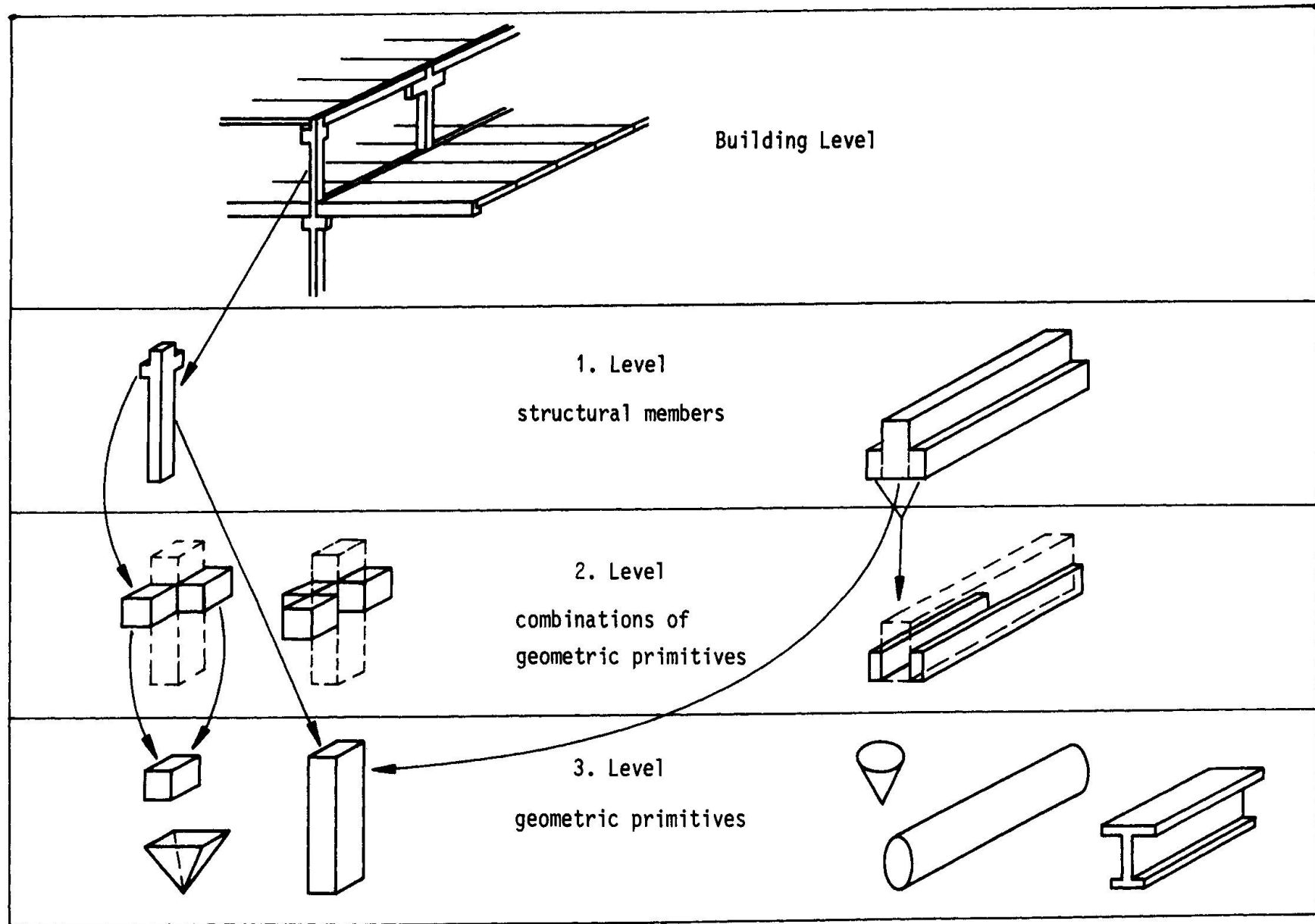


Fig. 1 3D-modelling of buildings



modelling level	information stored
building level	locations of structural members
1. level structural members	pointers to combinations of geometric primitives and to geometric primitives pointers to reinforcement units pointers to embedded items amounts of labour (hours)
2. level combinations of geo- metric primitives and reinforcement units	pointers to geometric primitives pointers to reinforcement primitives
3. level	geometric primitives (s. Fig. 1) reinforcement primitives embedded items

Fig. 2 Modelling levels and corresponding levels of information storage

In Figs. 1 and 2 one can see that the informations are structured in a hierarchical way and therefore a hierarchical data base concept was used to store the data.

### 3. USER INTERFACE - INPUT

Since ground plans were available at the beginning of the project, a batch oriented input is chosen, to prepare the input data. In most cases, one line of input is needed to describe one structural element and its location. One line of input data consists of the following information

- grid numbers for the location
- keys for cross sections, haunches, reinforcement, embedded items etc.

Special schedules are developed to prepare the input data. The input data are prepared by structural engineers and entered in the computer by data typists.

### 4. CHECKING LISTS AND DRAWINGS

#### 4.1 Structural checking

In order to detect errors in the input data and in the original plans, the CAD/CAM system is able to check the structural elements and assemblies of

structural elements. A typical check of a structural element is to compare the shape of a structural element with the corresponding reinforcement unit. If for example the reinforcement unit is longer than the structural element, an error message is given to the user.

A typical check of structural assemblies is shown in Fig. 3.

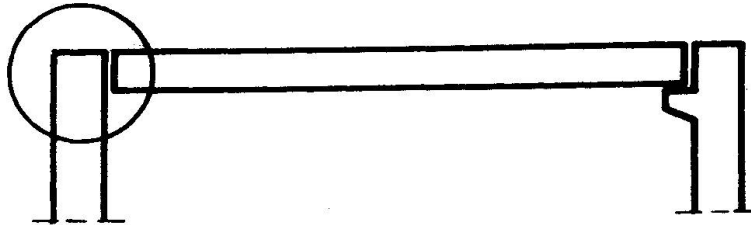


Fig. 3 Example - Structural Checking

The program checks in this case whether a column has a haunch at the location where a girder should be supported by the column.

By these checking routines errors can be detected which are either in the original plans or which occurred during the preparation of the input data.

#### 4.2 Automatic Type Numbering of the Structural Members

Since the engineer who prepares the input data does not know whether the structural member for which he just prepares the input data is already located at other places the CAD/CAM system checks all the already existing structural members in level 1 (see Fig. 1) whether one existing structural member is equal. If a structural member with equal shape, reinforcement and embedded items is found the new structural member gets the type number of the already existing one which is equal. Otherwise, the new structural member gets a new type number and the corresponding information is stored in the different information levels.

This automatic type numbering is of great importance since it ensures that equal structural members have equal type numbers and thus great series of equal elements can be identified which enable a cost effective fabrication of the structural members.

#### 4.3 Work Shop Drawings

Two different types of drawings were produced by the system.

- erection layout (1 : 200)  
This plan shows the structural members for a specific building, level and section. The plan contains also the type numbers of the structural members but not the more detailed information about haunches and embedded items etc.
- erection layout (1 : 50)  
This plan shows more details on the erection layout (1 : 200) such as haunches of girders. It is used for difficult sections of the buildings.



Because the plans are modified during the application of the CAD/CAM system the drawings are produced several times. The modification are done, using the plans produced by the CAD/CAM system.

#### 4.4 Reports

Various types of lists and reports are produced by the system. Typical examples of these lists are

- lists of the structural members, sorted according to buildings, levels, and sections of the reference grid
- structural members in specific buildings, levels inside specific sections of the reference grid. The building sections for which the lists are produced usually refer to the production of prefabricated members of one week
- summation lists of structural members for the production

On the basis of these lists, the production of the prefabricated members can be planned effectively. This information is stored on a magnetic medium and forms the basis of a program system for the updating and control of the production.

This description of the effective use of building data in a CAD/CAM system is by no means complete. Its main purpose is to demonstrate that these data can be used to rationalize the planning and fabrication process of buildings made of prefabricated concrete members.

#### 5. FURTHER DEVELOPMENTS

The CAD/CAM system described in this paper does not cover the design stage. Currently such a program development is almost completed. Thus in the near future, a program system will be available which covers the interactive modelling of buildings, the production of drawings and the report and list generation with regard to rationalize the construction stage.

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