# EXCHANGE OF PRODUCT DATA OF PREFABRICATED CONCRETE STRUCTURES

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**Abstract**

As part of efforts to adopt manufacturing automation in a scattered organizational structure the Finnish precast concrete industry has initiated the development of a number of solutions for data exchange.

Guidelines concerning various aspects of using computers in the design/manufacturing process were defined in a manual which was widely distributed to involved parties. Standardized neutral file formats for data exchange between dissimilar computer systems were developed for three kinds of data: 1) drawings, 2) tables (e.g. bills of materials) and 3) product model -based data. Translator programs were developed for a number of common CAD-systems as well as a set of software tools to the users of standardized exchange files and software developers.

The result of these developments have been widely adopted by fabricators, designers and software developers.

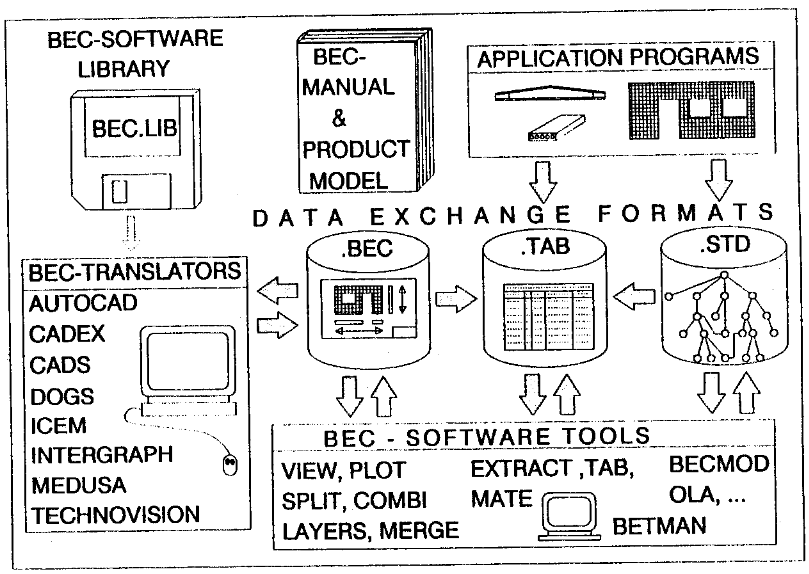


Figure 1. An overview of the BEC system

## 1. INTRODUCTION

Precast concrete structures are very widely used in Finland. Very few limitations are imposed on the freedom of design and most components are individually designed. (Note: in this paper "design" means what is in some countries called "detailing" rather than dimensioning). The design is usually carried out by independent designers rather than by fabricators. Standardized data exchange was reqognized as a prerequisity to the adoption of automated manufacturing and computer integrated management. In late 1984 a development project "BEC" was initiated by SBK Ry, the Association of Concrete Industry in Finland. The first results were published in May 1987. At the same time, in 1987, the concept of product modelling was gaining increasing attention. A further refinement of the results was started in 1989 in order to cope with the first practical experiences of BEC and with the new developments of product modelling. The updated final report of BEC-project was published in May 1991. This paper gives a summary of the development.

## 2. CAD -GUIDELINES

The printed BEC-manual includes guidelines of practice and standards concerning the utilization of CAD by different parties in the design/manufacturing process. The manual was widely distributed to designers and fabricators. Recommendations on notations, layout and information contents of design documents were given. A conceptual product model of precast concrete structures was defined and published as a part of the guidelines. The manual also describes BEC-compatible software from various sources. The following list of contents gives an overview of the manual:

- 0 OVERVIEW OF BEC-SYSTEM
- A GENERAL PART
  - A1 Description and implementation of BEC-system
  - A2 Design process of prefabricated concrete components
  - A3 Product model of prefabricated concrete structures
- B DATA EXCHANGE INSTRUCTIONS OF BEC-SYSTEM
  - B1 General principles of documentation and data exchange
  - B2 Graphical output documents (drawings)
  - B3 Tables
  - B4 STD-90 *(=updated version of physical file format and contents)*
  - B5 Text documents
- C BEC-COMPATIBLE SOFTWARE
- D ADDITIONAL INSTRUCTIONS

## 3. CAD DRAWINGS

### 3.1 Application independent neutral file format for 2D drawings

Data exchange between dissimilar CAD systems is needed mostly by designers in order to communicate with other designers. Standardized neutral file format was defined for the exchange of 2D drawings. The main reasons for not adopting the existing IGES standard were large file size, lack of limited subsets and poor compatibility of available translators. Small file size was considered mandatory for AEC-industry because usually only low-capacity physical transfer methods like PC-discettes or telephone lines are available. The main features of the neutral drawing file format, called "BEC-format", are:

Due to an effective compression algorithm a BEC-file is about 3-5 % of IGES, about 10-20 % of DXF and about 50 % of original native binary file. The file contains ASCII characters only but is not human-readable due to compression.

The logical content is essentially according to ISO/GKS standard for 2D computer graphics with some modifications in order to satisfy CAD-oriented requirements such as layers, symbols, alphanumeric attributes, dimensioning, coordinate transformations etc. The number of entity types is very limited in order to keep translator development simple.

It should also be noted that the BEC-format is application independent and has no bias to precast concrete or construction industry.

### 3.2 Common software library

In order to assure compatibility of various translators and other programs a common subroutine library was developed and was then used as a part of each translator. This library hides the file format, the compression and decompression algorithms and provides a high level programming interface for developers. As an example, a call to the library subroutine

```
GPL( Number_of_points, X-coordinates, Y-coordinates )
```

in a translator program creates a polyline entity into the BEC-file. Most of these subroutines comply with the standardized GKS programming interface.

## 3.3 Translator programs

Using the common software library translator programs were developed for a number of common CAD-systems by various companies:

| | |
|---|---|
| AUTOCAD | Cadex Oy, Finland |
| CADS | Kymdata Ky, Finland |
| DOGS | Tekla Oy, Finland |
| ICEM | Pöysälä & Sandberg, Finland |
| IGDS | Intergraph Finland Oy, Finland |
| MEDUSA | Cadex Oy, Finland in collaboration with CASE & CAD-Engineering, Sweden |
| TECHNOVISION | Technocad AS, Norway |

## 4. ALPHANUMERIC TABLES

The exchange of quantity data (e.g. bills of materials) is mostly emphasized in the communication between design and manufacturing. For this purpose a generic neutral file format TAB for alphanumeric tables was defined.

In addition to the data lines, a TAB-table file consists of a table-definition, a number of table-wide header lines, column headers and a presentation code defining the frame of table. The table-definition defines for each column of the table the format (width, number of decimals, etc) and an invisible column identifier. These identifiers refer to attributes of the product model.

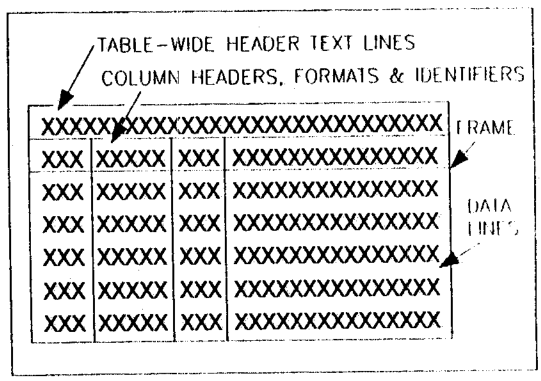

Figure 2. Elements of the neutral TAB-format

Using the embedded table-definition a receiving computer system can extract the desired data regardless of the specific presentation format.

Based on the prescribed generic table format recommendations were given as part of the guidelines on specific tables such as bill of quantities, list of precast concrete components, bending list of reinforcement bars and nets etc.

It may be questioned why alphanumeric tables are needed since the product model file obviously contains the same data. Introducing both was actually a compromise: tables provide product data in a simply manageable form without the complexity of the product model file while still preserving some internal structure. For instance, tables can be printed out as such and are human readable. Tables can also be embedded in drawings and can be extracted.

## 5. PRODUCT MODELS

As a long term basis for data exchange a standardized product model was emphasized. However, an evolutionary transition starting from the exchange of "dummy" drawings to "intelligent" drawings with embedded attribute data and alphanumeric tables was envisioned. A conceptual product model for precast concrete structures was developed to support data exchange on a high logical level.

### 5.1 Generic object oriented product model

The model is based on a generic object oriented model which is shortly characterized as follows:

All data about the "things" of interest, here buildings, assemblies, precast concrete components and their details etc, are described as objects. An object encapsulates all data about a real world "thing" as attribute values and relationships with other objects. The attributes are bundled by classes. A class defines a number of attribute sets, each set consisting of a list of "atomic" attributes. Attribute sets bundle interrelated attributes together. In the physical transfer only the relevant sets need to be included. For a set all of it's attribute values are always included in the physical exchange. A subclass may inherit attribute sets from it´s superclass. The main relationship type is a hierarchical composition or "part-of" relationship. Also a generic "connected-to" relationship is available mainly for the description of physical connections. A "similar-with" relationship allows several instances of a type to be described without redundancy.

### 5.2 Physical file format

The selected physical product model file is based on the syntax of the LISP programming language which provides a close mapping to the generic model, is easily human- and computer-readable and can be flexibly enhanced with new capabilities. It should be noted that the syntax is independent of the data: the file can be interpreted by a software which does not "understand" the contents of the file.

The basic element of the syntax is a list which is enclosed by paranthesis. The first item of the list is a keyword which defines the meaning of the remaining items. Other items of the list are parameters. Any parameter may be a list itself i.e. a hierarchical structure is described by the nested parenthesis. Thus objects can be stored as packages which can be clearly distinguished from other objects. Also complex objects consisting of subobjects can be stored respectively.

```
(OBJ 123456                                   ; Object-id
    (COM 'Cantilever beam at roof level')     ; Comment text
    (POS 6400 7200 15000 1 0 0 0 1 0)         ; Relative position & orientation
    (CLA BEAM                                 ; Object is member of class
        (MAXDIM 6789 300 400)                 ; Values of an attribute set
        (SHAPE  123 45 678)                   ;
    (CLA ... )                                ; Member of another class etc
    (REL 234567 345678)                       ; Relationship with other objects
    (OBJ 4567890 ...)                         ; Subobject etc
)                                             ; End of object
```

Figure 3. Principle of the physical file: presentation of an object (instance). The syntax does not require division into lines as shown here. The Finnish keywords are here tranlated to English

The format allows also the application specific definitions of object classes (i.e. the conceptual product model schema itself) to be presented in a physical file. Actually, this is how the product model definition is presented in the BEC-manual.

## 6. AUXILIARY SOFTWARE TOOLS

A set of software tools were developed for the receivers and users of standardized exchange files:

VIEW: Previewing of BEC-files

PLOT: Plotting of BEC-files on a plotter or laser printer

SPLIT: Division of a BEC-file into smaller drawings with selected layers

COMBI: Combination of several drawings, tables and text files into one drawing

EXTRACT: Extraction of embedded alphanumeric data from graphical BEC-files

TAB: Manipulation of alphanumeric tables in the neutral TAB-format in a various ways, e.g. calculate new values from give values, sum, sort, reformat, modify text strings etc.

BECMOD: Prototype data base management of BEC/STD product model with import/export of neutral product model files in the STD-format.

BECMAN: Management of files and directories

LAYERS: Extraction and combination of selected layers from a BEC-file

MERGE: Merging several BEC-files together

The most urgent needs of the manufactures are related to applications like automated production of hollow core slabs and numerically controlled cutting and bending of reinforcement bars. Therefore the following programs which allow designers to store design information and translate it to standardized formats have been developed and distributed to designers:

OLA: Translation of hollow core slab designs into product model files.

MATE: Editing tables (of materials etc).

## 7. PRACTICAL IMPLEMENTATION

Many companies have adopted their existing computer system to the BEC-standards and some software products supporting the standards have emerged. At national level about 80 % of all design documents are reported (in 1991) to comply with recommendations of the BEC-manual. Exchange of CAD-drawing files is also widely used. Exchange of standardized tabular and product model data is still emerging. Data exchange using the neutral BEC-format has been mainly used in integrated building design projects in which various designers have different CAD systems. Since some of the software tools, especially translator programs for various CAD systems, are application independent they have been adopted to a range of other applications than precast concrete or construction in general. Figures 4 and 5 show some further examples.

## 8. CONCLUSIONS

Very few technical problems have been encountered during the development. It seems that providing simultaneously alternative solutions to data exchange has not been purely fruitful but has also made coordination of various implementation efforts more difficult. The main difficulty, howay, is clearly to achieve the necessary changes in the traditional construction processes so that companies can fully benefit from the potentials of data exchange. The commercial demand of data exchange solutions is still hardly sufficient to support continuous development. It is likely that more attention from now on will be paid on international harmonization.

## 9. REFERENCES

1. BEC-manual, SBK Ry (The Association of Concrete Industry In Finland), May 1991.

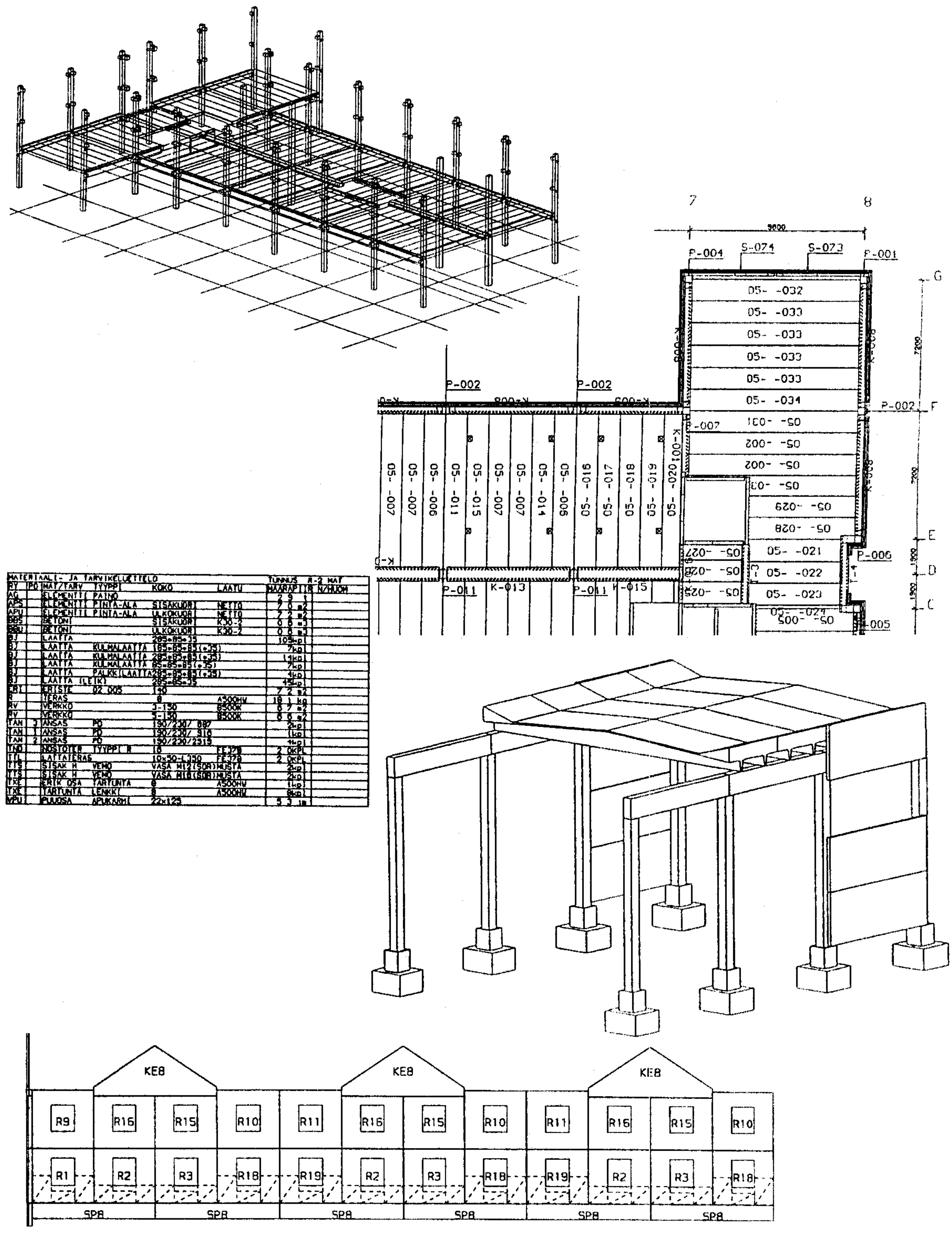


Figure 5. Specialized CAD-system for concrete, steel and wood structures by Cadex Oy supports the BEC product model and the three neutral file formats for data exchange. The system derives various documents from product model data base.

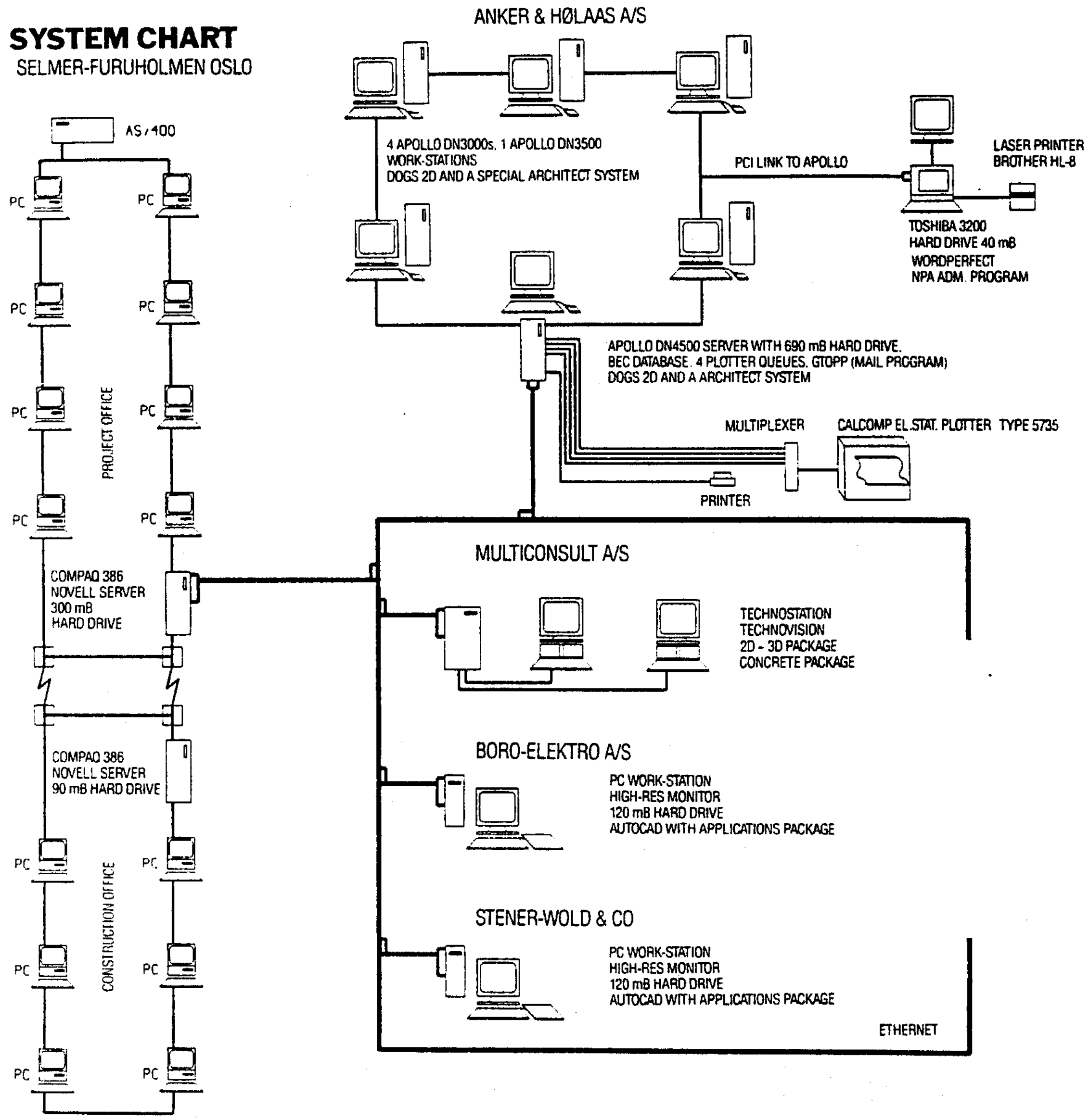


Figure 4. Computer network in an integrated design project "Grönlands Torg" in Oslo. The project is managed by construction company Selmer-Furuholmen Oslo AS. All design is done with different CAD-systems which are integrated by using BEC-format for data exchange.

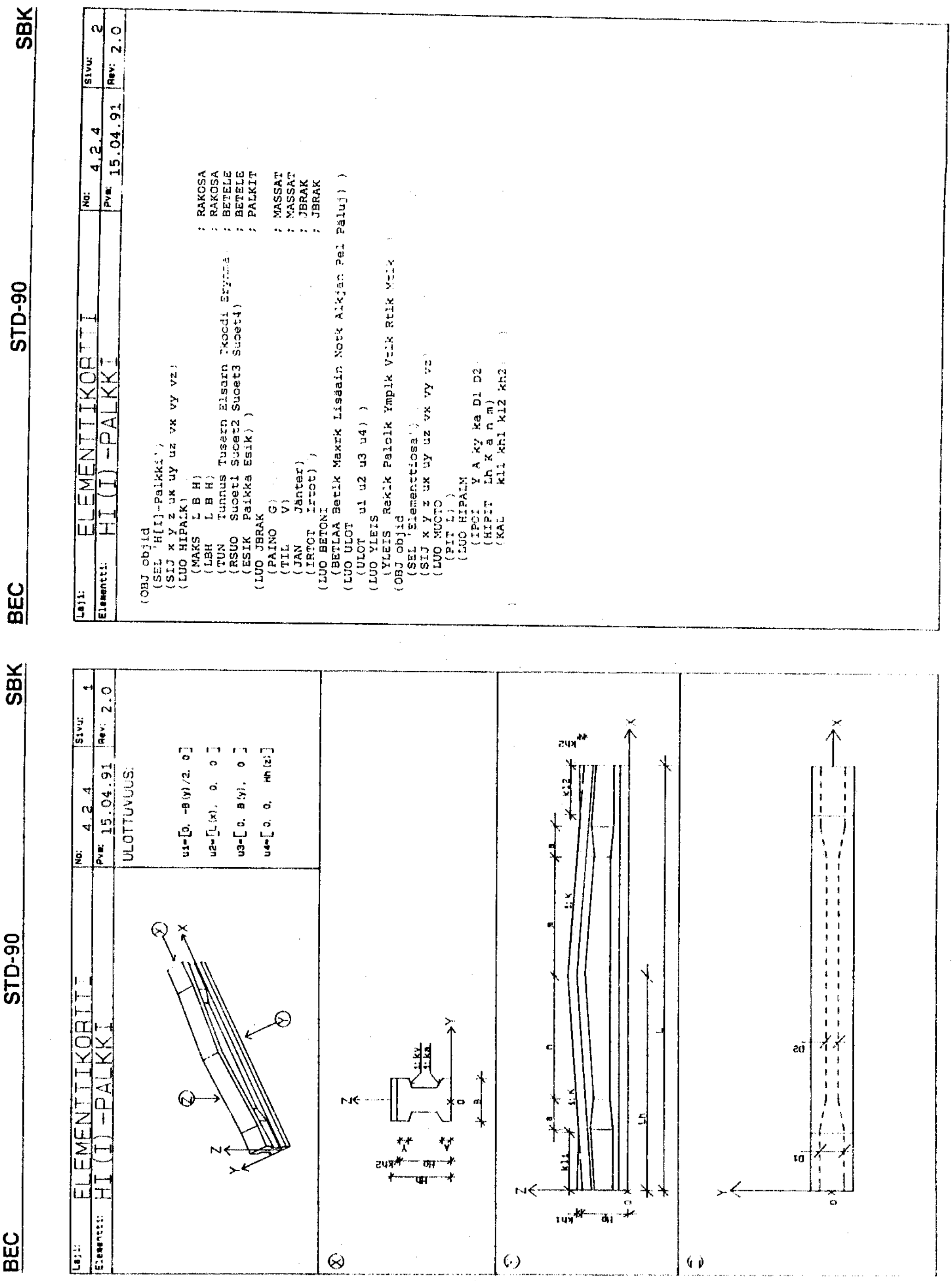


Figure 6. An example of a product data definition card in the BEC-manual. On first page the product specific parameters are defined. On the second page the presentation of product data in the neutral STD file is described.