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ISBA, a Technical Information System for the Construction of Nuclear Power Plants

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ABSTRACT

Civil engineering work for a nuclear power plant requires a vast amount of data. This applies in particular to loads, as normal loads from general structural engineering must be taken into account as well as special loads and faulted loads. The new rules for the Eurocode concerning the combination of load effects intensifies the quantity problem to a higher degree of complexity. Implementation of compatible software systems is essential. The application, however, of separate special software systems, which communicate through interfaces, involves the well-known disadvantages of information loss. Consistent availability of information and data exchangeability are required.

This contribution details a global product data model integrating object-oriented CAD and database technologies which are used for setting up technical information systems. The aim, area and product data models will be clarified. The advantage of this new modeling technique concerning the ability of trouble-free integration is illustrated for representative examples.

1 PRELIMINARY REMARKS

Day-to-day office life without computer support is no longer conceivable. Following the introduction of workstations and their subsequent networking, comprehensive data flow is becoming ever more crucial to planning, especially for larger projects. This report describes an information system which makes all civil engineering project planning data available.

The volumes of data and information to be processed during project planning for nuclear power plants are continuously increasing. This has prompted the decision to create an information system which should contain all data which required for planning, calculation, design and documentation. This system has the task of presenting the administered data in such a way that they can be easily understood as well as enabling fast, reliable access to them. Today, object-oriented CAD systems and databases provide the engineer with tools for realizing what were previously only visions.

2 TASK

The civil engineering information system (ISBA, acronym based on the German) is intended to maintain the information which is of global interest for civil engineering during project planning of a nuclear power plant and for its documentation following project completion.

From a current standpoint, it contains the following individual information:

- Geometric modeling of all components,
- Graphical representation of all loads and their combinations,
- Static system idealization and loading of individual components,

- Construction materials used,
- Integration in determination of construction costs as well as invitation to bid, contract award and invoicing (hereinafter AVA, acronym based on the German),
- Construction sequences for supporting scheduling as well as optimization of construction processes and
- Object-oriented storage of all planning documents and information.

3 FIELD OF APPLICATION

The heart of the system is the 3-D building model.

A central task is that of processing the large number of loads and their combinations to be accounted for in nuclear engineering.

The loads to be considered for can be subdivided into the categories dead weight, operating loads and special loads. The last two categories in particular contain operating conditions which cannot all occur simultaneously. The rules which describe the corresponding dependencies and relationships are implemented in the system and enable automatic determination of the requisite load combinations.

Previously, operating conditions were specified in loading plans and special loading conditions in special loading reports. The possibilities described here enable combination of load collectives in accordance with any desired aspects and allocation for design of static items or components. These can be output as a loading plan, in which the type of data depiction can be selected as desired. Interfaces to design programs for transfer of loads and static systems simplify processing and decrease the number of potential sources of error.

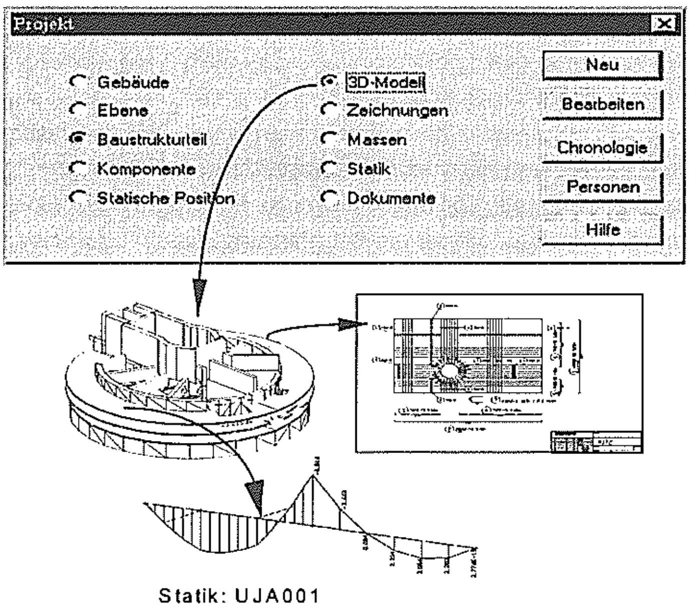

Fig. 1. Civil engineering project management: Information retrieval according to the structure (building, level, structural element ...) and type of information (3D modell, statics, drawings ...).

The materials used, which are also depicted in the model, can be used to determine quantities for the call for bids or calculation. Performance of finishing work planning thus becomes much more straight-forward. The individual objects in the building model are assigned to items in the bill of quantities in an "AVA" program, enabling full use of their functionalities in the system.

This is very advantageous for management of documents and drawings (Fig. 1). Extensive information can be called up by clicking on the component of interest. Object-oriented storage of all planning documents and loads is possible. The planning chronology can also be determined. A viewer enables direct examination of most of the documents on screen. It is thus possible even to retroactively examine the static design calculations in the 3-D model.

All in all, the ISBA civil engineering information system enables substantial rationalization in many areas of civil engineering processing and contributes significantly to quality assurance. The continuity achieved is based on an object-oriented product data model. The following sections explain its formulation, the relationship to practical engineering and programming implementation.

4 PRODUCT DATA MODEL

4.1 Object-Oriented Product Data Modeling

Integrated information processing requires constant availability and exchangeability of all planning data. This affects not only the disciplines of statics, design and construction but also licensing and design modification processes, tracking of planning versions and planning chronology, especially for planning of large structures. A prerequisite for this is the implementation of a global product data model combining the information in the areas listed above and extending to the corresponding requisite degree of detail. The heterogeneous nature of the information requires a correspondingly flexible modeling technology, which is available in object-oriented modeling.

4.2 Modeling of Structural Components

Classification of the structural components is based on the corresponding function in relation to supporting behavior of the structure (walls, ceilings, beams, columns) and accounts for the desired information access based on common structural elements (buildings, levels, rooms, etc.).

The product data model utilizes the inheritance feature in the hierarchical structure. Information and component behaviors are inherited by the subordinate classes from the classes above. Proceeding deeper into the hierarchy involves more precise definition of the special class characteristics.

4.3 Modeling for Load Effects and Combinations

The product data model for load effects must account equally for the various processes in integrated information processing. The following two steps must be accounted for:

- Load combination with *characteristic* values for load effects and
- Verification with *design values* for load effects.

Load figures are defined for the load combination step. Prototypes are available for point loads, line loads, area loads, etc. These are further classified by loads on structural components and room loads. Alternative loads (Fig. 2) are common in power plant engineering.

Marking a load with the attribute "alternative" is associated with an *or* link. If a leak is postulated in a pipe, the most unfavorable load results for the bending design in the center of the field for the geometrically closest structural components. In the example shown, these are loads A_1 and A_2, each of which are applied most unfavorably on walls W 1 and W 2. It is reasonable to combine both loads in a single loading condition, however A_1 and A_2 will never occur simultaneously. These are therefore marked as alternative, that is either A_1 *or* A_2 occurs.

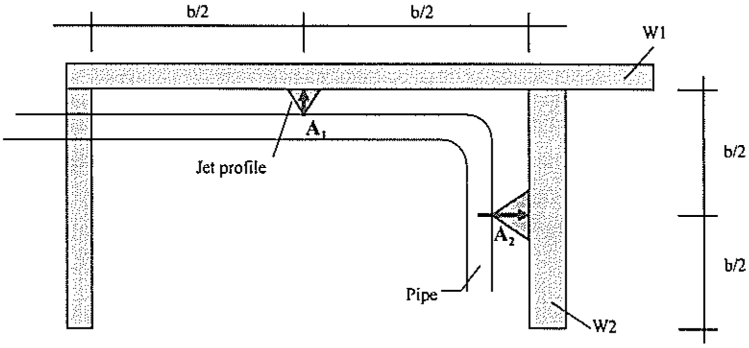

Fig. 2. Alternative Loads.

In the event of extraordinary effects the number of resulting design loading conditions, especially under consideration of alternative loading conditions, is a problem which must not be underestimated:

- Manual compilation of the design loading conditions is impossible; this task must be performed automatically using an algorithm.
- Comprehensive investigation with one calculation model is impossible as the capacity limits of common calculation and finite element method programs are reached.
- The verifiability of the design result which is determined from all of the combinations is highly questionable.

The ISBA technical information system subdivides the problem into its component objects (Fig. 3). The example shown with a combination table of 9 effects and 3 alternative groups results in a total of 186 combination, of which only the first 30 are shown.

In nuclear power plant engineering, special design situations beyond the normal design codes are described for plant design. The design situations are specified in a "General Load Combination Matrix" (Table 1). Depending on the design situation, a *safety level* is defined which must be achieved if a postulated event occurs. Special conditions apply to the safety level for nuclear power plant engineering. If this term is to be applied to the well-known codes and standards such as the Eurocode, two safety levels could be specified: one for the 'continuous and transient' design situation and one for the 'extraordinary' design situation (cf. EC 2 Part 1, Table 2.1).

The General Load Combination Matrix further defines various borderline states for which verification is to be performed. The individual borderline states are as follows:

- VSE: Verification of Static Equilibrium
- ULS.f: Ultimate Limit State
- SLS: Serviceability Limit State

Table 1 lists only two design situations. In real projects, 15 or more design situations are not uncommon.

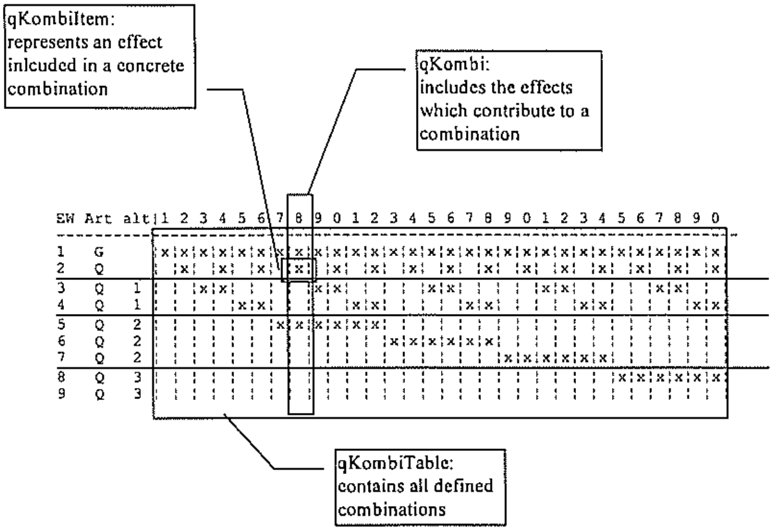

Fig. 3. Concepts of the classes in an existing set of combinations.

Table 1: Example of a General Load Combination Matrix used in nuclear power plant engineering

//Design situation	state	Gk,sup	Gk,inf	Psup,0	Pinf,f	Qk,L	Qk,c	Qk,test	Qk,T	Qk,w	Qk,s	Qk,wl	Qk,E	concrete	rebars
Construction	VSE	1.10	0.90	1.00	1.00		1.50			1.30	1.30				
Construction	VSE	1.10	0.90	1.00	1.00		1.30			1.50	1.50				
Construction	ULS.f	1.35	1.00	1.00	1.00		1.50			1.30	1.30			0.67	0.87
Construction	ULS.f	1.35	1.00	1.00	1.00		1.30			1.50	1.50			0.67	0.87
Construction	SLS	1.00	1.00	1.00	1.00		1.00			1.00				0.60	0.80
Normal Operating	VSE	1.10	0.90	1.00	1.00	1.50			0.80						
Normal Operating	ULS.f	1.35	1.00	1.00	1.00	1.50			0.80					0.67	0.87
Normal Operating	SLS	1.00	1.00	1.00	1.00	1.00			0.60					0.60	0.60

5 OBJECT-ORIENTED FORMULATION OF PROBLEMS SPECIFIC TO CONSTRUCTION, FACILITY MANAGEMENT

5.1 The Room Problem

In power plant planning, the room is the smallest unit with which geometric locations are indicated. For example, the location of a component is indicated with a room number. However, dead weight and loads under operating and faulted conditions are transmitted through foundations, hangers and supports to the surrounding building structural components. Ultimately the building structural components such as walls and roofs are required for dimensioning. Specification solely of the room number is insufficient for civil engineering processing. It is therefore necessary to establish the relationship between rooms and the surrounding building structural components.

The resulting problem is the classic problem of *many-to-many* relationships. This is demonstrated with a simple example in Fig. 4. Consider room R1, surrounded by the four walls W1, W2, W5 and W6. If wall W2 is considered, it can be seen that it separates two rooms from each other. Or, more generally, a room is surrounded by *many* building structural components, and a structural component separates *many* rooms from each other.

Many-to-many relationships cannot be realized without redundancy in database systems utilizing relational design models. Object-oriented database systems (OODBMS) enable the establishment of redundancy-free relationships with *associations* between objects. An association is a persistent link between two objects.

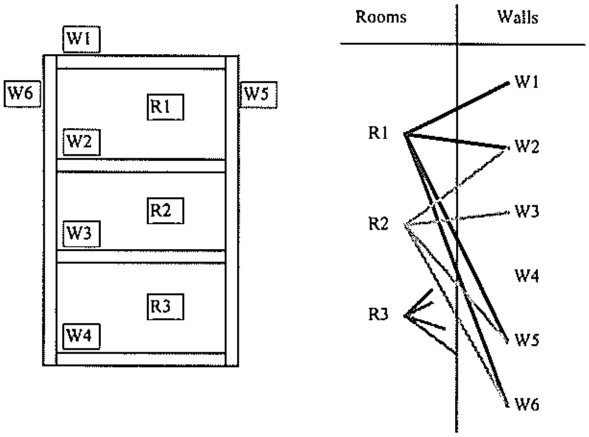

Fig. 4. The room-problem: representation of the many-to-many relation.

5.2 The Room-Wall Problem

Furnishing of a room is determined by its use and function in the plant. This results, for example, in different surfaces for a wall (Fig. 5). Modeling the product data by associations with attributes stores information in the object-oriented database which, although they are inserted for design reasons, already form the basis for determining quantities and costs as well as facilitating visualization.

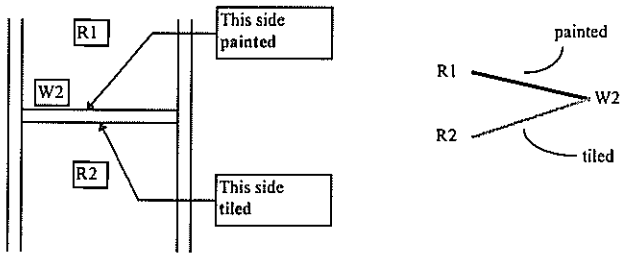

Fig. 5. The room wall problem: attributes of associations.

5.3 Integration in Calculation of Costs and Invitation to Bid, Contract Award and Invoicing (AVA)

The presence of a product data model is advantageous, especially for the effort associated with allocating cost centers and determining accurate material takeoffs. Information between the CAD and AVA programs is exchanged through the persistent objects in a common database.

Utilization and function-dependent volume and surface determinations are automatically possible in the 3-D model with the dimensions of the building structural components and with the information from the room-wall relationships. The ISBA uses these data for efficient and exact cost determination. This is performed in two steps:

- Allocation of building structural components to the items in the cost determination lists.
- Automatic determination of material takeoff, including related costs.

The information is used directly for the invitation for bids in detailed planning.

6 CAD FUNCTIONALITY AND OBJECT-ORIENTED GENERATION OF USER INTERFACE

There is a clear trend in the international market for commercial applications toward object-oriented programming. AutoCAD, for example, is a fully object-oriented CAD system featuring an object-oriented developer interface (ARX). ISBA is based on AutoCAD and makes consistent use of its object-oriented characteristics, as it is also based purely on object-oriented structures. The object-oriented database system Objectivity [4] is used as an external database. The information in the CAD system and database is synchronized at all times by the ISBA technical information system.

The use of a 3-D volume model was a significant criterion for implementation. The advantages are clear, including the following:

- Accurate reflection of actual as-built situation.
- Clear directions of loads (eliminates need for conservative load estimates).
- Clear exchange of information.
- Visualization options.
- Orientation and navigation.
- Automatic collision testing.

Fig. 6 shows the 3-D model of the EPR (European Pressurized Water Reactor see below) as an example. The figure gives an impression of the quantitative scope and qualitative complexity of the geometry of *commonly-used* structures in power plant engineering. The 3-D objects are designed with the CAD system controlled by the ISBA technical information system. Additional technical information is associated with the building structural component as a function of context (wall, ceiling, loading, etc.) and is stored in the database.

Experience with ISBA shows that CAD systems represent a creative basis for implementation of technical information systems. Complete availability of the 3-D model in an external database enables visualization and multimedia presentation of the building structure (including all associated information) even in other environments [5]. (Fig. 6)

7 SUMMARY AND OUTLOOK

ISBA is a technical information system based on object-oriented technologies. It controls synchronous application of CAD and the database system based on an object-oriented product data model.

At first ISBA was developed to provide an information system that supports the civil engineer to process the vast amount of load data which have to be considered in nuclear engineering. Today it can provide information for the whole nuclear power plant and is an ideal tool for facility management tasks. It is a tool for the determination of construction costs, it communicates with finite element programs to perform static and dynamic calculations and it can depict the entire plant in virtual reality thus making accessible the entire information of ISBA.

The (planning) world is growing together with the rapidly developing possibilities for communication and visualization (ISDN, Internet, multimedia). Cooperation between all of the civil engineering planners involved in construction is becoming increasingly closer, and is no longer restricted to the confines of regional borders. ISBA with its interfaces to all these possibilities is prepared to meet this challenge.

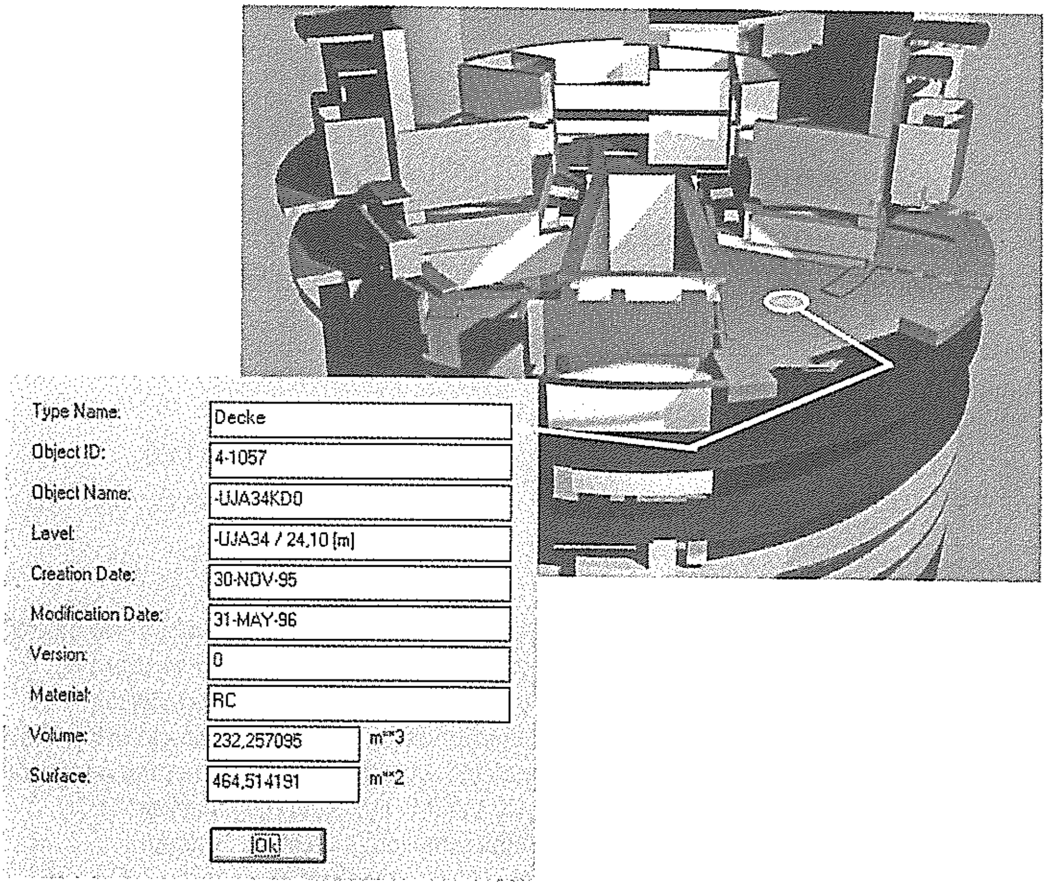

Fig. 6. Visualization with the help of multimedia of technical design information shown for the example EPR (European Pressurized Water Reactor)

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