

# INTEGRATION OF CONSTRUCTION, CALCULATION AND DOCUMENTATION "THE STRUCTURAL EDITOR"

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**ABSTRACT:** *This paper presents a methodical and consistent concept for modeling and computer-aided support of Structural Reports. The concept includes the object-oriented model of the Structural Report and the specification of the Structural Editor. The Structural Editor integrates construction, calculation, documentation and checking of a structural system and enables a distributed application in a computer network.*

**KEYWORDS:** *Structural Report, Technical Documentation, Collaborative Engineering*

## 1. INTRODUCTION

Modern computer and network techniques offer sufficient support for technical documentation and collaborative engineering, which are important tasks in civil engineering. Civil engineering is a conservative discipline in the use of computer networks. The main reason for this point is, that every civil engineering project is an individual project. Each particular project requires an individual planning process, considering specific attributes like the natural environment or the composition of the involved experts and companies. In contrary to the mechanical, chemical or motor industry there is no in-house mass production. So the use of modern computer and network techniques in civil engineering has special and high requirements, which makes it a demanding task to develop and apply them for practical civil engineering projects.

In the field of civil engineering the Structural Report is one important technical document. This report documents the construction, analysis and dimensioning of a structural system. The Structural Report as a technical document consist of text, graphics and tables, all of them are structured in paragraphs and chapters on standard size pages. The process of setting up the Structural Report is iterative and involves the architect, the structural engineer, the checking engineer, the draughtsman for the construction drawings and the supervising engineer on the construction site. The structural system is selected and calculated by a structural engineer for a given architectural design, which is mostly specified in drawings. In Germany the Structural Report is checked by a government-appointed engineer. The detailed construction drawings for the building site base directly on the structural system documented in the Structural Report. The experts involved in the structural planning process strongly depend on mutual exchange of information, which is part of the Structural Report.

A lot of research and commercial software systems exist for the different working steps of the Structural Report. Examples are technical software for structural analysis and design (e.g. FEM), CAD-software for technical drawing and desktop-publishing software for technical documentation. Interface definitions allow to exchange information between the software systems. Standard interface definitions (e.g. STEP, RTF, DXF) are mostly combined with information loss, special interface definitions depend on the software and are not generally useful. A consistent concept to integrate construction, calculation and documentation information of the Structural Report in one information system applicable in a heterogeneous network environment does not exist.

This paper presents a software independent concept for an information systems in civil engineering, which integrates the construction, calculation and documentation information of the Structural Report. The concept includes a consistent generalized model of the Structural Report and the specification of the related software called Structural Editor.



## 2. MODELING CONCEPT

The Structural Report consists of a complex and diverse information structure. In the modeling of the Structural Report a lot of requirements have to be taken into account. To consider all necessary conditions an advanced object-oriented modeling technique has been used to model the Structural Report and to specify the Structural Editor. The concept was developed as a research project completely independent of any commercial software product in this domain to identify the fundamental model properties and useful modeling techniques. The complete concept is documented in Molkenhain [1]. The main idea of the presented concept is the generalized description of the Structural Report with three independent models:

- Structural Model
- Presentation Model
- Media Model

The interactions between these models are defined separately in the global model of the Structural Report. All four parts, the three partial models and the global model of the Structural Report are modeled object-oriented using the notation of Rumbaugh [3] with some extensions. The components of the Structural Report are described by classes of complex objects using the principle of aggregation. The relationships between the components are described by classes of linking objects using the principle of association. These classes are designed to transfer information between the linked objects. Using the principle of generalization/specialization the model can be easily adapted and extended deriving new classes for specific types of elements. Frequently reused element types are defined as standardized classes, which can be used to extend the model by the composition of new classes for complex objects.

The object-oriented technique provides the fundamental feature to treat functions equivalent to data. This is indispensable to the Structural Report. The structural system and its structural state are described by data, the structural behaviour (response) is defined by functions. In common analysis software the structural system and its structural state are saved as a model in a (object-) database. The structural behaviour however is part of the software, which is used to edit the model. In this new concept however, the structural behaviour is part of the structural model and independent of software.

The Structural Report is composed of a large variety of different types of structural, presentation and documentation elements. The form, layout and composition of a Structural Report is not standardized. Each engineer is free to use his own documentation technique, it is not possible to specify all conceivable types of the used elements. The technical progress in civil engineering demands for continuous changes in technical standards and rules. This circumstance is reflected in the model of the Structural Report by the principle of generalization and standardization. The engineers as user can extend and adapt the model to consider the technical progress and his individual documentation techniques.

The Structural Report has a nonlinear information structure given by the structural system to be documented. The structural system consists of structural members, which are linked for load transfer and support. So the structural system can be represented as a complex network of linked structural members, which indeed is nonlinear. The traditional sequential documentation form of the technical report cannot represent nonlinear information structures explicit. Cross references are frequently used as a rudimentary form to present nonlinear information structure. This way is insufficient, especially for the checking engineer and can be replaced by an explicit consideration of nonlinear information structures by hypermedia elements.

Analysis software to calculate and to dimension a structural system is available on the market in a great variety and on a high quality level. These systems have been developed over a long time span and are well proofed in practice. They are mostly up to date in the numerical and the engineering part but not completely compatible to modern information and communication techniques. These systems can be reused to describe the structural behaviour of the structural members.

### **3. STRUCTURAL REPORT**

#### **3.1 Structural Model**

The structural model consists of structural objects. These objects describe the structural members such as slabs, beams and frames of concrete, steel or wood. Structural objects are specified in a generalized manner by one class. Common attributes of all types of structural objects like the consistency of the structural state are members of this class. Frequently used elements like crosssections, materials or load forms are described by standardized classes and objects in libraries. These libraries can be used to extend easily the structural model composing new classes and objects for structural members.

The generalized class considers the structural behaviour by virtual functions. The virtual functions are overridden in the derived classes for special structural members. The structural behaviour is described by numeric algorithms for solutions of differential equations and by calculation- and construction rules of technical standards. So, the structural model contains the structural system, its structural behaviour and its structural state. Existing analysis software can be easily reused to model the structural behaviour of the structural objects. The affiliated class functions in the structural model can start analysis software directly via system calls. The necessary data transfer can be performed by the data interfaces of the analysis software or with IPC techniques. The reused analysis software is not subject to modifications.

The structural objects are coherent units with no information about their environment in the structural model. Load transfer between structural members and supports of structural members are modelled with structural joints which are linking objects. The structural joints are described by one class, which includes virtual functions for the information transfer between two or more structural objects. These functions are overridden for special structural joints. One example of a special structural joint is the link between a beam and a column. The functions of this structural joint transfer the bearing-load of the beam as a concentrated load to the column and the width of the column as bearing-width to the beam.

#### **3.2 Presentation Model**

The presentation model contains the presentation objects of the Structural Report. Examples are texts, formulas, tables or diagrams. Presentation objects are specified by one generalized class. Common attributes of all types of presentation objects like width and height are members of this class. Functional dependence like the geometric alignment is considered by virtual functions which are overridden in the derived classes for special presentation objects.

Frequently used elements like words and values or parts of technical standards are described by standardized classes and objects in libraries. Values are the presentation of physical scalars with data and physical units. Each value has an active physical unit. The engineer can choose his own active physical units. The conversion of the value data by a change of the physical unit (e.g. [m] → [cm]) is modeled by functions in the class value.

The presentation objects are coherent units. They have no information about their environment in the presentation model. Cross references are used to transfer data of values between presentation objects. Calculation rules are used to describe functional dependence between presentation objects. Cross references and calculation rules are modelled generalized with presentation links which are linking objects. One example of a special presentation link is a copy link between a table to calculate horizontal loads due to wind and a dialog box with the load-summary of a supporting wall. The functions of the linking object copy the data of a table value to a value of the dialog box.

In addition to the described traditional presentation elements of technical documents the presentation model can be extended to provide advanced presentation elements. Examples are multi-media elements with video and three-dimensional visualization. Structures are naturally three-dimensional and have a time dependent behaviour. These new presentation elements define a higher presentation level for the structural system information. Examples are the three-dimensional model of a reinforced concrete construction, the animation of a tower vibration, of instationary flow of water, heat and sediment or of the construction sequence.

### 3.3 Media Model

The media model contains the media objects of technical documents. Examples are reports, drawings and sheets. Technical documents are specified in a generalized manner by one class, which holds common attributes and functions of all types of technical documents. The technical report is the documentation form of the Structural Report. Technical reports are composed of pages, paragraphs and media windows for the geometric arrangement. Chapters and tables of contents define the semantic structure. The geometric alignment of media windows inside paragraphs and of paragraphs inside pages are modelled with functions in the classes paragraph and page. Media windows define the areas to project presentation objects within a technical document. They are defined standardized in one class which is used in all types of technical documents.

The technical documents are coherent units. They have no information about their environment in the media model. Book functionality is used to combine the technical documents of an engineering project. These relationships are modelled generalized with media links which are linking objects. One example for a special media link is the summary of technical reports in one book. The functions of the media link transfer information for a continuous numbering of the pages and chapters in all linked technical reports. A second example for media links are interactive hyperlinks, comparable to HTML-- links.

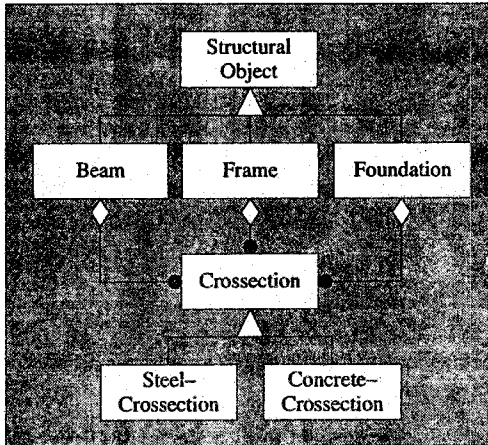


Figure 1. Part of the Structural Model

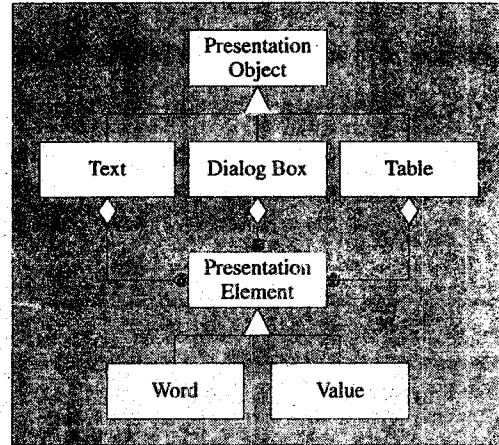


Figure 2. Part of the Presentation Model

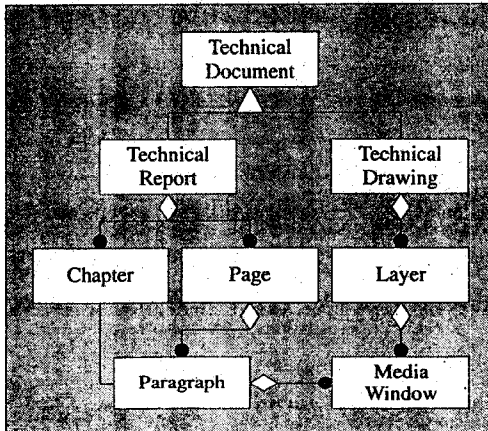


Figure 3. Part of the Media Model

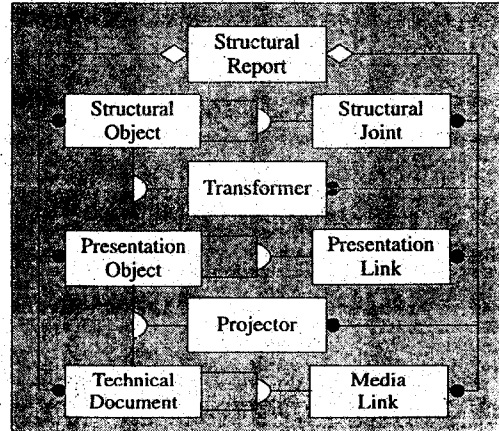


Figure 4. Model link in the Structural Report

### 3.4 Model Link

The interactions between the three presented models are described by linking objects in the global model Structural Report. Structural objects and presentation objects are connected by linking objects called transformers, presentation objects and media objects by linking objects called projectors.

The task of a transformer is the information transfer between the abstract data of a structural object and the visible data of a presentation object. For example the geometric data of a frame as a structural object is transformed into polygons and lines in a diagram as a presentation object. Transformers are described by a generalized class with virtual functions for the information transfer. These functions are overridden to link special structural objects and special presentation objects. The task of a projector is the transfer of data like width and height of a presentation object to a media window in the media model. This information transfer is performed by one function in the class projector.

This concept defines a  $n1 : n2 : n3$  association between structural objects, presentation objects and media objects. Structural objects can be presented in several presentation objects. Presentation objects can be projected in several technical documents. For example the attributes of a beam can be presented in a dialog box (length and support), in a table (loads) and in a diagram (displacements). A table of steel construction members can be used in a Structural Report and in a construction drawing.

Especially this feature is an important advancement compared to the common documentation- and CAD-systems in which a presentation object is always projected in one single technical document. The distinction of documentation systems and CAD-systems can be replaced by a flexible toolset with report and drawing elements and corresponding functionality. The use of a distributed object base system can realize the network-wide interaction of the different software tools.

### 3.5 Engineering Project and Technical Office

The principle of setting up three independent models can be generalized for all types of engineering projects and can be extended to a virtual technical office. An engineering project integrates as a global model all computer models of the planning and execution process subjects. Aside from the Structural Report the architectural design, the construction drawings and the execution schedule can be managed in the described way of the Structural Report. The documents and models of an engineering project can be semantically linked with linking objects to a completely integrated construction planning and execution model. The different experts e.g. architect, structural engineer and draughtsman can communicate and cooperate directly using one distributed information system in a network environment.

In addition to the integration of technical documents and engineering models in an engineering project the technical office itself can be modeled. Desktop publishing systems and documentation systems contain a lot of useful elements of technical offices to manage technical documents. But they do not manage associated engineering models like the structural model. Desktop conferencing software is available to realize the communication components of a technical office. But they can only exchange visible elements, no abstract data or functions of the engineering models. Therefore the concept of the Structural Report has been extended by some simple classes to demonstrate the fundamental properties of a computer supported technical office.

One examples for this extension are archives. The technical office contains three kinds of archives: central archive, local archive and personal archive. The archives are modeled with one generalized class and three derived special classes. The classes are specified for the management of all types of models (engineering, presentation and media models) and for information retrieval with technical, economical, ecological and organizational aspects. The personal archive is normally the desk of an engineer. The engineer manages and edits the technical documents and associated engineering models in this archive. The local archive is the shared domain of a (distributed) workgroup, the central archive is the shared domain of a whole company.

#### 4. STRUCTURAL EDITOR

The Structural Editor is the tool set for the computer-aided preparation and approval of Structural Reports. The editor was implemented in a pilot version to demonstrate the applicability of the concept. It is no commercial product yet. The editor is based on UNIX, C and X-Window. The new modeling concept for Structural Reports contains features, which cannot be implemented in conventional software. Conventional desktop-publishing systems are restricted to visible objects. Relationships between these objects on the basis of physical behavior can not be handled in such systems. In the new concept, the interdependence between the structure and the technical report is part of the model. This is reflected in the functionality of the Structural Editor. One example of the new functionality is the visualization of the relationships between the different load bearing mechanisms, of which the structural system is composed. Another example is the computer-aided control of the load transfer between the load bearing mechanisms by the engineer. These two features and the tools for the user interface and the information management are described in the following sections.

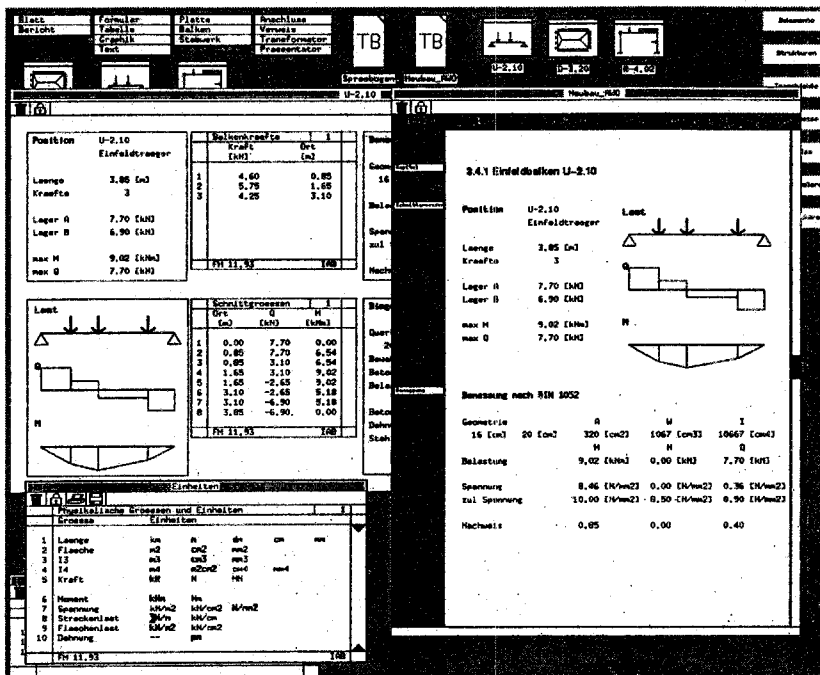


Figure 5. User Interface of the Structural Editor

#### 4.1 User Interface

The user interface of the Structural Report was implemented using the toolset "Desktop-Dienste" (Molkenthin/Laabs [5]). Common GUI Builders are available to build user interfaces on a high level with small effort. But they are mostly specified "policy free". This means, that powerful UI elements are provided, but the rules to combine them and to adapt their attributes have to be defined by the user. Such tools are insufficient for special disciplines like civil engineering, where the policy of an user interface can be fixed. The functionality of the "Desktop-Dienste" is designed for applications in civil engineering. The special attributes and functions to support engineer editing techniques are integrated directly in the classes of the desktop objects. For example the class table includes special functionality like the considering of physical values, staggered rows, mixed row and column calculation variable presentation formats, sorting and searching functions or the identification of local and global extrema. Common GUI Builders do not support these functionalities.

## 4.2 Object Base System

Commercial object base systems, which can handle class functions persistent and distributed in a computer network, are available only recently. For the information management of the Structural Editor an object base system (OBS) with the desired features has been developed [6] and used for the information management in several civil engineering applications. The main feature of the OBS are:

- Class inheritance to realize the principle of generalization/specialization
- Persistent pointer attributes to realize the principle of association
- Objects as attributes to realize the principle of aggregation
- Class and object libraries to realize the principle of standardization
- Class attributes and object attributes (persistent and transient)
- Class functions and object functions (persistent and transient)

Persistent class functions are necessary to consider the structural behaviour of structural members in the model of the Structural Report. The source code of the functions is stored in the object base and automatically compiled and linked to a separate class process. A function call in the application process initiated the execution in this class process using a RPC-technique based on semaphore and shared memory.

The object base system consists of the object base service (OBI) as application programming interface and the object base editor (OBE) as user interface of the object base system. The OBI allows the software developer to transform the concept of object oriented modeling directly into object oriented programming. The OBE presents all information of an object base with textual and graphical elements. The user can edit objects and classes of the object base. This enables an interactive adaptation and extension of a model by the user (engineer) independent of the software developer.

## 4.3 Visualization of the Information Structure

The documentation form of the technical report has a linear information presentation, structured by the sequence of pages and paragraphs. This is insufficient for the presentation of nonlinear information structures like the structural system and of functional information like the structural behaviour. For this reason, the Structural Editor includes the functionality of hypertext-systems and expert-systems.

The relationships inside the structural model are presented with hypertext entries in dialog boxes and tables. Figure 7. shows these instruments on the user interface. Tables and dialog boxes for structural joints ("Anschluss") include the names of the linked structural objects ("Tragobjekt"). The user can navigate easily in the information structure. By the selection of entries, he gets new tables and dialog boxes for the selected structural objects and structural joints. This method for visualization and navigation is used for all types of linking objects in the model Structural Report.

Another example for hypertext features is an editable browser for the structural model ("Tragwerksmodell"). The structural objects are presented as nodes, the structural joints are presented as edges. The consistency status of the structural object and the structural joints is considered by color and line-width. The entries of the graphic presentation are editable to get dialog boxes for the structural joints and objects and to define new connections between the structural objects.

The visualization of structural behaviour is realized by the integration of the objectbase editor OBE. The functions model the structural behaviour are presented in their description language. In the pilot version the language is "C"(Figure 6.). For a commercial development it is necessary to use an engineering language to describe the structural behaviour. The specification of such a language is a research project for the future. The visualization of structural behaviour supports the checking engineer in understanding the supposed structural system. This feature is an important improvement compared to conventional checking of Structural Reports.

The screenshot displays the Integrated Object Base Editor interface. It features several panels:

- Class Definitions:**
  - Tragobjekt:** A class with attributes like `name` (string), `id` (string), `transformator` (long), `anschluss` (long), `steuerung` (long), `konstante` (long), `setzeTragobjektInkonsistenz()`, `setzeTragverhalten()`, `tragehalten()`, and `destroy()`. Methods include `setzeTragobjektInkonsistenz()`, `setzeTragverhalten()`, `tragehalten()`, and `destroy()`.
  - Balken:** A class with attributes like `querschnitt` (double), `lagerkraft` (double), `anzahl` (long), `u` (double), and `h` (double). Methods include `querschnitt()`, `lagerkraft()`, `anzahl()`, `u()`, and `h()`.
  - Kraft:** A class with attributes like `wert` (double) and `wert` (double). Methods include `wert()` and `wert()`.
- Methodenliste:** A list of methods for each class, showing their signatures and return types.
- Variablenliste:** A table listing variables, their types, and associated classes.

Attribut	Datentyp	Speicher	Dim	class	W	Periode
1	querschnitt	Zeiger	Skalar	1	querschnitt	009811
2	lagerkraft	double	Skalar	2	lagerkraft	peristote
3	anzahl	double	Vektor	2	anzahl	peristote
4	u	double	Skalar	1	u	peristote
5	h	double	Skalar	1	h	peristote
- Code Editor:** A window showing C++ code for the `Balken` class, including methods like `setzeTragverhalten()`, `tragehalten()`, and `destroy()`.

Figure 6. Integrated Object Base Editor

The screenshot displays the Visualization- and Control-Instruments interface, showing various data tables and diagrams:

- Tragobjekte:** A table listing objects and their consistency.

Tragobjekt	Typ	Konsistenz
1	Balken	konsistent
2	Balken	inkonsistent
3	Balken	konsistent
4	Balken	konsistent
5	Balken	konsistent
- Ereignisse:** A table listing events.

Sender	Richtung	Anschluss
1	U-1.0	Vorne
2	U-1.16	Vorne
3	U-1.16	Vorne
4	U-1.8	Vorne
5	U-1.24	Vorne
6	U-1.24	Vorne
- Netzplan:** A network diagram showing connections between nodes U-1.0, U-1.16, U-1.24, U-1.40, and U-1.32.
- Positionenplan Tragerrast:** A diagram showing the positions of objects U-1.32, U-1.8, and U-1.24.
- Tragerrast:** A table listing the structure of the support system.

Tragobjekt 1	Tragobjekt 2	Steuerung	Konsistenz
1	U-1.0	U-1.16	inkonsistent
2	U-1.8	U-1.24	inkonsistent
3	U-1.16	U-1.32	konsistent
4	U-1.16	U-1.40	konsistent
5	U-1.24	U-1.32	inkonsistent
- Anschluss:** A table listing connection details.

Anschlussart	Tragobjekt 1	Tragobjekt 2	Konsistenz	Steuerung	Lastabtrag
Balken_Balken	U-1.8	U-1.16	inkonsistent	Ereignis	1 -> 2, 2 -> 1
- Tragobjekt:** A table listing object details.

Typ	Position	Titel	Konsistenz	Steuerung
Balken	U-1.32	Einfeldträger	konsistent	Automatisch
Balken	U-1.32	Einfeldträger	inkonsistent	Tragverhalten
- Tragerrast:** A table listing the support system details.

Anschlussart	Tragobjekt 1	Tragobjekt 2	Steuerung	Konsistenz
Balken_Balken	U-1.16	U-1.32	Ereignis	konsistent
Balken_Balken	U-1.24	U-1.32	Ereignis	inkonsistent

Figure 7. Visualization- and Control-Instruments



#### 4.4 Control of Information Flow

The Structural Report is a complex graph of linked objects. The modification of the attributes of one object can cause a lot of information transfer inside the graph. For example the change of the roof-loads can cause changes of the loads for many structural objects and possibly a necessary modification of the construction by the engineer. The information transfer in the graph has to be supported by different kinds of control mechanisms.

The requirements for the control mechanisms are dependent on the linking objects. Projectors and transformers need an automatic control of their information transfer without any interaction of the user. The information transfer of structural joints must be under control of the structural engineer. He decides which load transfer has to be carried out and which structural joint can remain in a inconsistent status. For this reason, three different control mechanisms are considered in the Structural Editor:

- automatic transfer
- manual transfer
- event-oriented transfer

For commercial implementation it would be useful to consider more than these simple mechanisms.

All classes of linking objects are derived from one class. The control of the information transfer is defined generalized by attributes and functions in this class. A linked object announce a change to its linking objects. The linking objects check the relevance of the change and register the status of consistency. The automatic mechanism transfers the information without an interaction of the user. The manual mechanism leaves the link in the inconsistent status. The user can activate the information transfer manually with the instruments of the user interface described in section 4.3

The event-oriented mechanism ascertains all necessary information transfer in the network by events in an event queue. Each event ("Ereignis") is associated with the information transfer of one linking object. The event queue is presented by a table on the user interface. The engineer has a general view of the effect caused by a change in the graph. He can manipulate the queue and activate the desired information transfer by selecting events in the table.

The described control mechanisms are an important improvement for the setting up and checking process of the Structural Report. The influence of a change in the structural system can be easily identified using the event-oriented control. This is a powerful support of the structural engineer as well as the checking engineer to assess a change and to check the completeness of the performed modifications in the structural model.

## **5. FUTURE PROSPECTS OF THE COMPUTER-AIDED STRUCTURAL PLANNING**

The concept to integrate construction, calculation and documentation in the computer model of the Structural Report enables a new kind of structural planning sufficiently supported by information technology. The traditional structural planning process will change to a modern computer-aided collaborative engineering process. Precondition to this change is the availability of modern application software, the ability of the engineers to use modern information techniques and a revision of engineering techniques. The first condition has to be granted by the commercial software developer. The second condition has to be realized in the education and training area, where applied computer science in civil engineering ("Bauinformatik") has to become equivalent to other basis subjects like physics or mechanics. The revision of engineering techniques includes the technical standards, the working process and the technical documentation form.

### **5.1 Commercial Software Development**

The commercial development and practical introduction of a toolset for computer-aided structural planning with broad functionality like the Structural Editor is a long term project. Some developers favour a gradual improvement and extension of existing software, others believe, that modern software quality and functionality can only be achieved with a new project. The author agrees with the latter opinion. In the new project the modular core of a modern software tool has to be specified and implemented. In a second step existing software with valuable engineering knowledge and experience but aged software technology can be reused by the modern software-(re-)engineering tools.

Core of a commercial software development is the generalized model of the Structural Report stored in a commercial object base system. This core contains all generalized information of structural, presentation and media objects and the transformer and projector objects to link them. The structural model is completely stored with all specialized properties in this object base system. The structural behaviour can be described by the calculation parts of exiting analysis software. The way to reuse such software is described in section 3.1

The user interface and the special presentation and media elements can be realized by modern desktop-publishing systems like Interleaf or FrameMaker. These systems include an object-oriented model for the desktop and for documents and provide application program interfaces on the base of IPC. These interfaces can be used to implement the information transfer of the transformer and projectors to link objects in the desktop-publishing system and in the core model in the object base system. CAD-systems can be integrated in the same way.

The communication and cooperation of the involved expert can be supported on several level. Using a distributed object base system it is possible to exchange information on the object and class level. The integration of desktop conferencing software like InPerson enable the exchange of the visible presentation elements. Modern desktop-publishing systems provide hypertext functionality and interfaces to the world wide web (WWW), which can be used to exchange documents with nonlinear information structure like the Structural Report. With the recent development of Java functions can be transferred in a heterogeneous network. This feature would open a new dimension in the use of the internet. The application of this techniques for models in civil engineering is a research task.

### **5.2 Technical Standards**

The equivalent treatment of functions and data in the model Structural Report allows an innovative concept for the definition and use of technical standards. Technical standards for structural members can be defined as classes in a standardized engineering notation (e.g. STEP, EXPRESS). These classes are independent from commercial software and contain the calculation and construction rules of structural members. The definition and checking of these classes can take place in a central standardization-institute (e.g. ISO). The classes form the core of commercial software. A change of a standard would have a reflection on the classes of the structural model and not in the used software. The adaption of the structural model can be performed by the user himself or can be provided as software independent class libraries on the market.

### **5.3 Distributed Application**

The Structural Report is the information base of the structural planning process. The involved experts cooperate by an iterative exchange of these information. Using the computer model of the Structural Report the traditional communication methods like mail, phone and fax can be replaced by a modern collaborative engineering method in a computer network.

A simple method to exchange Structural Reports via computer network has been described in Rucker [4]. In this project the Structural Report has been translated into a HTML document. Using the interactive features of HTML and the WWW browser Netscape the structural engineer and the checking engineer can edit the same technical document.

The full potential of a computer network can be exploited by an internal integration of the network. One example is a distributed object base system. The used object base system has been extended with a network component based on the client-server concept. The model of the Structural Report and the Structural Editor are stored on separate machines. The Structural Report is stored on one or more server machines. The Structural Editor is running on local client machines in the offices of the involved experts. It can be adapted to several versions with special functionality for the different experts (architect, structural engineer, checking engineer, construction engineer). The OBS manages the distribution of the information, the access of the different clients and the consistency of the information base.

This concept enables a lot of useful features for collaborative engineering in a world-wide network. For instance, a civil engineer at the building site can communicate directly with engineering colleagues in other locations of the world. He has to be equipped only with a portable computer as client machine, a satellite link as a network interface and the Structural Editor as software. In this way he can get all relevant information of the structural system and the applied construction drawings just in time.

### **5.4 Technical Documentation**

The traditional documentation form is fixed by the use of paper as the main information carrier. The use of computer models enables new sufficient documentation forms like hypertext or multimedia elements. This progress in technical documentation can only be used, when the law and regulation in civil engineering changes. In Germany the Structural Report is an official document which has to be submitted and stored in printed form. The use of nonmaterial documents can only be introduced if all security problems are solved. This is a general task in computer sciences and not only in civil engineering. But it has to be demanded by the engineering disciplines.

### **5.5 Project Management**

The developed concept integrates all technical information of the structural planning process. This is indeed an improvement for the field of civil engineering but it is not complete for practical engineering projects. In building and engineering projects the technical execution is only one part of the whole project. Economic and ecological aspects become more important planning factors. For a sufficient computer supported project management a higher integration level has to be found. On this level business management, facility management and technical management have to be considered equivalently.

A simple method to integrate economic and ecological aspects with technical information is to link economic and ecological objects to the corresponding technical objects. The economic or ecological objects are part of an economic or an ecological model. Comparable to the model link between the presentation model and the structural model with transformers as linking objects new classes of linking objects can be defined. For example to support this part of the cost accounting, economic objects which include material and execution costs can be directly linked with structural members by calculators which are linking objects. For a complete integration of all important parts of project management a global concept has to be developed. Nevertheless this concept has to integrate all technical information like the Structural Report completely and can not be specified independent of the structure.

## 6. CONCLUSION

The presented concept for the computer-aided modeling and application of Structural Reports is an important step to a completely computer-aided structural planning. It integrates design, construction, calculation and documentation of structural systems in the model of the Structural Report and creates new efficient functionality in the Structural Editor. Important advantages of the presented concept are:

- Integration of the structural behaviour and the structural state in the structural model
- Visualization of structural behaviour, load transfer and technical instructions
- Mechanisms to control the load transfer in a structural model by the engineer
- Explicit presentation of nonlinear information structures (hypermedia)
- New presentation forms using multimedia elements
- Extensibility and Adaptability for the progress in civil engineering and computer sciences
- Distributed application in a computer network: "Collaborative Engineering"

The future task for research in computing in civil and building engineering is to develop standard models with the desired features. These models are the base for the computer-aided integration of design, analysis, documentation and execution of engineering projects up to a global system for project management. Important initial stages for these research tasks have been derived from the computer-aided application of the Structural Report.

The presented concept for modeling and computer-aided application of the Structural Report is only a small contribution to these future developments. It shows however, that the use of modern computer technique has a great innovation potential in civil engineering.

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