PRODUCT MODELLING AND DATA EXCHANGE FOR CONSTRUCTIONAL STEELWORK

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ABSTRACT: The paper includes summaries of three national development projects, which all deal with product modelling and data exchange of structural steelwork. Two of the projects belong to Finnsteel technology program, one belongs to Vera technology program and both these programs are organised by Technology Development Centre of Finland (TEKES). In all the three projects product data models applying ISO 10303-11 (EXPRESS) and product data exchange based on ISO 10303-21 have been used to define the models and to carry out the data exchange between organisations and between disciplines. The views to structural steelwork have been different in all the projects. The experience obtained in the projects is a good starting point to the new century with its challenges. The most essential results of the three projects are presented and summarised in the paper.

KEYWORDS: product data technology, data exchange, constructional steelwork

1. INTRODUCTION

One concept to start the design of steel structures is a geometrical modelling (including detailing, Salonen et al, 1998). After that, follow such tasks as structural analysis, strength check, costs analysis, fabrication, transportation, erection, renovation, and finally re-use of steel structures. Also, the information transfer to and from other disciplines such as architects and other designers, main contractor, developer, financial institutes, owners and end users of the building is important during the life cycle of the building. The simplified design process of steel structures is presented in the Fig. 1. Note, that a box in the figure means file, not action.

In this paper, three national development projects, which all deal with product modelling and data exchange of structural steelwork presented in Fig. 1 (with notation STEP-file) will be summarised.

The use of neutral formats when transferring data between disciplines and organisations is recommended (Heinisuo, 1997). The two parts of ISO 10303 Product data representation and exchange, also known as a STEP standard (ISO, 1994a), 11 (ISO, 1994b) and 21 (ISO, 1994c), are widely used as stand alone tools in practice. This means that we are working in a hardware and software independent environment.

In all the three projects product data models applying ISO 10303-11 (EXPRESS) and product data exchange based on ISO 10303-21 have been used to define the models and to carry out the data exchange between organisations and between disciplines. The views to structural steelwork have been different in all the projects.

- **APPLIED 4.5-D DESIGN PROCESS OF STEEL STUCTURES:**

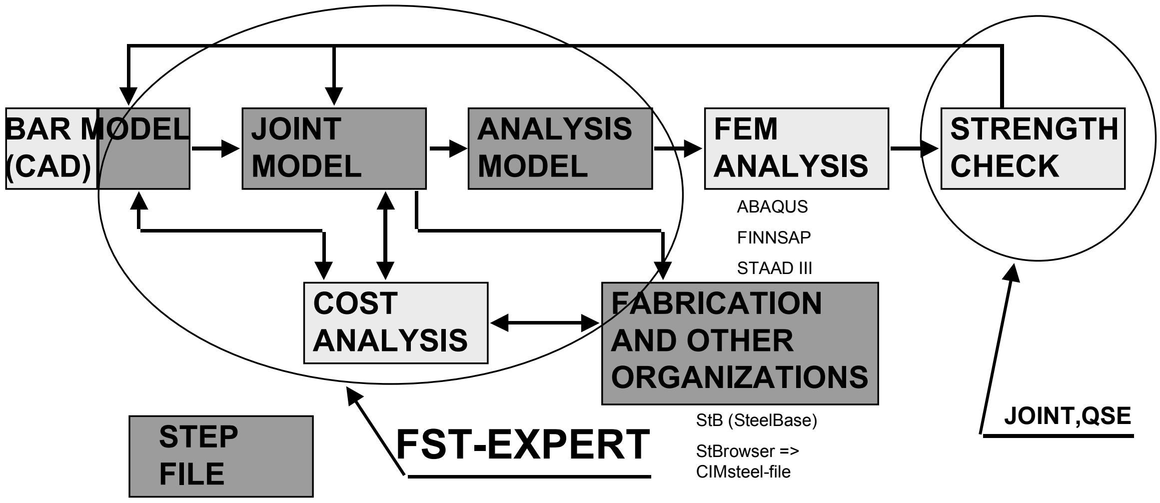


Figure 1. Proposed design process (Salonen et al, 1998) of steel structures

2. SteelBase

The largest project, SteelBase (three years, 28 companies, (Karstila, 1998)) focused on the data exchange between the steel designer and the steel product fabricator and to the education of the designers and the end-users of the product data. The SteelBase project was co-ordinated by the Finnish Constructional Steelwork Association.

The starting point of the project was to define the needs of information and possibilities to produce and to use the information by the organisations (designer and fabricator) involved in the project. The result was presented in nine different bills of materials (b.o.m.). These include such as b.o.m. for order, for steel supply, for fabrication, for fasteners, for erection, for as-built etc. The fabricators (two of the three largest fabricators in Finland) also defined a format (TXRec) to put the information into their material control systems. The use of these standard b.o.m.s and databases need harmonisation within steel products; profiles and steel grades as examples. EN-standards and others were used whenever they were available. Own standards were needed e.g. for the identification of welded profiles widely used in Finland.

Next step in the project was to define the neutral way to produce this information from different CAD systems used by the designers. All product data model based and other formats to the data exchange available were evaluated. Other formats were e.g. a national "Tampella-Ahlström boiler plant" format (Desborough, 19993) widely used for the data transfer between structural design CAD and process designer CAD in Finland. Also so called "Fluor Daniel" format (Fluor Daniel, 1995) was another format. Three product data models (CIS, 1995, Haller, 1994, Hyvärinen, 1996) were evaluated in the SteelBase project for the national standard for data exchange. The CIMsteel model (CIS 1.1, DEP 4, (CIS, 1995)) seemed to have a largest potential to be a world wide standard and it was supposed that the software developers would implement that in the future. So, the CIMsteel model was chosen as a national "standard". All the three product data models included about all the information needed by the fabricators, which was the most important feature of those compared to the other formats, although the others had already been implemented by some software vendors.

The CIMsteel model did not include all the information needed by the Finnish steel fabricators, so some "Finnish flavours" had to be added to the model. Also, the data management was a great challenge for all the organisations using these new computer tools for the data exchange. A special "log-file" was defined for this purpose and the main idea was, that with all the STEP-files the special "log-file" follows, where is shown to the other organisation, which has been changed compared to the possible previous file(s). Later on, these "Finnish flavours" raised issues for the CIMsteel model 1.1 and they are nowadays taken into account in the revision 2.0 of the CIMsteel model.

Some designers use still rather modest CAD systems or they do not use any CAD. For those designers a very simplified product data model (StB-model) was defined in the project. The main idea was, that the product models following this model can be produced using without any product model based program, e.g. produced from EXCEL-sheets. The information appearing in this simplified StB-model was enough to produce the TXRec-format and the b.o.m.s defined above.

Next task in the SteelBase project was to write a StBrowser program. This program can be used for the mapping between different models. The StBrowser program can read StB-files and SteelBase-files (CIS 1.1, DEP4 with "Finnish flavours") and it can write StB-files, SteelBase-files and TXRec-files. Moreover, it can produce the standard b.o.m.s via Access®. Later on a limited DSTV-NC-file output has been added to the StBrowser program.

One important feature of the StBrowser program is the possibility to navigate in the product model. The product models applying ISO 10303 standard are still very new things for all the people (designers and end-users of the models) involved in the building projects. Moreover, new "standard" names and b.o.m.s are all new. The StBrowser program was used to teach the new things to 30 Finnish steel designers and fabricators. The StBrowser system overview is presented in Fig. 2.

The latest developments in the SteelBase project are the standardisation efforts of difficult thin walled structures and migration from the CIMsteel model 1.1 to the CIMsteel model 2.0 (CIS, 1998). This work is still going on and it should be ended at the early third millenium. Also, the output of CIS 2.0 files from one widely used CAD program belongs to the SteelBase project.

The most important results from the SteelBase project can be summarised as follows:

- evaluation of product data models for steel structures
- data definitions needed for the data exchange between designer and fabricator
- the effect of that definition to the CIMsteel standard (from R1.1 to R2.0)
- perform the mapping of product data following the needs of different organisations
- StBrowser, mapping and navigation of product models
- education of these new things.

Just today no STEP-files are used for the data exchange of steel products between organisations in Finland. This is due to fact that only one design company can write those files and no fabricator can read those files. However, it looks that the most latest efforts (especially the implementation of CIS 2.0) causes, that these neutral files will become more widely used. This will happen if, the fabricators see, that it would be economical to them to get the steel product information in neutral files compared to the situation now: the material data is put manually from the drawings to their material control systems.

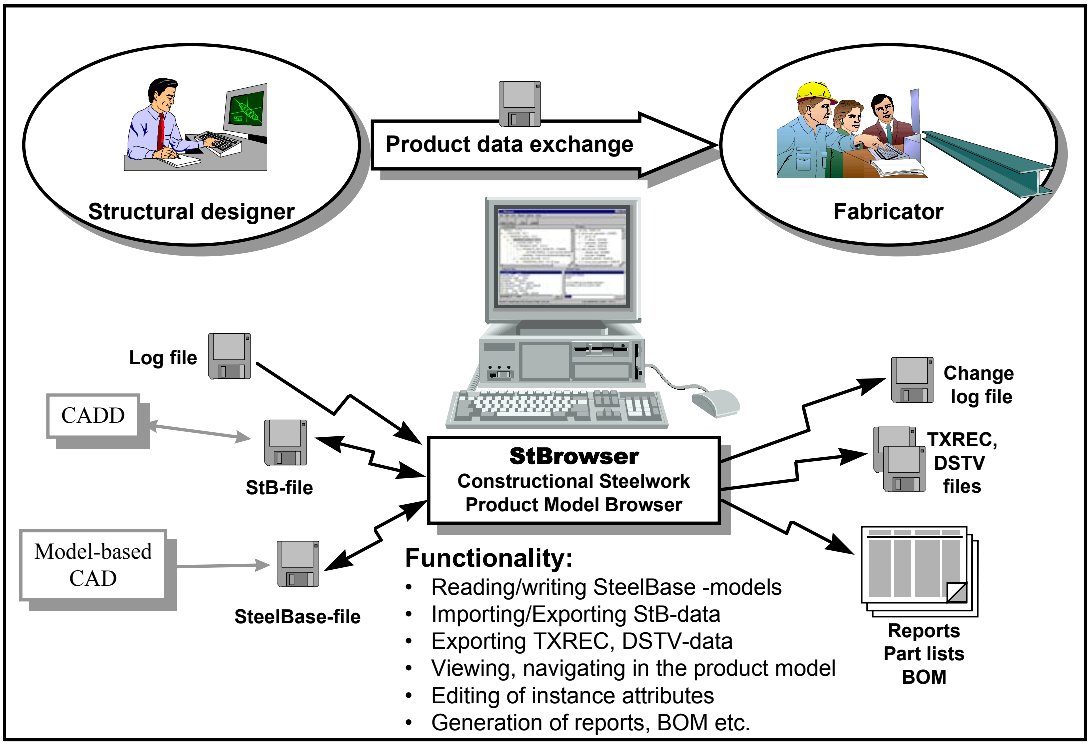


Figure 2. StBrowser system overview (Karstila, 1998)

3. FST-EXPERT

The second project, FST-EXPERT was mainly focused on the data exchange between geometrical modelling, structural analysis and cost estimation i.e data exchange within the organisation (usually) but between disciplines (or tasks). In Finland the structural analysis and the final steel design (including detailing and fabrication data) are often done by the same organisation. Of course these tasks can be done by different organisations. One goal of this project was to perform the data exchange between geometrical modelling and structural analysis modelling (FEM) using neutral STEP-files. The main goal of this project (FST-EXPERT) was to develop an expert system for the design purposes, but this paper concentrates to the product modelling.

When starting this project the CIMsteel model (CIS, 1995) was not available. So, the starting point was to develop a product data model of the material entities (geometry) of steel structures (Hyvärinen, 1996). The demand of simulation of fabrication and erection processes was one goal in this project in order to use the model to analyse e.g. costs of steel structures.

One idea in this project was that the geometrical model and the analysis model are in the separate models, because usually they are used by different programs. The analysis model used in this project is presented in (Heinisuo et al, 1999). The model borrows some constructs of (CIS, 1995) and (Haller, 1994) and ISO 10303-104, but some special features appear in the model e.g. to perform the analysis using two or three dimensional elements near joints. Also, the model includes the possibility to use many explicit stiffness matrices e.g. for composite beams. So far, the loading and the result schema are missing from the model.

When generating the analysis model from the geometrical model, the problems arise near the joints. The analysis model for the bars between the joints is rather easy to generate. When applying exact explicit stiffness matrices for bars then the analysis model is exact for bars.

The most simplifle way to model the joints to the analysis is to use rigid links of beam elements between the bar ends near the joints. This model is generated by the FST-EXPERT firstly (Heinisuo, Rautakorpi, 1998) for the first stage analysis (e.g. in the preliminary design phase). This information can be used for the cost estimation, too, but this information (both in the geometrical model and in the analysis model) does not include any information of the joints. The information at this stage includes only the information of the bars. Hence, the designer can put e.g. hinges to the ends of rigid links if he assumes that the joint used will be a hinged one. At least the eccentricities at the joints will be modelled for the analysis using this model.

Next stage is to put the candidate joints to the model. FST-EXPERT can be used to estimate (using so-called shallow knowledge) which joint would be the best taking into account e.g. fabrication and erection. After the joint candidates have been chosen with details (joint parameters), the final cost can be estimated for the whole skeleton (using now very deep knowledge). Moreover, some more profound analysis models are proposed for some joints programmed to the system. The more profound analysis model would be either a beam model or a two-dimensional plate model (so far) for some joints where for design purposes is needed e.g. peak factors for the joints. The STEP-file for the analysis will be generated using this detailed joint information. The mapping programs from the neutral analysis models (STEP-files) are written for the demonstration to the input files of three analysis programs (ABAQUS, FINNSAP and STAAD III).

The strength check of bars can be done using e.g. the same program as the analysis was done (e.g. STAAD III) or the data can be exchanged to some other programs (no STEP-files available for this, so far). The strength check of joints can be done using some separate program, too.

The mapping between the geometric product data model and the analysis product data model has been done applying the EXPRESS-C language (WWW-ECCO). The same mapping techniques was used for mapping the data from the FST-model to the StB-model defined in the SteelBase project. So, all the facilities of the StBrowser program can be used and, as an example, the FST-model can be mapped to the SteelBase-model (CIS 1.1).

The FST-EXPERT project can be summarised as follows:

- the mapping with some "intelligence" between the geometrical model and the structural analysis (FEM) model can be a powerful tool if neutral data files are used for the data exchange
- the power means here total independencies of the CAD-program and the FEM-program, this is a good feature when thinking of the future
- the cost estimation and strength check (and other tasks, too) can be integrated to the design process rather easily due to well-defined product models
- EXPRESS-C is a good tool to perform the mapping

The FST-EXPERT project was done in Tampere University of Technology during 1996-1998.

4. FinnST-1

The third project, FinnST-1 was scoped to the structural steelwork data exchange between organisations, generally. The FinnST-1 project includes the mapping (and corresponding definitions for that) between the CIMsteel Integration Standards from the CIMsteel Eureka project (Release 2, (CIS, 1998)) and the Industry Foundation Classes from the International Alliance for Interoperability (IFC, IAI, Releases 1.5.1 and 2.0, (IAI, 1999)). The main goal of this project was to concentrate to the space reservation of steel structures dealing with the main assemblies of steel skeleton, not details. The national FinnST-1 project is a Finnish contribution to the international IAI ST-1, Steel Framed Structures project.

The two models (CIMsteel and IFC) are different in details and in other scopes, too, which causes that the mapping between the two models is interesting and somewhat difficult. The project did not focus on developing any new models, but the goal was to use the two models, which are well defined and well documented. When doing the mapping in details some limitations for mapping program and new proposals to IFCs had to be made. The details of the mapping can be found from the official Draft 4 of the ST-1 project available by the members of the IAI.

The most difficult thing when mapping the two models was the different hierarchical aggregation form of the models. Typical parts (e.g. end plates of columns) appearing in steel structures (and other structures, too) are not found in IFC (R1.5.1). In IFC (R2.0) the class called building element is used for parts and classes called beams and columns are used for assemblies. Typical steel assemblies such as trusses, braces, handrails etc are missing from the IFCs. The class storey is missing in the CIMsteel-model but it must appear in the IFCs.

Also, some details had to be considered carefully when performing the mapping (both the document and the demonstration program), but it looks, that the most important parts of the steel skeleton could be mapped from the model to another.

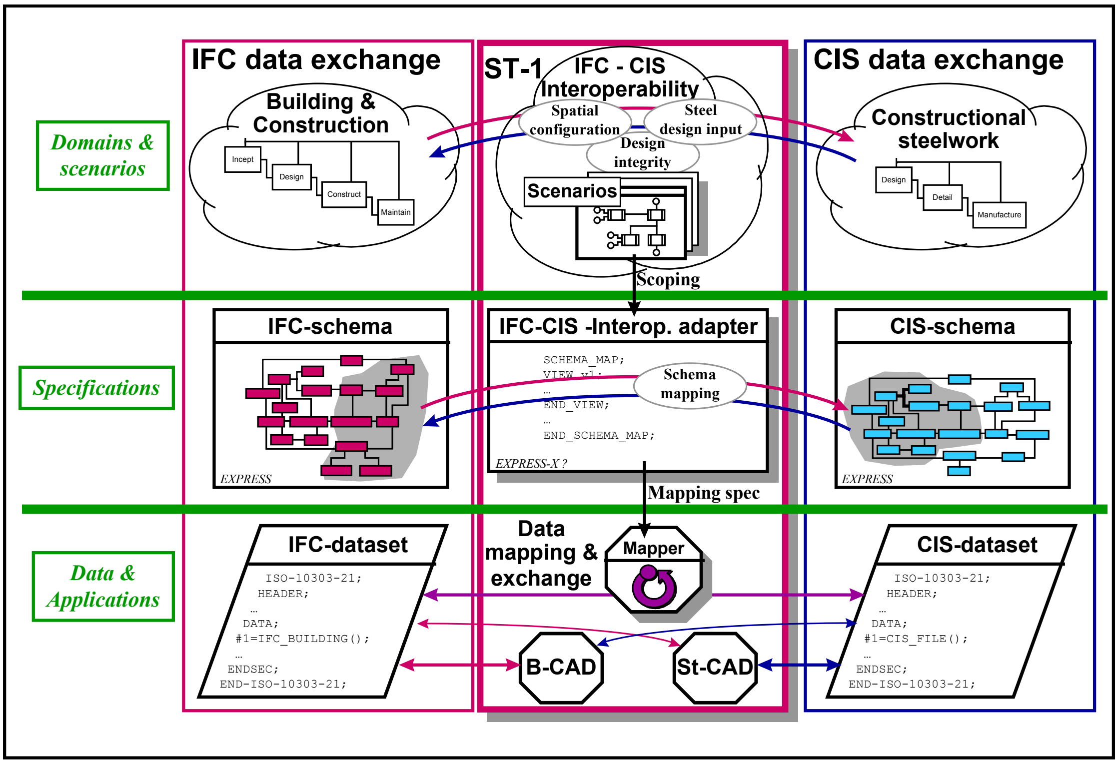
One demonstration program to create the IFC-classes from a typical AutoCAD design application was written and moreover, the mapping program (iciMapper) between the CIMsteel-model (R2.0) and the IFC-model (R1.5.1 and R2.0) was written in the project. The demonstration programs are essential in these kinds of projects to tests the ideas in practice. When writing the program all details must be considered more deeply than when only considering theoretical models.

Finally, the FinnST-1 project brings all the work done in the other projects to the use of all the organisations involved into the building projects. Also, the possibilities to perform the mapping between product data models include new information.

Short summary of the FinnST-1 project is as follows:

- The project was a study of the co-operative use of two models (IFC and CIS)
- Information dealing with steel structures (spatial reservation of steel structures) can be transferred to other organisations and to other disciplines starting from CIMsteel (R2.0) model and ending to IFC (R1.5.1 or R2.0) and vice versa.

The last result will perhaps have a positive effect to the steel business in the future. The overall FinnST-1 project environment and components are illustrated in Fig. 3. The FinnST-1 project was co-ordinated by the Finnish Constructional Steelwork Association.



Figuge 3. Overall ST-1 Steel frame construction project environment and components.

5. SUMMARY OF ALL THE THREE PROJECTS

In the following some results which deal with all the three projects described in this paper are presented shortly:

- All the three projects were efforts towards the use of product models and neutral data exchange
- The feedback of practical experts is of the most importance when developing and starting to use the models
- The education of the new techniques must be involved into the projects, this will lower all the barriers to use these new things
- The product models seem to be the most potential ways to perform the data exchange both between organisations and between disciplines in many tasks of design
- The real use of product models in everyday practical engineering problems is waiting to be realise, the financial benefits of the invested capital is still at a very low level
- It is essential to write a demonstration program to test all the ideas and models generally when dealing with product models
- It seems that the interoperability is increasing in the architectural, engineering and construction industry and especially when considering steel structures, this must mean some competition ability for steel structures in the future.

REFERENCES

Salonen M., Rautakorpi J., Heinisuo M. (1998). Proposal for 4.5 Dimensional Design via Product Models and Expert System, Lecture Notes in Artificial Intelligence 1454, Subseries on Lecture Notes in Computer Science, Ian Smith (Ed.), Artificial Intelligence in Structural

Engineering, Information Technology for Design, Colloboration, Mainetance, and Monitoring, Springer-Verlag, Berlin, pp. 464-468

Heinisuo M. (1997). Product Models for the Data Transferring in Building Projects, Application Steel Structures, Proceedings of the 7th International Conference on Computing in Civil and Building Engineering (ICCCBE-VII), 19-21 August, Seoul, Korea

ISO. (1994a). ISO 10303-1 Industrial automation systems and integration - Product data representation and exchange. Part 1: Overview and fundamental principles. International Organization for Standardization, Geneve. 18 p.

ISO. (1994b). ISO 10303-11 Industrial automation systems and integration - Product data representation and exchange. Part 11: Description methods: EXPRESS language reference manual. International Organization for Standardization, Geneve. 208 p.

ISO. (1994c). ISO 10303-21 Industrial automation systems and integration - Product data representation and exchange. Part 21: Implementation methods: Clear text encoding of the exchange structure. International Organization for Standardization, Geneve. 57 p.

Karstila, K. (1998). SteelBase - Implementing product data exchange for constructional steelwork. In Proceedings of CIB W78 Conference on The life-cycle of construction IT innovations, eds. Björk, B-C. and Jägbeck, A. Stockoholm, June 3 - 5, pp. 259 - 268.

Desborough J. (1993). CONSTU, CONstruction STeel Utilities, Steel Structures AutoCAD (AutoLISP) Applications, POWER ENGINEERING LTD, Version 1.0, 31st August

Fluor Daniel. (1995). Neutral data exchange format for steel structures

CIMsteel Integration Standards (Release One). (1995). University of Leeds, Department of Civil Engineering

Haller H.-W. (1994). Ein Produktmodell fur den Stahlbau, Doktor-Ingenieurs Dissertation, Bauingenieur- und Vermessungwesen der Universität Friedericiana zu Karlsruhe (TH), Karlsruhe

Hyvärinen J. (1996). FST-Finnish Product Model of Steel Skeleton, Proceedings of the 3rd Workshop of the European Group for Structural Engineering Applications of Artificial Intelligence, CIVIL-COMP Ltd, Glassgow, Scotland, pp. 41-46

CIS. (1998). WWW-CIS. Http://www.cis2.org

Heinisuo M., Hyvärinen J., Salonen M. (1999). Product model for structural analysis of steel frames, Rakenteiden Mekaniikka, Vol. 32, Nrot 1-2, pp. 4-24

Heinisuo M., Rautakorpi J. (1998). Teräsrungon rakenneanalyysin tuotemallin generointi geometrian tuotemallista, Report 25, Tampere University of Technology, Department of Civil Engineering, Structural Mechanics, Tampere, (in Finnish)

WWW_ECCO. ECCO toolkit, Karlsruhe University of Technology, Germany, Http://www.rpk.mach.uni-karlsruhe.de/~ecco/.

IAI. (1999). An introduction to the International Alliance for Interoperability and the Industry Foundation Classes. Industry Foundation Classes - Release 2.0. International Alliance for Interoperability, March 15