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STEELSTRAC: Steel Structures Automated Coding

STEELSTRAC: système de codification automatique des structures métalliques

STEELSTRAC: Automatisches Entwerfen von Stahlstrukturen

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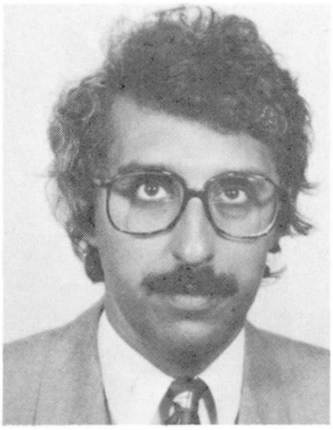

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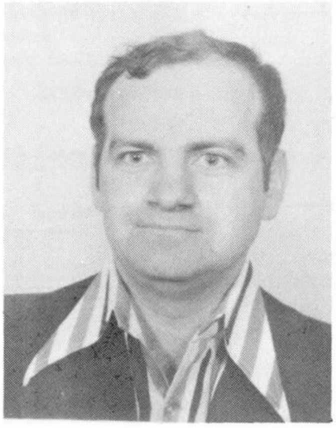

Edgard Backx, born 1948, obtained his mechanical engineering degree and his doctor of applied science degree at the Catholic University of Leuven. He spent 4 years at the Von Karman Institute making measurements in hypersonic turbulent boundary layers. Since 1975 he has been at the Catholic University of Leuven.

SUMMARY
STEELSTRAC is an intelligent software-package consisting of modular programs which can be used separately or can be built together to form a CAD package. It is developed for Wang mini-computers and programmed in BASIC. A specially developed engineering data-base system makes it possible to use a unique data-base for the structure to be designed. This data-base will be used for generating drawings, for making the necessary calculations, for detailing and for planning. STEELSTRAC allows constructors to start effectively with a moderate investment and to expand gradually the hardware and software configurations.

RESUME
STEELSTRAC est un logiciel composé de modules utilisables séparément ou qui peuvent être regroupés pour former un système de CAO. Il a été développé pour les mini-ordinateurs «Wang» et les programmes sont écrits en BASIC. Une base de données techniques développée à cet effet permet la description complète sous une forme unique de la structure étudiée. Elle fournit toutes les indications nécessaires au calcul, au dessin, à l'étude des détails constructifs ainsi qu'à l'organisation des travaux de construction. STEELSTRAC permet aux constructeurs de démarrer avec un investissement modéré et d'étendre progressivement leur installation.

ZUSAMMENFASSUNG
STEELSTRAC ist ein intelligentes Software-Paket, das aus modularen Programmteilen besteht, die entweder einzeln oder zusammen benützt werden können. Es ist auf einem «Wang» Mini-Computer entwickelt und in Basic programmiert worden. Ein speziell entwickeltes Datenbank-system macht es möglich, eine einzige Datenbank für eine zu entwerfende Struktur zu verwenden. Diese Datenbank wird gebraucht um Zeichnungen zu generieren, um die nötigen Berechnungen zu machen, für Planung und Ausarbeitung der Details. STEELSTRAC erlaubt es einem Konstrukteur effizient und mit mässigen Investitionen zu beginnen und die Hardware- und Software-Konfiguration stufenweise auszubauen.

1. THE INFORMATION FLOW IN A STEEL CONSTRUCTION FIRM

Table 1 outlines the exchange of information in a firm starting from a bid till final delivery of a structure.

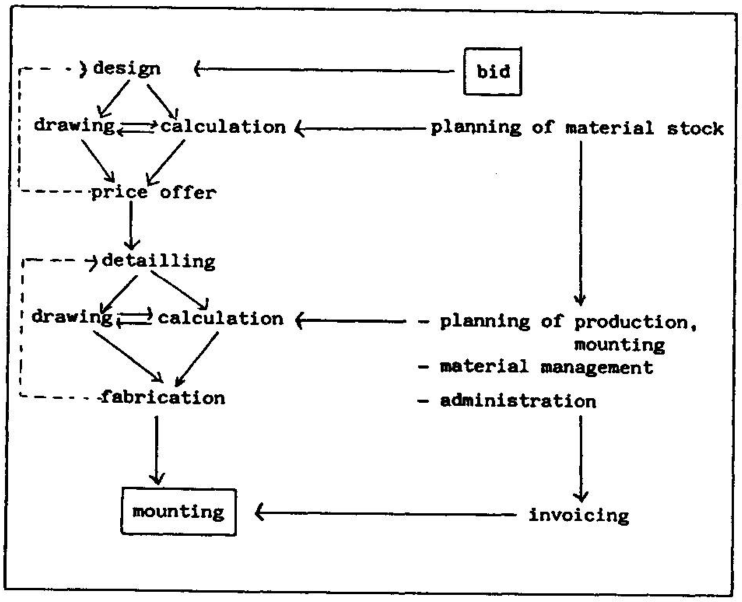

Table 1

The good progress of all these interdependent actions requires technical as well as administrative skills and the knowledge of firm dependent customs.
Because several people from different departments are involved, an exchange of internal reports and memo's is necessary and its volume increases with the size of the firm and the size of the project.
The computer makes it possible, provided that the software is available, to decrease drastically the amount of reports and memo's, thereby eliminating a large source of errors and misunderstandings.
The goal is :
- to make more refined calculations
- to automate drawing to a large extent
- to use data-banks which contain information on selected profiles, stocks, prices
- to have access to a library containing previous projects which could be used as a starting point for new projects
- to assist the managing of projects and to controle costs
- to produce punched tapes, floppies or programs for NC machines and robots.

To meet all those objectives, a large amount of software is required and is to a certain extent, firm dependent. That is the reason why a modular approach has been chosen, such that each module can be developed, tested and used on its own. These modules can be divided into 6 categories (Table 2).

	Computations	Drawings	Administration
Total Structure	(linear & nonlinear) - static - dynamic - optimization - stability - verification	- general overview - sections - projections - implantation, ...	- data for price offer
Details	- steel profiles - connections - foundation - stock-management	- monoplans - connections - anchorage - welding details - mounting plans	- parts list - punched tapes - work sheets - production planning - cost controle

Table 2

Superimposed on this scheme, there is a need for a global management system which controls the follow-up of the project, handles the stock control and the financial administration.
Each category (Table 2) consists of more than one module and will briefly be described in section 2.
Section 2 gives an overview of characteristics which are common to all modules.

2. THE STEELSTRAC SOFTWARE. GENERAL CHARACTERISTICS.

It is not that difficult to develop a program on a desktop computer that gives a good answer for simple testcases. The step from writing such a program to a commercial product is not a small one.
A commercial program has to be correct, reliable, robust, easy to modify and extend, user-friendly and must be maintained by its authors.
To meet all these requirements for a series of programs which use the same database requires even more discipline and organisation from the program developers.
Because the STEELSTRAC software is designed for a small computer (WANG), one has to be aware of the specific limitations of these type of computers :
1. small core
2. processor speed limitation
3. accuracy of calculation.

To take account of the first limitation, a dynamic memory allocation and management system has been designed. (1) This system has the same aim as a virtual memory system in mini-computers. This means that regardless the size of the problem, no action of the user is needed because the software will check if a variable needed is in memory or not. If it is not in memory, the required page will be loaded. This has for effect that a large problem can run as well on a 32K machine as on a 64K machine provided sufficient external memory is available. However, the problem will be solved much faster on a 64K machine because fewer paging will occur.

A special problem is posed in F.E. calculations where a large system of equations has to be solved in a small core. The first algorithm implemented used a blocked Gauss elimination. (2) This algorithm was implemented to take into account that the matrix is symmetric and banded.

The new release uses the same algorithm but the required primary and secondary core is further reduced because only non-zero blocks of coefficients are taken into account. This is especially favourable for problems with a variable bandwidth.

To account for the second limitation especially severe when using a BASIC interpreter, the processor speed limitation, machine coded instructions are used whenever possible.
These instructions include matrix functions such as matrix multiplication, inversion e.a. and sort and search instructions.
The positive side is the reduction in program development time :
we estimate by experience a 5 to 1 gain in interpreter/classical compiler program writing time.

The accuracy of the calculations is guaranteed for well-posed problems because all computations are made with 13 digits. All input is checked for validity and extensive use of graphical controles has been made.
Equilibrium- and algorithm checking is provided whenever possible.

3. THE STEELSTRAC SOFTWARE : DESCRIPTION OF MODULES

The Steelstrac software can be used without manuals after a few hours of training. This is obtained by using menu's on the screen which show the different possibilities. (3)

3.1. Software for computation of the total structure (4), (5)

The computational procedures implemented are based on the displacement method for bar- and beam-structures and on the finite element method for 2-D, axisymmetric and plate structures.
Table 3 shows a menu taken from the package as it appears on the screen.
This menu illustrates the different possibilities.

```
E S A - 3 ***   SCIA - Software  ** 2D Frames  * Version 1 *

                                            SCIA s.v.


 1 .......... PROJECT DESCRIPTION - TYPE OF ANALYSIS
 2 .......... COORDINATES
 3 .......... BOUNDARY CONDITIONS
 4 .......... TOPOLOGY
 5 .......... BEAM HINGES
 6 .......... PROPERTY TABLE
 7 .......... CORRECTION FOR SHEARFORCE
 8 .......... EXCENTRIC CONNECTED BEAMS
 9 .......... ELASTIC CONNECTED BEAMS


                               Number   --- (0=NO ) 0

 Loaded  :EXAMPLE STRUCTURE -A12 121221 77 /B12
 Date    :06.06.82
```

Table 3

The menu approach facilitates input corrections, editing, additions on an interactive basis without programming knowledge of the users.

The following modules are in use :
- linear static analysis for two- and threedimensional beam structures
- second order elastic analysis
- plastic analysis
- dynamic analysis with spectral or time response
- module for automatic optimization using linear programming (fullplastic design)
- influence lines, load combinations (minimum, maximum)
- generation routines with parameterized input (simple one span, two span portal frame buildings)
- finite element plate and 2D elasticity analysis
- mesh generation scheme for geometry, supports and loadings.

To check the results graphical methods are used, as illustrated in figure 1, where the bending moments are drawn.

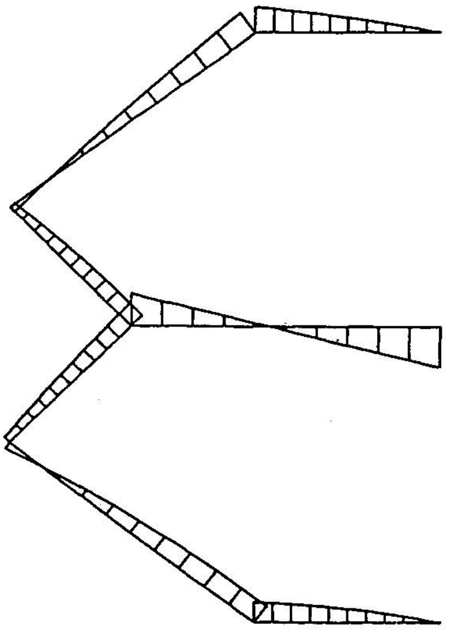

Fig. 1

Other possibilities are : deformed structure, loading schemes, perspective drawings, isolines for finite element results.

3.2. Drawing of the structure

At this stage the structure is drawn to have a complete overview and to present the structure to the designers.
More drawing details can be added : axis lines, girders, wind bracings, purlins, non-structural components.

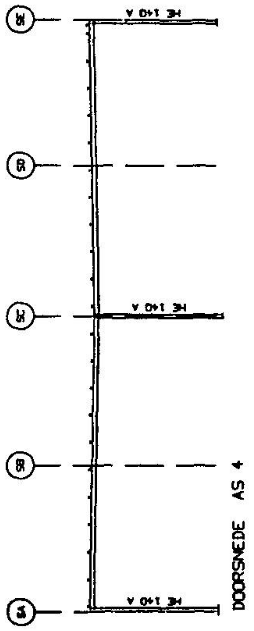

Fig. 2

An example drawing is shown in fig. 2 where a section through the building is represented.
Standard foundation connections (anchorage plan, concrete stands) may also be introduced.
All input for the finished drawings can be formulated with the help of the results of the design calculations.
Straight input of columns, girders, ... is also possible.

3.3. Price offer

A provisional bill of material is printed covering : a list of the profiles (standard, non-standard) with lengths and sorted in function of range of order, pointing surface, weights.
In a more general word processing software the latter data are assembled and a global text with additional activity descriptions is produced.

3.4. Detailing

The computations include the automatic optimal selection of profiles and joints as well as checking of structural loaded components to see which are conform to the building codes or regulations (e.g. TGB Netherlands, NBN Belgium, DIN Germany).
The modules allow a user to set up, change or extend the list of available profiles.
As an example some screens on the stress calculation are given below.

```
====>     STEEL Package - Dutch regulations    (TGB) <====
============================================================
1     BUCKLING HE-PROFILES IN UNSHORED FRAMES - - - - -      1
2     BUCKLING  I-PROFILES IN UNSHORED FRAMES - - - - -      2
3     BUCKLING HE-PROFILES IN SHORED FRAMES - - - - - -      3
4     BUCKLING  I-PROFILES IN SHORED FRAMES - - - - - -      4
5     BUCKLING CORNER-STEEL IN UNSHORED FRAMES - - - - -     5
6     BUCKLING CORNER-STEEL IN SHORED FRAMES - - - - - -     6
7     DETERMINATION MINIMUM HE-PROFILE - - - - - - - - -     7
8     DETERMINATION MINIMUM TUBE-PROFILE - - - - - - - -     8
9     LATERAL BUCKLING OF  I-PROFILES - - - - - - - - -      9
10    STRESS CALCULATION IN I/HE PROFILES - - - - - - -      10
11    INPUT AND/OR CORRECTION OF PROFILE-LIBRARY - - - -     11
15    CONNECTIONS - - - - - - - - - - - - - - - - - - -      15



'0=START / '1=INITIALIZE        GIVE NUMBER AND 'RETURN'? --/
```

Table 4

The results of a static calculation are automatically sent to the detail calculations.
In table 5 the effective buckling length is determined to find the reduction coefficient for the stress calculation.
One can immediately verify if the choosen profile fulfills all requirements.
(Table 5 : see next page).

```
*** PROFILE TYPE ***
PROFILE  :  HEA200
DIRECTION :  X
================================================================
I  = 36920000 mm4        Iy = 13360000 mm        Wx = 389000 mm
A  =  5380.00 mm2        ix =    82.80 mm        iy =  49.80 mm
================================================================
Nx-max .....:     45.000  kN    <*>  Sx-max .....:     12.000  kN
Mx-max .....:     23.300  kNm   <*>
Nx-top .....:     38.000  kN    <*>  Nx-bottom ..:     45.000  kN
Sx-top .....:     12.000  kN    <*>  Sx-bottom ..:     11.000  kN
Mx-top .....:     11.200  kNm   <*>  Mx-bottom ..:     23.300  kNm
X-top ......:  5.104E-02 m      <*>  X-bottom ...:  0.000E+00 m
Y-top ......: -6.610E-03 m      <*>  Y-bottom ...:  0.000E+00 m
Phi-top ....: -1.090E-02 rad    <*>  Phi-bottom .:  3.410E-02 rad
L-scheme X .:      3.000 m      <*>  L-scheme Y .:      3.000 m
================================================================
CORRECTION DATA   (1=YES/0=NO/STD 0) :? -/
```

```
PROFILE  :  HEA200
================================================================
Rho-top      =      0,42       <*>     Rho-botto =      2.64
Lb-x         =      6.95 m     <*>     Lb-y      =      3.00 m
Lambda-X     =     84.01       <*>     Lambda-Y  =     60.24
Omega-max    =      1.68       <*>     Sigma-Eul =    293.65   N/mm2
Nx:(Nx-1)    =      1.02       <*>     Theta     =      1.00
================================================================
Sigma-Buck + Sigma-Bx(red.)   =   14.09   +52.40 =  66.50   N/mm2
Sigma-Comp + Sigma-Bx(max  )  =    8.36   +59.89 =  68.26   N/mm2
================================================================
'0' = ANOTHER PROFILE/  '1'= NEW CALCULATION    /  '2'= PRINT
'3' = CORRECTION RHO-BOT. /  '4'= CORREC. Lb-x   / '0 = MENU
                                   ** YOUR CHOICE (STD 0) :? -/ **
```

Table 5

In the same sense the connection details are designed.

```
====> Index CONNECTION DESIGN following plasticity        <====
================================================================
1      Column - foundation Connection (method 1)  - - - -     1
2      Column - foundation Connection (method 2)  - - - -     2
3      Bolted hinged connection (L profiles) - - -  - - -     3
4      Bolted  CROSS connection - - - - - - - - - - - - -     4
5      Bolted  TEE   connection -- - - - - - - - -  - - -     5
6      Bolted  KNEE  connection - - - - - - - - - - - - -     6
7      Welded  CROSS connection - - - - - - - - - - - - -     7
8      Welded  TEE   connection - - - - - - - - - - - - -     8
9      Welded  KNEE  connection - - - - - - - - - - - - -     9
10     Initialisation basic design parameters - - - - - -    10
11     PROFILE LIBRARY - EDITING / INPUTTING / CONSULT. -    11
12     Standard dimensions table 1 - check  - - - - - - -    12
13     go to stress calculation - - - - - - - - - - - - -    13
================================================================
'0=START / '1=INITIALIZE          Give Number & 'RETURN'? --/
```

Table 6

Table 6 shows the program menu with selection of type of connections.
In table 7 the results of a calculation for the bearing plate under a column is shown.
High strength bolts and weld dimensions are designed.

```
============= P R O F I L E   P O S I T I O N I N G ===========

 ---------------------------------------------    +
 I                                           I    I  20
 I             II           II               I    +
 I             II           II               I    I
 I             II           II               I    I
 I             IIIIIIIIIIIIIII               I    I  100
 I             II           II               I    I
 I             II           II               I    I
 I             II           II               I    +
 I                                           I    I  20
 ---------------------------------------------    +
      10              200          ? 30
 +--------------+-------------+--------------+

==============================================================
*** COLUMNPROFILE **  PROFILE  -  IPE200          DIRECTION - X
==============================================================
f'bd       =        13.50  N/mm2 <*>  f'vd       =    18.00  N/mm2
Depth      =       390.00  mm    <*>  Height     =   215.00  mm
free span  =        95.00  mm    <*>  free span  =    57.50  mm
Amin       =      5555.27  mm2   <*>  Sigma  vd  =     1.19  N/mm2
M(I-I)     =        81.22  kNm   <*>  t(I-I)     =    45.06  mm
M(II-II)   =        90.83  kNm   <*>  t(II-II)   =    47.65  mm
==============================================================
'0' = ANOTHER PROFILE/  '1'= NEW CALCULATION    /  '2'= PRINTING
'3' = OTHER PLATE DIMENSIONS  / '4' = BEGIN  / '5' = ANCHORS
                                   **  CHOICE  (STD 0) :? -/ **
```

```
'0 = INDEX <*> '1 = INITIALIZE BASIC PARAMETERS <*> '7 = BEGIN
```

Table 7

3.5. Production drawings

The details are ready for preparing the monoplans.
Figure 3 shows a detail of the column-foundation connection.
Each of the parts can be drawn separately and various lists of materials are prepared.
(Fig. 3 : see next page)

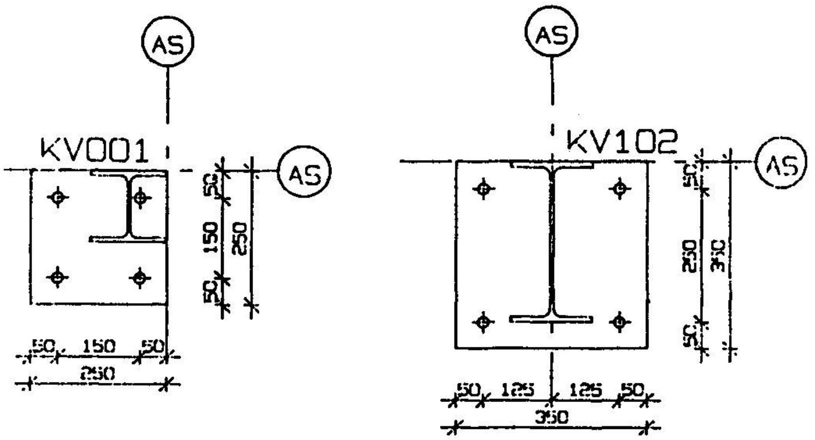

Fig. 3

To have a minimum effort in designing the connections, it is preferred to use standardized connection types with parametric values of bolts, plate dimensions, etc. In principle, the software has no restriction in drawing complex assemblies.

3.6. NC machinery & production planning

The drawings generated in 3.2. and 3.5. are used to prepare the production.
The structural data-bases are consulted to extract machine-operations.
A typical application is the preparation of punched tapes for drilling holes in standard profiles.
The sequence of operations and bore positions is automatically programmed.
Other operations are classified and listed in sorted order to be used in the management decision & planning.

4. CONCLUSIONS

The STEELSTRAC software offers a complete solution to steel constructors.
The software is developed for WANG computers and is written in BASIC.
Starting from the design, it allows the user to make drawings and strength calculations of the complete structure and details.
It also makes a link to management and cost-control.
Each module can be used separately or can be used in connection with the other modules because it is based on a unique data-base accessible by the standard modules or by user written special purpose programs.

5. ACKNOWLEDGEMENTS

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CSM (Constant Schuurmans Metaalwerken N.V., Achel - Belgium) is participating in the development of STEELSTRAC.

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