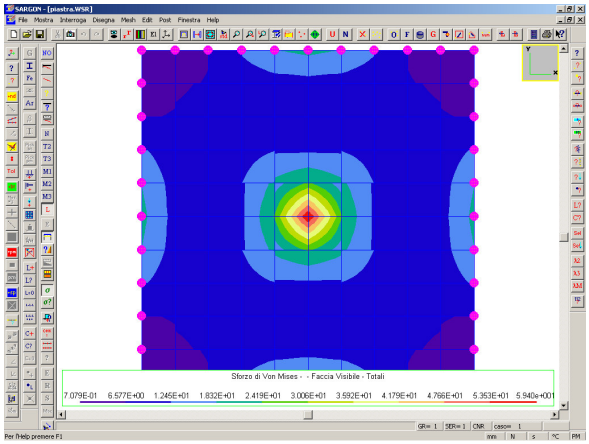
VALIDATION CRITERIA



http://www.castaliaweb.com

Via Pinturicchio, 24

20133 Milano

staff@castaliaweb.com

Rev. 2.0 September 2008

Added to documentation in November 2007

Sargon is a broad finite element program mainly oriented to steel structures. It was created in 1990 and has been continuously developed since that time.

Validation is a key point in software development, and this is particularly true for design-oriented softwares which are used to perform complex structural analyses.

Sargon has a powerful set of validation tools, and has been extensively tested by the producer and by several hundreds of customers, in tens of thousands of different computer runs. In addition to this significant set of designs and of built structures worldwide, Sargon validation is continuously – i.e., at each version of the program – being improved.

The main validation sources and strategies can be summarised as follows, not necessarily in order of importance:

1. Steps taken by experienced structural engineers in the last 18 years (since 1990) for the continuous improvement of the program;
2. Internal tests executed by the producer before releasing each new functionality of the program;
3. Theoretical tests published in books where the program's performances are compared to existing results and/or results obtained using other programs or procedures;
4. Test benchmarks added to program documentation, or published on the company web site;
5. The systematic use of a procedure to test each version of the program by running a set of reference tests in a standardised way;
6. The Systematic, independent control of results obtained for each run by users executing the ad hoc program "Checksolvers";
7. Reference list of the program users, a set of highly qualified engineers and engineering firms, and a list of projects realised using the program;
8. Important contributions to research and standards in Italy that have arisen from the use and development of the program (with the main results in the fields of steel structures, load combination rules and earthquake engineering), which testify to the high level of the software author's knowledge;
9. Internal use of the program by the producer for structural consulting;
10. Program openness, which allows data transfer to and from the program.

In what follows each key point will be briefly described.

1 Improvements made since 1990

Sargon is not a newly released program. It was created in 1990 and since then it has been continuously developed and improved. Born in standard C, it was later partially rewritten (the interface) in C++ under WIN 32 shell (1994). This very

Web: http://www.castaliaweb.com
Email: staff@castaliaweb.com
Ph.: +39 (0) 2 266 81 083
Fax: +39 (0) 2 266 81 876

long time span, from a developmental standpoint, has made possible the in-depth testing of virtually all main program paths and functionalities. Some of the main program features have been used continuously for 18 years as of September 2007. The program is developed in close collaboration with users, mostly comprised of highly experienced structural engineers and firms.

2 Internal tests executed by producer before each version release

The producer makes a rule of not releasing any functionality without its having first been tested by developers. This greatly reduces the probability of errors or malfunction. Major improvements and program modules are extensively tested before release, and only after these first level tests are releases made. Very often new functionalities are added to the program after they have been found to be of help in everyday consulting with the program itself, i.e., they are thoroughly tested directly in real-work situations.

3 Published theoretical tests

Results obtained with the program have been extensively compared with those expected in theory and with those obtained by other programs. Also, samples of design work have been used to verify the program's correct functioning in a wide range of design situations.

Presently there are five books published in Italy (with more than 4000 copies sold worldwide) which describe results obtained by parts of the Sargon program. Another book related to Eurocode 3 is currently in preparation and expected to be published in 2009.

The five books available are:

P. Rugarli, *Calcolo strutturale con gli elementi finiti* EPC LIBRI, Roma, 2003 (*Structural Analysis with the Finite Element Method*, in Italian)

http://www.insic.it/libro.asp?id=70646&tipo=4&q=rugarli

An introduction to finite element analysis. Many theoretical tests are published here, comparing Sargon results to exact or available ones. The book also has a limited version of the program (models up to 50 nodes). To date, this book has sold more than 2,000 copies.

Web: http://www.castaliaweb.com
Email: staff@castaliaweb.com
Ph.: +39 (0) 2 266 81 083
Fax: +39 (0) 2 266 81 876

P. Rugarli, *Analisi modale ragionata*, EPC LIBRI, Roma, 2005 (*Modal Analysis Explained*, in Italian)

http://www.insic.it/libro.asp?id=72379&tipo=4

An explanation of modal analysis, frequency response analysis, and response spectrum analysis. It embeds many Sargon tests regarding beams, plates, membranes, comparing frequencies to available closed formulae results, or to the results of other programs. To date, it has sold more than 1,000 copies. The book also contain a limited version of the Sargon program, for models up to 50 nodes (modal analysis included).

P. Rugarli, *Calcolo di strutture in legno*, CD BOOK, EPC LIBRI, 2006 (*Calculation of Wooden Structures*, in Italian)

http://www.insic.it/libro.asp?id=72454&tipo=4

This CD BOOK offers an explanation of Eurocode 5. It embeds a beam program limited to straight elements, using the Sargon automatic checker. To date it has sold more than 1,000 copies. It includes several examples which are worked using the Sargon checker.

P. Rugarli, *Strutture in acciaio. Eurocodice 3. La classificazione delle sezioni. Commento*, CD BOOK, EPC LIBRI, Roma, 2007 (*Steel structures. Eurocode 3. Cross section classification. Commentary,* in Italian)

http://www.insic.it/libro.asp?id=72476

This CD BOOK is a commentary on the part of Eurocode 3 referring to the classification of sections. It also embeds a program which has been obtained by Sargon's automatic Eurocode 3 checker, for performing section classification in the most general case of biaxial bending plus axial force. To date the book has sold several hundred copies (in less than one year since its release). It also offers an explanation of a new method (implemented in Sargon since 1992) for performing cross section classification in a general case.

Web: http://www.castaliaweb.com
Email: staff@castaliaweb.com
Ph.: +39 (0) 2 266 81 083
Fax: +39 (0) 2 266 81 876

P. Rugarli, *Calcolo di strutture in acciaio. Guida all'Eurocodice 3: EN 1993-1-1*, CD BOOK, EPC LIBRI, Roma, 2008 (*Calculation of Steel Structures. Guide to Eurocode 3: EN 1993-1-1*, in Italian),

http://www.insic.it/libro.asp?id=72476&tipo=6

A guide to Eurocode 3, and an introduction to the standard that refers to checks of the resistance and stability of members. It also embeds 100 test schedules in which Eurocode 3 is applied to the computations of simple members under a number of possible loading conditions. The tests are carried out by cross-checking results obtained manually against those of the Sargon automatic checker.

4 Benchmark tests available in documentation and website

The Sargon producer is continuously adding test schedules which are systematically added to the "validation" section of the Castalia srl website, for free consultation and downloading. Before publishing the test schedules on the website, Castalia prefers to publish them in books, to insure the greatest accessibility to this work, especially in fields such as code checking, where few if any results are available.

The Castalia srl website page related to validation is:

http://www.castaliaweb.com/ita/s/val/validazione.asp

Presently two sections are available:

- The "main beams" section, where 130 test schedules are available, demonstrating the reliability of the static solver

  (http://esercizistatica.it/schede/main_beams/statTotale.pdf);

- The "nastran comparison" section, where a number of models have been run using the Sargon solver and NX NASTRAN © and NE NASTRAN © solvers for purposes of comparisons (http://www.castaliaweb.com/ita/S/VAL/sargonvsnastran.asp).

Currently a set of 100 test schedules, referring to EN 1993-1-1 tests are in preparation for publication on the Castalia web site: they were first published in a CD BOOK released at the beginning of 2008.

5 Systematic use of a procedure to test each version of the program

A program named "Checksolvers" has been prepared by Castalia to perform two different, very important tasks:

Web: http://www.castaliaweb.com
Email: staff@castaliaweb.com
Ph.: +39 (0) 2 266 81 083
Fax: +39 (0) 2 266 81 876

- To check automatically that the binary output files of a given model embed the expected results in a given position, in relation to a given structural result (like node displacements or element stresses);
- To check automatically that the binary results of a given model respect general theoretical rules (like global equilibrium, Betti's laws, the point of application of the resultant of the applied forces and moments, and so on).

The first functionality will be briefly described here, the second in the next paragraph.

Checksolvers can compare expected results to those actually computed. It is a program that is independent of the solvers: it merely reads an ASCII input file listing "target" values definitive, and compares them with "computed" values written in the binary output files by solvers such as static solver, modal solver, or an automatic checker like that specified in Eurocode 3, at each program version. Since it can compare in a single run hundreds of different model results (many models at once), this procedure is the best for systematically testing each version of the program, to catch unwanted possible new bugs.

A set of benchmarks has been created, and Checksolvers is run before each new release to properly assess that results are those expected. Even more importantly, these kinds of checks are available to each program user, who can set up his/her own set of tests, and enjoy the same ease in performing the checks which is available to developers.

6 Systematic independent check of each model run

Each time a user runs a model and obtains static results, he/she can run Checksolvers to judge the correctness of results. Checksolvers is a program independent of the solvers; it merely reads binary files to obtain results and input data, and then performs a set of internal checks to insure that the results match theoretical rules, which is of course a necessary condition for the reliability of results. Checksolvers output file can be added to model documentation as a further demonstration of correct computation. Results checked are: comprehensive resultants; point of application of resultants; residuals; work of residuals; Betti's law for mixed works, and more.

Web: http://www.castaliaweb.com
Email: staff@castaliaweb.com
Ph.: +39 (0) 2 266 81 083
Fax: +39 (0) 2 266 81 876

7 Reference list of program users and built projects

Here is a list of some of Sargon users:

- ALSTOM POWER s.p.a. - Milano
- ACAI s.r.l. - Milano
- AGIP S.p.A. - Marina di Ravenna (RA)
- ALLIEVI DEL CORSO DI "TEORIA E PROGETTO DI COSTRUZIONI IN ACCIAIO" del Prof. Giulio Ballio al Politecnico di Milano
- ANIT s.r.l. - Genova
- ANSALDO INDUSTRIA s.p.a. - Genova
- AUSTIN ITALIA s.p.a. - Milano
- BOLDROCCHI s.r.l. - Biassono (MI)
- CARLO GAVAZZI IMPIANTI s.p.a. - Milano
- CATANIA PROF. ING. MARIO - Milano
- CENTRO RICERCHE FIAT - Orbassano (TO)
- CETA PONTEGGI TUBOLARI s.p.a. - Bergamo (BG)
- COGEFARIMPRESIT s.p.a. - Sesto S. Giovanni (MI)
- COIND sas (MI)
- COLOMBO s.p.a. - Como
- CO.MEC. s.p.a - Badoere di Morgano (TV)
- ECP ENICHEM POLIMERI s.r.l. - Ferrara
- ELC ELECTROCONSULT s.p.a. - Milano
- ENEL Direzione delle Costruzioni - Milano
- ENEL Direzione delle Costruzioni - Venezia
- ENEL Direzione delle Costruzioni - Roma
- ENEL D.P.T. - Torino
- EUROTECNICA CONTRACTORS & ENGINEERS s.p.a. - Milano
- FBM HUDSON ITALIANA s.p.a. - Milano
- FIAT ENGINEERING s.r.l. - Torino
- FILIPPO FOCHI ENERGIA s.p.a. - Bologna
- FIP PONTEGGI s.r.l. - Torino
- FV PROGETTI - Milano
- GP srl - Milano
- INSO s.p.a. - Firenze
- IRITECNA s.p.a. - Genova
- I.S.P.E.S.L. - Roma
- ITALTEL s.p.a. - Carini (PA)
- KEC International Limited – Jaipur (India)
- KIRCHNER ITALIA s.p.a. - Milano

Web: http://www.castaliaweb.com
Email: staff@castaliaweb.com
Ph.: +39 (0) 2 266 81 083
Fax: +39 (0) 2 266 81 876

- METALMECCANICA FRACASSO s.p.a. - Fiesso d'Artico (VE)
- NATIONAL POWER CORPORATION - Manila (Filippine)
- NUOVA CIMI MONTUBI s.p.a. - Vimodrone (MI)
- OCRIM s.p.a. - Cremona
- OCML s.p.a. - Carrobbio degli Angeli (BG)
- PILOSIO s.p.a. - Feletto Umberto (UD)
- POLITECNICO DI BARI - Bari
- PONTEGGI DALMINE S.p.a. – Milano (Marcegaglia Building & Storage)
- RAMBALDINI ING. ROBERTO - Olgiate Olona (VA) – Walley Design srl
- RECCHI s.p.a. - Torino
- SAIPEM s.p.a. - S. Donato Milanese (MI)
- SCIBILIA PROF. ING. NUNZIO Palermo
- SCL Ingegneria strutturale, Milano
- SIRTI s.p.a. - Cassina de' Pecchi (MI)ss
- SIFA s.p.a. - Reana del Rojale (UD)
- SOIMI s.p.a. - Milano
- Studio Engineering Srl (Genova)
- TECHINT s.p.a. - Milano

A list of some of the projects designed using Sargon can be found at:

http://www.castaliaweb.com/ita/P/SR/casi.asp

8 Important contributions to research and standards in Italy

Sargon's development is carried on by highly specialized structural engineers, whose work comprises important results and has led to significant contributions to research and the fine-tuning of Italian standards.

The most important contributions are the following:

- A method for cross section classification for generally loaded I-shaped cross sections, dating from 1992. This is a very important contribution to the implementation of steel checking;
- The reporting of the incorrect formulae for load combinations in Italian DM 1996 in a paper published in *Ingegneria Sismica* (Seismic Engineering), an Italian technical journal. The rules have subsequently been modified;
- The reporting of several errors in Italian Ordinance 3274/2003 (ministerial decree 3274/2003), published in the Italian newspaper *La Repubblica*, and not embedded into the program, even though the decree was enacted. These errors were subsequently removed from the decree in its later emendment.

Web: http://www.castaliaweb.com
Email: staff@castaliaweb.com
Ph.: +39 (0) 2 266 81 083
Fax: +39 (0) 2 266 81 876

- The error factor response spectrum method, defined in *Analisi Modale Ragionata* and embedded in Sargon since 2005. Here the deceptive nature of high-precision modal analysis in civil engineering is shown and managed via special “error factors”.
- The chapter 10 requirement of the new Italian structural standards (Norme Tecniche per le Costruzioni, 2008), which makes cross checking between different models run via different solvers compulsory for projects covered by the standards, was suggested by Ing. Rugarli, Sargon’s author.
- Misleading rules for interpolation to compute seismic data referring to geographic grids, which appeared in the Italian D.M.14 of January 2008 “Norme Tecniche per le Costruzioni”, was pointed out in the widely-read paper “Zone Griglie o…stanze”, published in the Italian scientific journal *Ingegneria Sismica*.

9 Internal use of the program by the producer for structural consulting

Sargon is developed by professionals who use it in structural engineering every day. This is a very important point, because it means that the program is used as well as developed. In this way its development and quality testing are done at the highest level: programming is just another way for engineers to perform engineering, not an aesthetic operation by programmers to create special graphic effects that have no relevance to actual engineering practice. In particular, Castalia srl has used Sargon to model and/or to run structures like cruise ships, whose estimated value ranges to hundreds of millions of dollars. Highly specialized, proprietary dynamic linked libraries, in conjunction with the Sargon project, have been used to create finite element models of cruise ships, which have been tested and managed in Sargon to obtain intermediate as well as definitive results.

10 Program openness

Sargon is capable of importing and exporting a finite element model in many different file formats. This permits the easy transfer of data to and from Sargon, which, in turn, makes it very easy to perform cross-checks on complex structures. This concept, as already mentioned, is at the core of the chapter on validation in the new Italian structural code. There are no secrets, no restrictions, and no barriers which can limit the complete managing of the model and its results. Sargon also has a free reader version, making it possible for third parties to read results properly in a graphic environment.

Web: http://www.castaliaweb.com
Email: staff@castaliaweb.com
Ph.: +39 (0) 2 266 81 083
Fax: +39 (0) 2 266 81 876