

COLEÇÃO

DESAFIOS DAS ENGENHARIAS:

ENGENHARIA DE PRODUÇÃO 2



CARLOS EDUARDO SANCHES DE ANDRADE
(ORGANIZADOR)

Atena
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APRESENTAÇÃO

A obra “Desafios da Engenharia: Engenharia de Produção 2” publicada pela Atena Editora apresenta, em seus 18 capítulos, estudos sobre diversos aspectos que mostram como a Engenharia de Produção pode atender as novas demandas de um mundo globalizado e competitivo.

A evolução da sociedade e da tecnologia no mundo atual impõe novos desafios, tornando urgente a busca de soluções adequadas a esse novo ambiente. O desenvolvimento econômico das cidades e a qualidade de vida das pessoas dependem da eficiência e eficácia dos processos produtivos, objeto dos estudos realizados na Engenharia de Produção.

No contexto brasileiro, num período pós pandemia, a crise econômica se agrava e é necessário procurar novos caminhos para alavancar o crescimento econômico. Assim a Engenharia de Produção pode ser um elemento importante para enfrentar esses novos desafios.

Os trabalhos compilados nessa obra abrangem diferentes perspectivas da Engenharia de Produção.

A gestão de processos e a gestão financeira são abordadas. Diversos outros temas, em português, espanhol e inglês são também abordados, como os impactos ambientais e epidemiológicos do processo produtivo.

Agradecemos aos autores dos diversos capítulos apresentados e esperamos que essa compilação seja proveitosa para os leitores.


Carlos Eduardo Sanches de Andrade

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CAPÍTULO 7

DEVELOPMENT OF THE TOOL “APERMET” FOR COMPLEMENTING THE ANALYSIS OF STEEL STRUCTURES IN TEACHING

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Jesús Montero Martínez

Universidad de Castilla-La Mancha -
Departamento de Producción Vegetal y
Tecnología Agraria – Campus de Albacete –
España
<http://orcid.org/0000-0002-0309-3367>

Santiago Laserna Arcas

Universidad de Castilla-La Mancha -
Departamento de Producción Vegetal y
Tecnología Agraria – Campus de Albacete –
España.

Jorge Cervera Gascó

Universidad de Castilla-La Mancha -
Departamento de Producción Vegetal y
Tecnología Agraria – Campus de Albacete –
España
<http://orcid.org/0000-0001-5287-6299>

RESUMEN: Las materias relacionadas con el cálculo estructural en carreras universitarias de ingeniería conllevan una importante carga lectiva que en ocasiones dificulta un seguimiento fluido para los alumnos. En este contexto se desarrolla la Herramienta de Análisis de Perfiles Metálicos adaptada al Código Técnico de la Edificación, APERMET con unos objetivos claramente enmarcados como elemento de apoyo en docencia. Es una herramienta caracterizada por su sencillez de manejo y pensada para guiar al alumno paulatinamente en cada una

de las comprobaciones que deben realizar para analizar elementos lineales de estructuras metálicas. Además, la creciente tendencia al “self-study” y a la enseñanza a distancia en la docencia universitaria han marcado el diseño de esta herramienta para crear un entorno evolutivo que muestra progresivamente los parámetros a calcular. Así, el usuario es capaz de verificar rápidamente si el análisis realizado manualmente es correcto, y/o identificar cual es el punto donde existe un error, permitiendo corregirlo de forma autodidacta. Resulta destacable que el uso de esta herramienta se encuentra más extendida entre los alumnos con dificultades de asistencia a las lecciones presenciales y/o tutorías, y que encuentran en la herramienta APERMET un complemento perfecto para reforzar su aprendizaje.

PALABRAS CLAVE: Software; estructura metálica; CTE; docencia; self-study.

DESARROLLO DE LA HERRAMIENTA “APERMET” PARA COMPLEMENTAR LA DOCENCIA DE ESTRUCTURAS METÁLICAS

ABSTRACT: The learning contents related with the structural calculation on university engineering degrees suppose an important teaching load which sometimes makes difficult an fluid follow of these lessons by the students. On this context, the Metallic Profiles Analysis - APERMET tool, according Spanish structural standards (CTE), has been developed with objectives clearly framed on helping as complement in teaching. This tool is characterized by simplicity of use and is thinking to guide gradually the student in

all checks needing to the analysis of linear elements of metallic structures. In addition, the increasing tendency to the “self-study” together with the distance university learning have marked the design of this tool to create an evolving interface which shows progressively all parameters to calculate. Thus, users are able to quickly verify if the manually calculation is right, and/or identify the wrong point immediately, allowing to correct it by self. Highlight, the use of this tool is more common among the student whit difficulties to attend classroom lessons and/or tutoring times, finding on APERMET tool a perfect complement to reinforce their learning.

KEYWORDS: Software; steal structures; CTE; teaching; self-study.

1 | INTRODUCTION

In the field of teaching in engineering, experimental subjects such as those relate to structural design, students pose for a major effort derivative and analyze the complexity of the regulatory standards that define its measurement. Specifically, the degrees related to agroforestry field, comprise an important part of the teaching content and why, competent engineer to enable the calculation and dimensioning of such structures. On the other hand, experience in teaching these subjects clearly determined that due to the complexity of the calculation codes which employ a large number of parameters and tables for structural testing, the procedure from the beginning in learning is complex so that the first sensation of students results, first, in uncertainty due to the proper selection of the parameters, and on the other and connected with it, an uncertainty when identifying and locating the possible error in the calculation .

In this preamble, and clearly marked for the help in teaching objectives, the Analysis Tool Metal Profiles adapted to the Technical Building Code (CTE, 2006), APERMET© unfolds. It is an easy to use tool, developed by MatLab® software, which runs on Windows® environment, and which include each of the checks that are performed sized metal profiles studied by the students during the development subjects. This tool, although it can be perfectly used as a traditional optimization software, is clearly designed for use in teaching, since the configuration and navigation through the different options is specifically designed to guide students in helping solving the problems given in the exercise of the subjects.

In relation to this guideline useful in teaching the tool and display the final results of sizing that can display any conventional calculation program, describe each of the intermediate parameters that are involved in the different tests performed, so the student is able to quickly check if all the verification procedure is performed manually correct, and if so, to identify which is the step that has made the mistake to correct. This improves the speed of student learning, because you can quickly focus on trying to learn or prop misapplied concepts in your problem.

2 | TOOL APERMET

2.1 Objectives of designing the tool

In this new situation, the objective of this work has been the development of a new user-friendly software tool that allows total control over the variables that influence the calculation of metal structures, specifically designed for use in teaching, so that the program is structured and designed to guide students learning of the calculation method that implements the Technical Building Code.

To achieve this goal, an “interface evolution”, in which the fields as required for a hypothetical case of structural evaluation is complete, you can move on and not before the checks are created. That is, to make progress along all checks to be made by the student, previously you must define the starting parameters necessary to perform each of the tests, and only when all input records are complete activated Streak different calculation options.

Prior to any analysis of calculation, the program will need to define the characteristic parameters of the MATERIAL. After completing this section, the program will enable the introduction of options EFFORTS calculation, and only completed this, the first of CHECKS will be activated. On the first test run will activate the second, and so in succession to complete the VERIFICATION of the validity of the metal profile (Fig. 1).

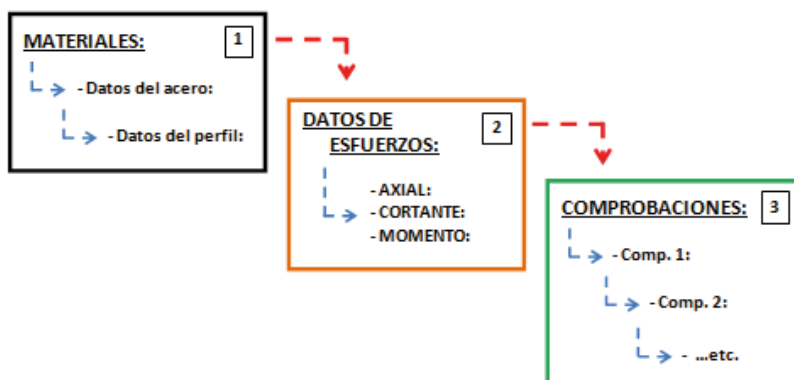


Fig. 1. Sequence evolution data entry tool.

For the interaction with the user is done in an interactive environment Windows type, taking into account at all times to generate an attractive picture with explanatory diagrams and clarification to the calculation elements that make the tool an element that helps the compression results being displayed on the screen, not just a visual output data but an ordered according to user inputs demanded item.

However, the tool requires the prior knowledge of the fundamentals of structural

design to start working with her. There is therefore a self tool, but a tool to support the learning and that allows the calculation consolidate the acquired skills and strengthen the weakest in a dynamic way. Still, the tool has a user manual provided to students for their learning.

According to the concepts of the subject in which this tool is framed, a calculation program designed to verify the ultimate limit states (strength and stability) allowing the calculation of metal parts as described in the CTE standard (CTE, 2006).

The methodology followed in the creation of this tool has been through the following sections:

- Fix the capabilities that will have the program and definition of benefits.
- Study of Technical Coding and the methodology extraction of adapted to calculation of benefits.
- Creating of coding in MATLAB language that complies with the equations described in the coding system.
- Checking of coding created and fragmentation in for the various checks to make subunits that will link the Fragments.
- Creating or visual environment with which the user will interact form the dynamic, with special emphasis on self - guided entry of data.

2.2 Capacities of the program

As mentioned, the current regulations in Spain governing the calculation of steel structures, The Basic Security Document-Structural Steel (DB-SE A), the Technical Building Code (CTE, 2006) is used to establish the methodology calculation applied. In addition, the sections are more blurred in this legislation with the Instruction of Structural Steel (EAE, 2011) and the European legislation, “Eurocode 3 steel structures project” complementary (UNE-ENV 1993-1-1, 1992).

Within the capabilities of the software program can calculate the Ultimate Limit States of metal parts from applicants’ efforts worst situation considered previously calculated and factored is designed. It is determined that the program is able to consider efforts in the two axes of flex profile to calculate checks.

The type of material is steel profiles. Specifically, different types of steel that are described in “4 MATERIALS” DB-SE Steel CTE and derived from the resistance of the material described in the UNE EN 10025 is applicable. Metallic profiles implemented in the calculation will be the series of simple laminated profiles (IPE, IPN, HEA, HEB) widely used in agricultural buildings.

Within the checks in CTE, you opt for the examinations to be able the program are as follows (described in the order of expected calculation):

- Checking of **CLASS SECTION**.

- Checking of **RESISTANCE OF SECTION LEVEL.**
- Checking of **SLENDERNESS.**
- Checking of **LATERAL BUCKLING.**
- Checking of **RESISTANCE OF BAR LEVEL.**

Thus, the different tests are structured in a logical order, which gives the notion of structure to follow when faced with a calculation in such elements.

The APERMET software has been developed using MATLAB software, version 7.6.0. R2008a using the GUIDING module for generating GUI's .

The structure chosen for the presentation of the software is (Fig. 2):

- **An initial window** for submission of the application.
- **A main working window.**
- **Six secondary windows** for the various tests to be analyzed, described in the previous section

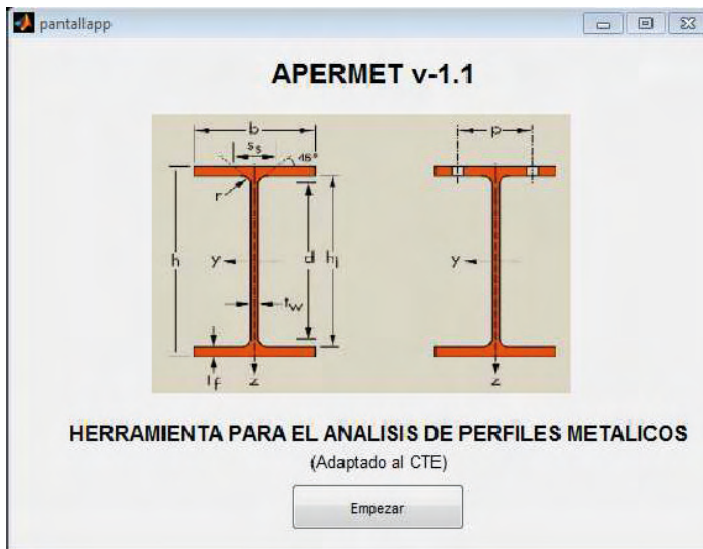


Fig. 2. Home screen of APERMET Tool.

The design of each window consists of the following general topics:

- **Introduction of the data:** Including the following zones
 - Data previously obtained from n previous introduction or by the user.
 - Specific Datas of checking (if precision is necessary as may be required).
- **Result Sections:** where mainly the final values of checking, and if this value is within the acceptable limits.

- **Making Calculation:** allows to understand the analysis of the results. The results that are properly detailed with supportive explanatory scheme help with the correspondence.

Within each window, the initial data are loaded by default, showing the corresponding location in the value of the variable, but the user is able to modify them. Editable data if the data input is performed by (Fig. 3):

- **Input boxes.** These types of actuator is selected, when the variable can take multiple values m or u , for example, the values of effort.
- **Selection buttons.** Was placed when the user must choose between two options that cannot coexist simultaneously to the checking.
- **Operation buttons.** Such controls are placed when you want to select the options written on and even sometimes drawn with the relevant charts.
- **Pop-up menus.** On the occasions that the values to select options have clearly defined and there is no possibility to select any option that is not on that list.

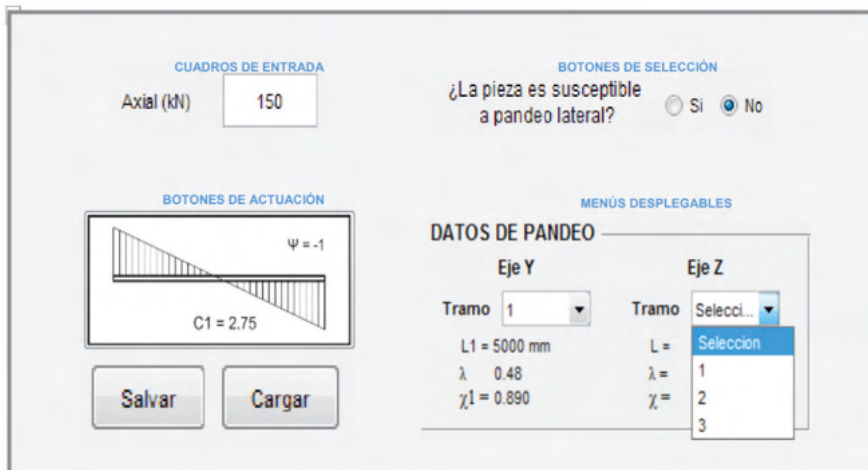


Fig. 3. Example modes of action with the program

In the main working window variables are common to all tests defined. Each test takes data entered into this window and run the calculation. In addition, for each test, child windows are enabled for the introduction of the characteristics of each variable.

The concept of evolutionary interface is justified because it is necessary in some other preflight checks run as it needs pre-calculated data for the result. Therefore, the findings are presented in a logical order according to the need of data each. Thus it is not possible to test without performing the above immediately, which is clearly designed for the student to be able to identify the different parameters involved in each moment.

The results of the tests are indicated by text boxes where the student clearly indicates whether the profile is valid (“MEETS”) or invalid (“FAIL”) on the input data, so that a bar that meets All checks can be considered valid address this hypothesis calculation.

To analyze these results, a paragraph is added in each window that exposes the internal calculations that earned the program after executing the code. Data variables considered most significant when the analysis of the result and ordered schemes Showing, enabling compression and analytical skills.

In creating the visual environment options “Save” and “Load”, which allow the user to save and load your jobs are added.

Then briefly describe different calculation screens, showing the most significant specifications of each and why its design from the educational point of view.

Main work screen:

With these guidelines, the main working window takes on the appearance shown in the following image (Fig. 4).

- **Introduction of the data:** In this window the incorporation windows introduction of data so that the information is necessary to be organized and the student does not deviate his attention, relating the data are grouped.
 - Data of the material: The first part refers to the material data. This section is to be prepared to enter data regarding the material and type of profile to be used in design.
 - Facts efforts: Completed material data, this part where the input data for the stresses to which you want to check the bar in question is incorporated ion is activated.

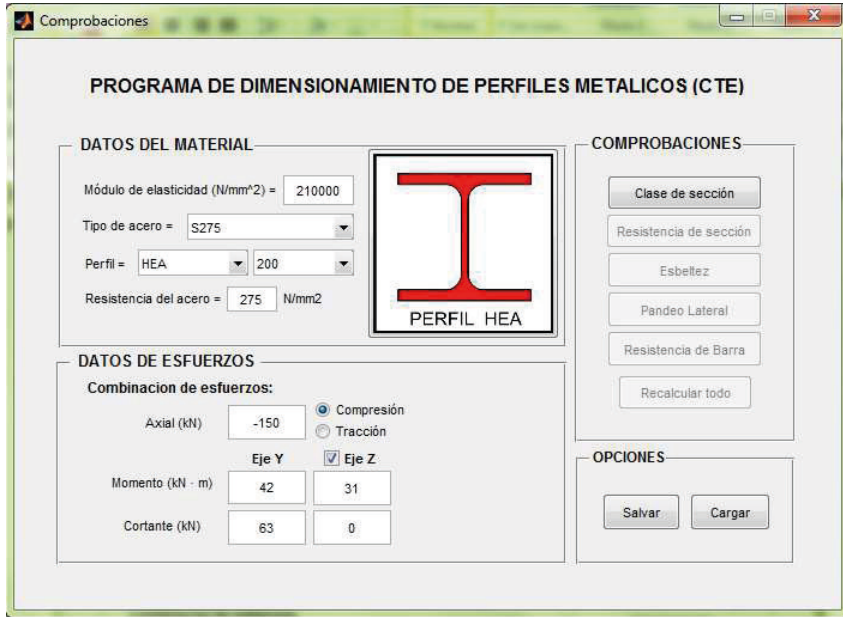


Fig. 4. Aspect of the main screen of the tool APERMET.

- **Checking:** Difference this main window with the above, lies mainly in the points to calculation results are incorporated, as these data in order to arrange each pair calculated to meters, are sorted and shows the corresponding the check. Thus a generic checks section appears in her place, where through different buttons gives way to a secondary windows to conduct analysis. These buttons are activated the function gradually that the input data (first CHECKING) are completed or post CHECKING (other tests) is run.

Options. Provide an option to save and store the generated jobs, so that students can save their exercises and to check them or recover them as the course progresses is enabled.

CHECKING 1. Section class.

As specified above, upon completion of the general data, you can access the various checks. The first corresponds to checking enabled TEST CLASS PROFILE. This window fits into the overall design Entering data and calculation results (Fig. 5).

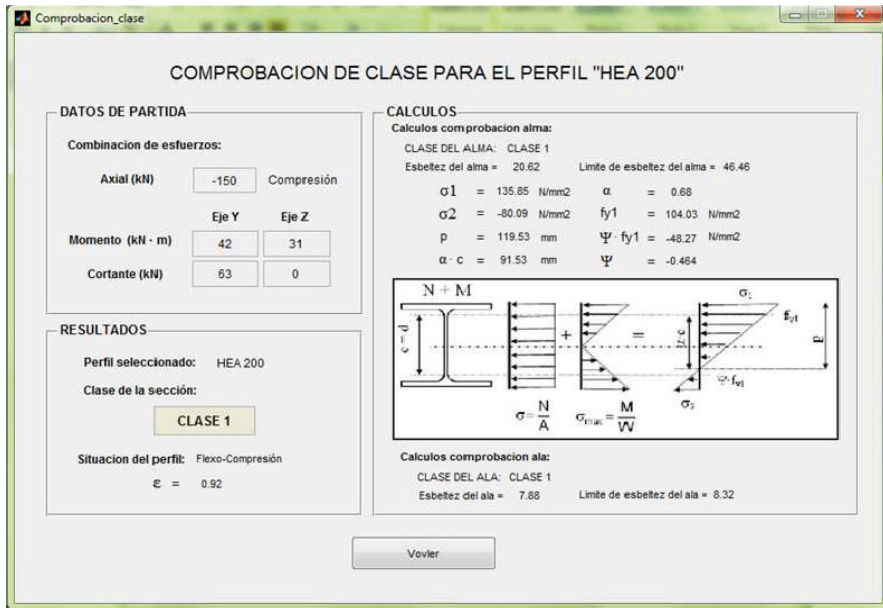


Fig. 5. Aspect Screen Checking Tool Class APERMET.

Introduction to the data. (Baseline data) In this case, the information in the window is inactive and are loaded from the previous window to change the values of calculation, it must act on the main window. This aspect, which generally repeated in the different tests, intended to give an idea of what perimeter are common in the checks, by allowing students to create a data structure and data become know as previous data or other CHECKING that can be successful.

Calculations. In this section the values of calculation is necessary to classify the profile of the corresponding supported scheme that identifies each of the variables described. The calculations for the flange and web are made separately, so that a result of class for each of these elements are obtained.

Results. The result of the calculation to the section is to be determined by the class resulting from unfavorable between the flange and web. Here, this section automatically generates result, appearing the resulting class section versus stresses introduced. In addition to the situation in which the profile is shown.

CHECKING 2. Resistance of section.

This test determines the strength capacity of the selected section. With it checks if the applicants selected profile resist stresses introduced in the main screen. At this level of advancement in the calculation, if the student section not detected that resisted such efforts, may elect to change the selected profile by no greater in the main editing window,

or continuing other checks.

This window is divided into two sections. The first, as happened in the previous window shows the start data taking program for the calculation. The second shows the calculation results. In this case the calculations section is not used, since this test does not require intermediate calculations break down.

Introduction to the data. As in the previous CHECKING, the data are loaded into the tab of general work, so to incorporate any change must take this last.

Results. In this case, in addition to incorporate the criterion of whether the profile is to (MEETS) or it is not, the level of depletion in turn broken down by the quantity shown corresponding to each type of effort: axial, moment and shear; calculated is specified in the CTE. This last data can be very useful to the student to conduct a preliminary sizing of any part, as a change to ask profile can go investigating how will affect the level of exhaustion in it, for the profile right to a pre-sized.

CHECKING 3. Slenderness

Through this window you can calculate the slenderness of the piece to be analyzed. This check is not necessary to include in any order of calculation, however, is positioned in the third place because for testing interact outside the bar and intrinsic characteristic of the structure analyzed conditions, therefore, it seems logical its activation as long as you are clear about the profile is starting to look and not before. Thus, in the hierarchy of analysis selected, the assimilation of concepts by students is a priority and try to locate the status of the calculation which is at all times (Fig. 6).

The particularity of this test makes data entry for this check is editable, so that data previously shown in white, and can only exit the application if completed and testing is calculated. The calculation option in turn, does not activate until all the data are not properly completed, similar to the data entry screen on the main job.

Furthermore, the results option is designed using a graphical output schemes, depending on where the divided sections to analyze the function of the shaft and rod are analyzed sample.

Introduction to the data. - For the calculation of the slenderness, the initial data used in previous mechanics are necessary concerning the character Profile Statistics therefore Baseline data in the selected profile on the main screen. To the calculation of slenderness is necessary to introduce new data to get the results, so are structured ion function of the two axes of the profile to be analyzed.

Results -. Results window by design a graphic output which is coupled to each of the intermediate values of calculation for each of the axes of the bar and each section therein. Therefore, the section "calculations" should be deleted to create a clearer the student environment, in which the characteristic parameters of each section and each axis

are encompassed around the outline. In order to display the values of outcome, each is necessary to calculate the intermediate values CHECKING, as it is coefficients and reduction or buckling to be necessary to calculate successful checks.

The particularity of showing the results grouped in this window, and that the data entry is done in the same field checking out the different sections, means that in this case the message validity (or FAIL COMPLY) is shown in part of the input. However, you can fully corroborate this in the results section, by simply comparing the limit introduced in the introductory paragraph is less than the reduced slenderness parameter λ shown in each section.

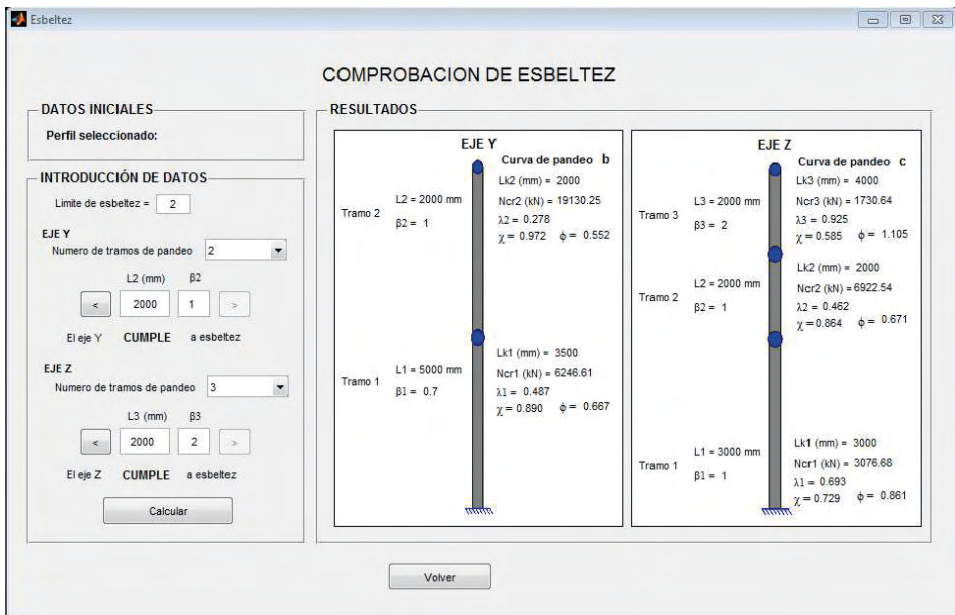


Fig. 6. Screen appearance of slenderness Checking Tool APERMET.

CHECKING 4. Lateral Buckling

Data Entry, Calculations and Results: When operating a new interface, structured similarly to the previous corresponding to this check button on the main screen. In this case, the initial data section has been combined with Data Entry, since the only data required is the characteristics of the profile. The window is distributed as shown in the figure 7.

Because of the similarity with the above checks, it is not going to expand on your explanation. However, as a particular aspect, a new concept appears in this section for determining the C1 parameter. In this case, we have designed a help button that calculates the value if it is not aware of it, so act on it a help window is displayed through action buttons with different diagrams printed on them. From them, the student can select the

option that best suits your problem automatically assigned the corresponding value.

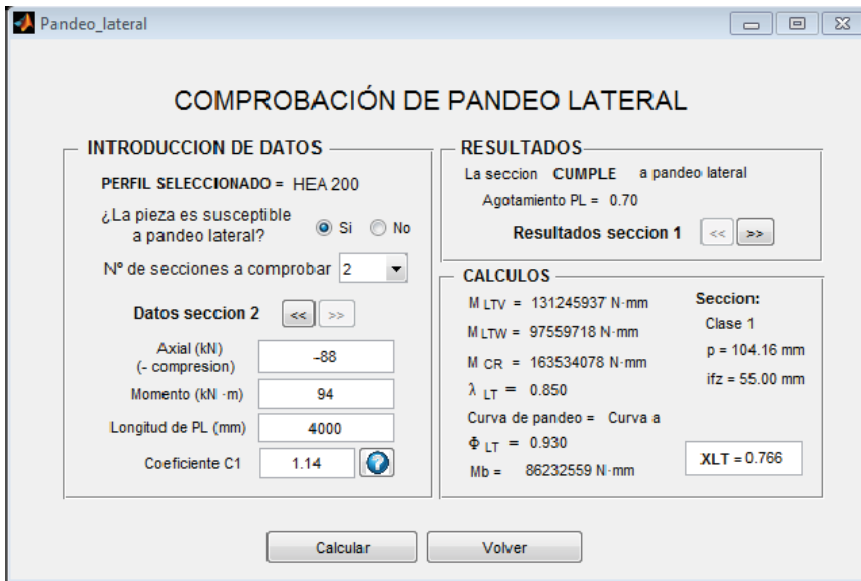


Fig. 7. Screen Testing of Lateral Buckling APERMET tool.

CHECKING 5. Resistance Bar

This is the last check and in turn the most complex of all, since it results in the rest of the checks and you need to calculate some new coefficients relative complexity involved. This is a test that requires full understanding of the concepts identified in the above checks and the students, as usual, have the biggest problems. Thus, the window is reserving a special space structure coefficients “more complexity” in its determination, showing a structured way the rest of coefficients from the above checks for selection.

As seen in the figure 8, the sections in which it is structured have been reconfigured due to the number of parameters involved in the same, resulting: Data mode, data Buckling, Data Lateral Buckling, calculator coefficients K, Calculation of coefficients Cm and Results.

Start data. - As happens in other checks, the data previously loaded in the main window, as derived from CHECKING class. Profile is analyzed and the stresses to which applicants workpiece is subjected to analysis.

Data buckling. - In this section, the user must define the pair to buckling meters that will influence the calculation of c to exhaustion and that have previously been calculated. You must select the position corresponding to the ion in which efforts are made to applicants the main window, to which the program take to the reduction coefficient or n by χ buckling and slenderness corresponding section.

Data lateral buckling. - Similar to the field reserved ratio (buckling), you must select

options for the lateral buckling.

Calculator coefficient C_{m_i} -. This is intended to calculate the different tees equivalent moment coefficient (C_m).. This is an interactive window despite being a section that displays data from calculation, which has been designed in this way with the fundamental objective of enmarar students to the calculation of each pair to metro, focusing on the same data to do so.

Thus, the paragraph is structured into three sets of input, one for each coefficient C_{m_y} , C_{m_z} and $C_{m_{LT}}$. Each coefficient is determined by the bending moment diagram that most closely resembles the situation of the bar shown to the right of the check (5 cases), to the axis of bending for each coefficient, and the dimension between points braced appropriate. Therefore, each coefficient is calculated similarly, given its bending axis and braced position points.

Calculation of the coefficients of interaction k - This is specified in the DB SE-A CTE, the following coefficients are set: k_y , k_z and k_{yLT} .

The screenshot shows the 'Resistencia_barra' software interface. It is divided into several sections:

- DATOS DE INICIO:** Perfil seleccionado: HEA 200. Esfuerzos: Axial (kN) -150, Eje Y Momento (kN·m) 42, Eje Z Momento (kN·m) 31, Cortante (kN) 63, 0.
- DATOS DE PANDEO:** Eje Y Tramo 1, L1 = 5000 mm, $\lambda = 0.48$, $\chi_1 = 0.890$. Eje Z Tramo 1, L1 = 3000 mm, $\lambda = 0.69$, $\chi_1 = 0.729$.
- DATOS DE PANDEO LATERAL:** Seccion 1, XLT = 0.766.
- CALCULO COEFICIENTE K:** $K_y = 1.034$, $K_z = 0.000$, $K_{yLT} = 0.984$.
- RESULTADO:**
 - Agotamiento para toda pieza: Agotamiento total = 0.54 CUMPLE. Agotamiento por axial = 0.12, Agotamiento por momento y = 0.42, Agotamiento por momento z = 0.00.
 - Agotamiento para piezas susceptibles a pandeo por torsion: Agotamiento total = 0.63 CUMPLE. Agotamiento por axial = 0.15, Agotamiento por momento y = 0.48, Agotamiento por momento z = 0.00.
- CALCULO DE COEFICIENTES C_m :**
 - Coefficiente C_{m_y} :** Calcular C_{m_y} , $C_{m_y} = 0.9$. Selección del caso de momentos flectores para el coeficiente C_{m_y} : 1. M_h (kN·m) = 60, $\Psi \cdot M_h$ (kN·m) = 35. $C_{m_y} = 0.83$.
 - Coefficiente C_{m_z} :** Calcular C_{m_z} , $C_{m_z} = 0.9$. Selección del caso de momentos flectores para el coeficiente C_{m_z} : No consid... M_h (kN·m) = [empty], $\Psi \cdot M_h$ (kN·m) = [empty]. $C_{m_z} = 0.00$.
 - Coefficiente $C_{m_{LT}}$:** $C_{m_{LT}} = 0.9$. Selección del caso de momentos flectores para el coeficiente $C_{m_{LT}}$: 1. M_h (kN·m) = 60, $\Psi \cdot M_h$ (kN·m) = 44. $C_{m_{LT}} = 0.89$.
- DIAGRAMAS:** Five cases (CASO 1 to CASO 5) showing bending moment diagrams with labels like M_h , ΨM_h , and M_s .

Fig. 8. Screen Testing of Resistant Bar APERMET tool.

Results. The result in this section is generated in a manner similar to the result for the CHECKING 2, so the criterion validity of the profile (COMPLY or FAIL TO COMPLY) joins the time it shows the level of exhaustion broken down by the quantity to each type of effort calculated is specified in the CTE for this CHECKING.

3 | UTILITY IN TEACHING

The result of this work is reflected in APERMET © Tool to calculate Metallic profiles according to the Technical Building Code, a matter clearly intended for use in teaching in engineering, but with the possibility of being used in the activity professional.

Thus, in the course of the subjects, the tool is presented to students as a tool of support that can optimize the time devoted to this subject since the time of conducting the study and exercises manually. They can check and/or advance the exercises by modifying different situations that reinforce the concepts applied.

The experience after several years presenting the tool shows that the use of this tool does not present a very high activity among students who enrolled subjects with regular attendance at classes, and who choose to ask directly in the tutorials or class.

However, it is pleasantly noteworthy that the use of this tool is widespread among the proportion of students who for various reasons cannot ordinarily attend the classes and / or tutorials, and need extra effort to reinforce the concepts studied. This makes it very useful for them to use a tool that helps them to confirm that the work done on the subject is correct and if not, the wrong focus quickly to advance and refine the concepts on working concept.

As mentioned, it is very important for them to identify mistakes since the large number of calculations required for the performance of a problem can lead to uncertainty of when and where the error presents the proposed resolution.

Furthermore, the design of evolutionary screen helps strengthen each item of evidence, so that they are given visual and intuitive way to follow developments in the different tests to be performed. Use Windows style applications to which students are very accustomed to using its utility makes it very attractive.

4 | CONCLUSIONS

The main conclusions obtained after the generation of the tool and made available to students are:

- The program fits nicely structured and the subject content form, so that it can be used perfectly for their support in teaching.
- The tool to evolutionary character of its interface allows to guide the student in the compression problems optimizing the time devoted to study.
- It is noteworthy that the highest activity with this tool is presented by students

who do not regularly attend the classes, recognizing APERMET as a valuable tool for learning complement.

- From experience, the tool as very interesting addition is proposed to be used in new formations that is now emerging, based on policy or telematic teaching to adopt the use of the internet where APERMET help clearly to enhance the study as related to structural calculation, because although as has been said its utilization requires prior knowledge in calculation of structures, the ease of handling makes it more intuitive to their learning.

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