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Graphic Preprocessor for Thermal Analysis via CS-ASA/FA

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Abstract. The structural analysis aims to determine the structure behavior and if it meets all the design's goals as adequate strength and stiffness for combinations of loading conditions in the ultimate limit states and service. Stresses, deformations, and displacements are examples of response that act according to the boundary conditions imposed on the structure. The process of this analysis has three basic steps: create the model, the calculation, and the analysis of the results. To facilitate this process, a software with preprocessing, processing, and post processing uses a numerical method for more realistic and efficient analysis. This work presented the development of a preprocessor for the computational module CS-ASA/FA. This module realizes a thermal analysis in a transient regime of common cross-sections in civil construction, which are fundamental for the fire analysis. The basic idea is to produce an intuitive environment, easier and efficient for modeling and releasing a numerical thermal analysis. Thus, for the elaboration of the preprocessor, used the graphical interactive environment, GiD. Performed implementation and modifications in GiD's problem type configuration satisfactorily to attend the demands of input data files for the CS-ASA/FA program.

Keywords: GiD-preprocessor, CS-ASA/FA, Thermal analysis, Fire situation.

1. Introduction

The structural analysis contemplates project verifications to attend the requisites of resistance and stiffness for the load combinations of the project. In other words, such analysis determines the structure resultant reactions thru tensions, deformations and solicitations under imposed conditions and loads. The structural analysis process can be divided into three main stages, which are: the creation of the structural model; the calculus of that model; and the visualization of the results. First, defined the geometry and properties, the material used, the active loading, boundary conditions, and others. Soon after, made the numerical solution and, in the last stage, seen the results in a way that the user can verify the response of the structure with all the necessary information.

The structural analysis process can be extensive and complex, but fortunately, the computer creation and its great capacity for data storage and manipulation, allied with new technologies, especially graphic computation, allowed to create of software with environments that facilitate the application of structural analysis programs that use numerical methods, like finite element method (FEM) [1]. It can mention many programs for structural analysis developed by Brazilian universities: an integrated research project coordinated by Professor Marcelo Gattass of the Department of Informatics of PUC-Rio and director of PUC-Rio's Tecgraf Institute (Technical-Scientific Software Development Institute), with funds received from CNPq (National Council of Technological and Scientific Development) developed the program Ftool (Two-dimensional Frame Analysis Tool; [2]). The responsibility for the Ftool is now in the hands of its author Professor Luiz Fernando Martha of the Department of Civil Engineering of PUC-Rio. The Ftool presents an interactive efficiently graphical system that, in the basic edition, enables the user to define models in an efficient and simple manner. It construes the structural model and gives many results, such as internal force diagrams and the structures deformed configuration, as well as influence lines for any point on the structure and load-train result envelopes. This program brings together in a single platform resource for the creation manipulation of the model (preprocessor), the analysis (processor) and the visualization of the results (post processor). Cross-sections defined either parametrically according to multiple templates (rectangular, T-, L- and I-shapes, etc.), by selecting from a diverse array of standard shapes (AISC, Gerdau, etc.), or generically (defining the sections geometric properties such as area and moment of inertia). Either Euler-Bernoulli or Timoshenko theory may calculate structural members. Supports may be rigid or elastic and inclined or suffer imposed displacements. This enables multiple types of structures, from the simplest to the more complex, to be modeled in Ftool in a matter of minutes; the INSANE (Interactive Structural Analysis Environment, [3]), is a structural analysis program for beams, trusses, two-dimensional frames and grids. It developed in the Department of Civil engineering of UFMG and its main proposition is to be an academic software, open coded, subject to alterations to adequate it to the educational demand; the AcadFrame [4] is about a tool developed in the school of engineering of São Carlos of USP, which uses FEM for the analysis of two-dimensional frames and trusses, including geometric nonlinearity, temperature effect and combination of external influences; and CS-ASA (Computational System for Advanced Structural Analysis; [5]) and its modules CS-ASA/FA (Fire Analysis; [6]) and CS-ASA/FSA (Fire Structural Analysis; [7]). It's about a homemade program, without a pre- and post-processor, which does, together with its both modules, the advanced numerical analysis of structural systems at room temperature and in a fire situation. A research group from the Federal University of Ouro Preto developed it from the initial work of Silveira [8]. It is important to highlight those preprocessors are, currently, important and indispensable tools to structural analysis programs based on FEM. That's because these tools provide a friendly and intuitive interface for the user, helping him at the edition/visualization of the structural model providing, thus, a more efficient analysis.

In this context, the present work shows the development of a preprocessor for the computational system CS-ASA and its modules CS-ASA/FA and CS-ASA/FSA. More precisely, developed the preprocessor for the module CS-ASA/FA that realizes the thermal analysis in a transient regime of common cross-sections in civil construction, which is fundamental for the structural analysis in a fire situation. The basic idea is to provide an intuitive, easier and efficient environment for modeling and realization of the thermal numerical analysis. The using of the preprocessor provides the analyst a major reduction in the effort required for the definition of a model, facilitating the supply of necessary data to the analysis program, letting greater precision and quality to the data that describes the analyzed problem. Thus, a graphical-interactive environment named GiD and elaborated by CIMNE [9] used by this work for the elaboration of the preprocessor. Performed implementation and modifications in GiD's problem type configuration satisfactorily to attend the demands of input data files for the CS-ASA/FA program. The GiD–CS-ASA/FA interaction is described in the next section.

2. GiD–CS-ASA/FA interaction

The thermal analysis is an important step in the structural analysis in a fire situation. Its temperature determination characterized it across the cross-section of the elements affected by the fire. For each instant of postulated fire, the thermal response is obtained through a numerical procedure for calculating the heat transfer at different points in the section. It's worth noting that time is a fundamental control variable in the analysis. So, the computational module CS-ASA/FA [6], which uses FEM, basically determines the temperature field in the structural elements in fire through a procedure of solution of simple incremental nonlinear equations. This procedure allows the consideration of the variation of the thermal properties of the materials as a function of the increase in temperature, following recommendations established by standards for advanced analysis models.

It needs two input data files for the thermal analysis in the CS-ASA/FA module, manually elaborated by the user through text files. The realization of this analysis depends on whether a series of data that need to be informed for the viability of the correct results. The first and most important is the discretization of the section into plane finite elements. In other words, the information on coordinates of nodes and the connectivities of the finite elements. Then, in addition to basic information related to the analyzed cross-section, like the material used and the fire exposure conditions (fire exposed face), the total duration of the fire, the time increment that adopted in the analysis and the curve that will characterize the behavior of the fire are also fundamental parameters to be provided. These are data that can vary according to the analyst's objective and, therefore, constant changes need to be made in the module's input files, which, naturally, demand work and can cause unwanted errors in edits. To improve and speed up the thermal analysis preprocessing step in the CS-ASA/FA module, it coupled the module to the interactive-graphic environment GiD [9]. The GiD presents the possibility of elaboration of personalized input files to meet the user's analysis demands through an intuitive and simplified analysis.

The interaction between GiD and CS-ASA/FA was possible through implementations in GiD's problem type that includes a set of text files used by GiD to customize the modeling that, in a thermal analysis case, present the materials used, the boundary conditions (exposed faces), geometry and other parameters necessary for the analysis, as illustrated in Figure 1. More details on this computational module are in Pires et al. [6] and Barros et al. [10].

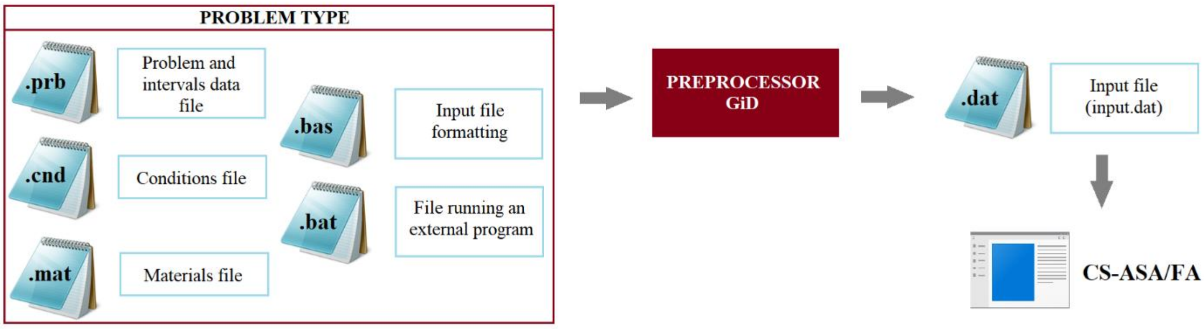
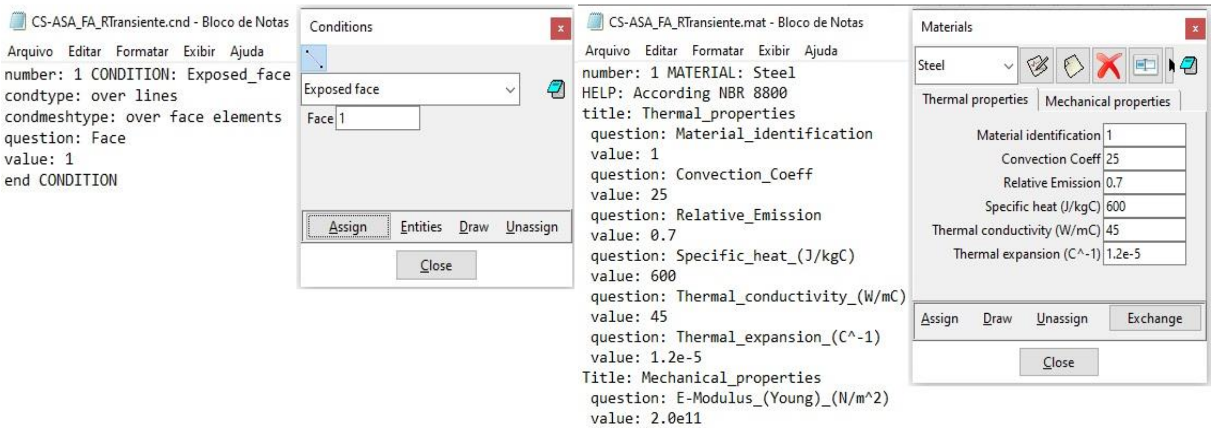


Figure 1- CS-ASA/FA – GiD interaction flowchart

The analysis starts with the section's geometry creation within the GiD's interface, facilitating the modeling and application management of the necessary parameter (.mat, .prb, .cnd files). The CS-ASA/FA input file (input.dat) created from the .bas file and the module executed through the .bat file. The .cnd file (Figure 2a) is responsible for informing the boundary conditions imposed on the thermal problem. For CS-ASA/FA, indicating which faces of the section exposed to fire is very important. The .mat file (Figure 2b) shows the thermal properties of the different materials that used in the cross-section. The computational module can perform the thermal analysis on steel, concrete, steel-concrete composed and wood sections. Besides, it is possible the consideration of thermal protection materials in the steel sections. The .prb file lists all the other essential parameters for the analysis that the user must inform to use the CS-ASA/FA. Based on the assignments performed by the user, the .bas file organizes the .dat, input file, according to the format accepted by the computational module. With the integration between GiD-CS-ASA/FA, it was possible to transform the two data input files, required before, into just one. Finally, the .bat file is the CS-ASA/FA execution command.

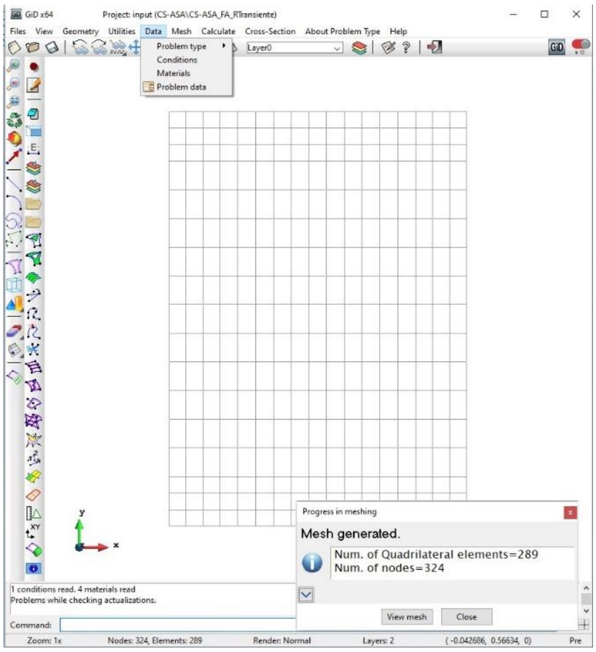


a) Condition file b) Materials file

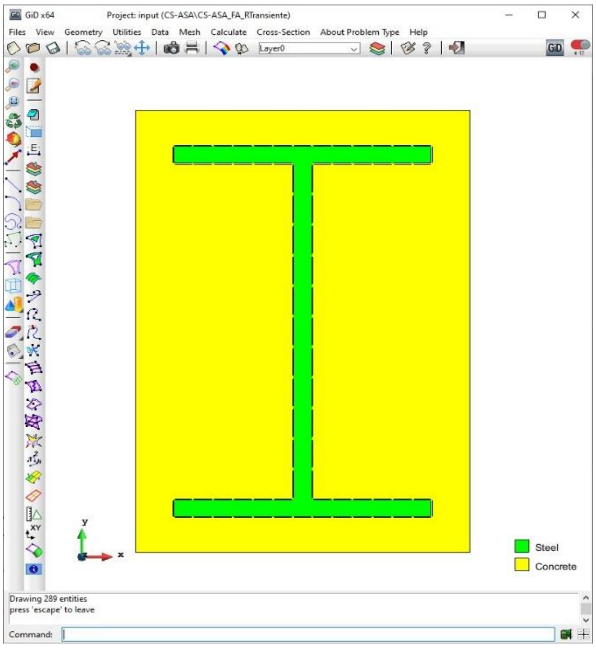
Figure 2- CS-ASA/FA's preprocessor text files format

3. Application of the preprocessor in thermal analysis via CS-ASA/FA

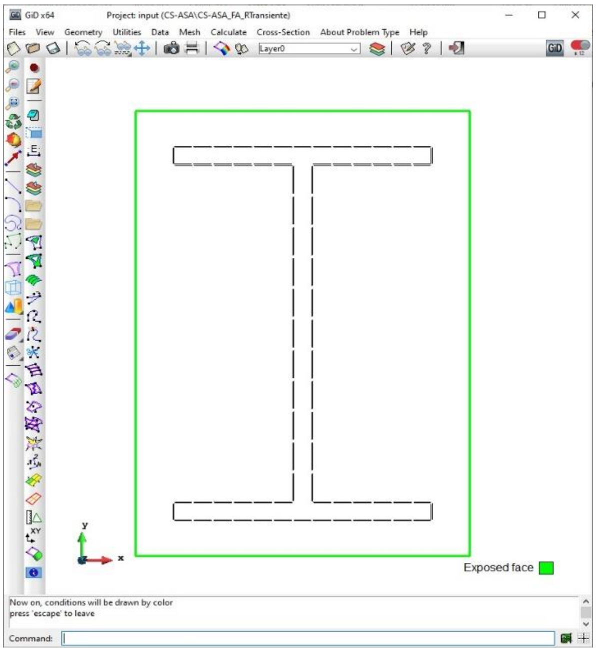
In this section, presented a model to exemplify and validate the implementations carried out for the preparation of the preprocessor (Figure 3). In the Figure 3a illustrates the geometric features and finite element mesh of a steel-concrete composite cross-section (Figure 3b), exposed to fire from all sides (Figure 3c), for transient thermal analysis. As seen in Figure 3d, considered the standard fire curve representing the fire, the total fire equal to one hour (3600 seconds) and the time increment for the analysis equal to 10 seconds.



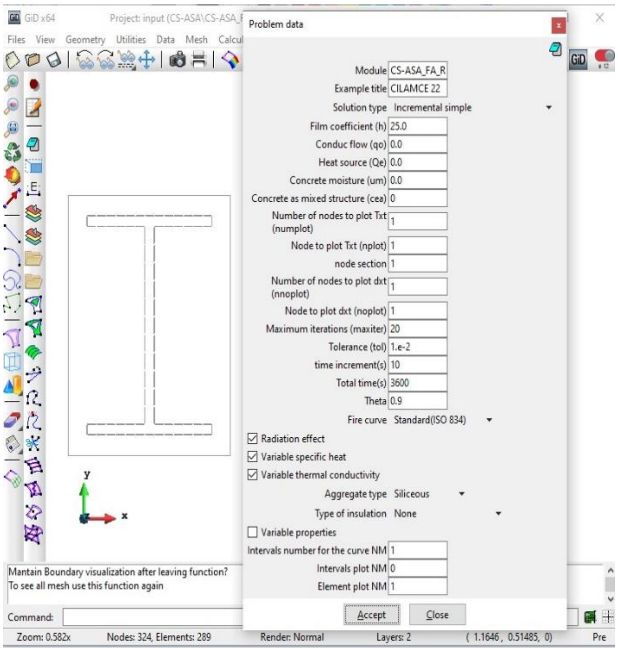
a) Mesh



b) Definitions of materials



c) Exposed faces



d) General problem data

Figure 3 - Modeling in the CS-ASA/FA's preprocessor

4. Conclusion

The present work aimed to develop a graphics preprocessor for the computational module CS-ASA/FA. According to the example presented, it was possible to perceive the success in the implementations carried out in the graphical-interactive interface GiD, which allowed the proper creation of the input file for the module. Thus, it concluded that the creation of the preprocessor facilitates and speeds up the modeling of the problem, allowing to the user to make direct and simplified changes in the parameters required for the analysis. In addition, the preview of all definitions contributes a lot to minimize the error occurrence in the modeling stage. As future steps, the development of graphic pre- and post-processor also stands out for the CS-ASA/FSA, which performs the thermostructural analysis, as well as the pre- and post-processor for the structural analysis in room temperature performed by CA-ASA.

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