



OPEN BIM WORKFLOW FOR THE DEVELOPMENT OF PROJECTS WITH STEEL STRUCTURES

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Abstract. This article presents the development of a collaborative, multi-disciplinary and multi-user OpenBIM workflow aimed at meeting the needs of the steel construction industry. The objective is to integrate new technologies into the project development process via a series of tools that facilitate the specialised work of technicians and allow information to be transmitted in standard digital format, reducing time and costs and avoiding a large number of problems that arise due to a lack of coordination between the project phase and the construction phase.

1. Introduction

The implementation of BIM methodology provides a reduction of costs and time in the construction industry, as it establishes the modernisation and restructuring of the processes related to the life cycle of buildings, with the consequent reduction of errors in the design, construction and operation phases [1].

OpenBIM is a universal approach to collaborative building design, construction and maintenance [2]. Through the use of this technology, the technicians involved in the development of the project can work in a coordinated and simultaneous manner, regardless of the software tools they use, in an open and transparent workflow.

The reason for implementing this workflow within a shared cloud environment is due to the need to respond to the current professional situation, which is becoming increasingly more specialised and collaboration is becoming even more necessary to achieve efficiency.

As the project develops, each of the parties involved in the project provide different layers of information, starting with a basic project model in which certain requirements must be met, and ending with a precision model with detailed information on construction and installation

needs. The final objective is the industrialisation of the construction process, allowing all the agents involved in the development of a project to have the necessary tools at their disposal from the initial design phase to on-site execution.

2. OpenBIM workflow

One of the main advantages of OpenBIM technology is that it is based on open and public standard exchange formats so that the contents of the BIM project are not linked to any specific application or programme. Moreover, thanks to the use of these exchange formats, the specific applications used to solve the different disciplines of a project (structure, facilities, etc.) do not have to be linked to a single software manufacturer. A representative diagram of the OpenBIM workflow on the BIMserver.center platform can be seen at Fig. 1.

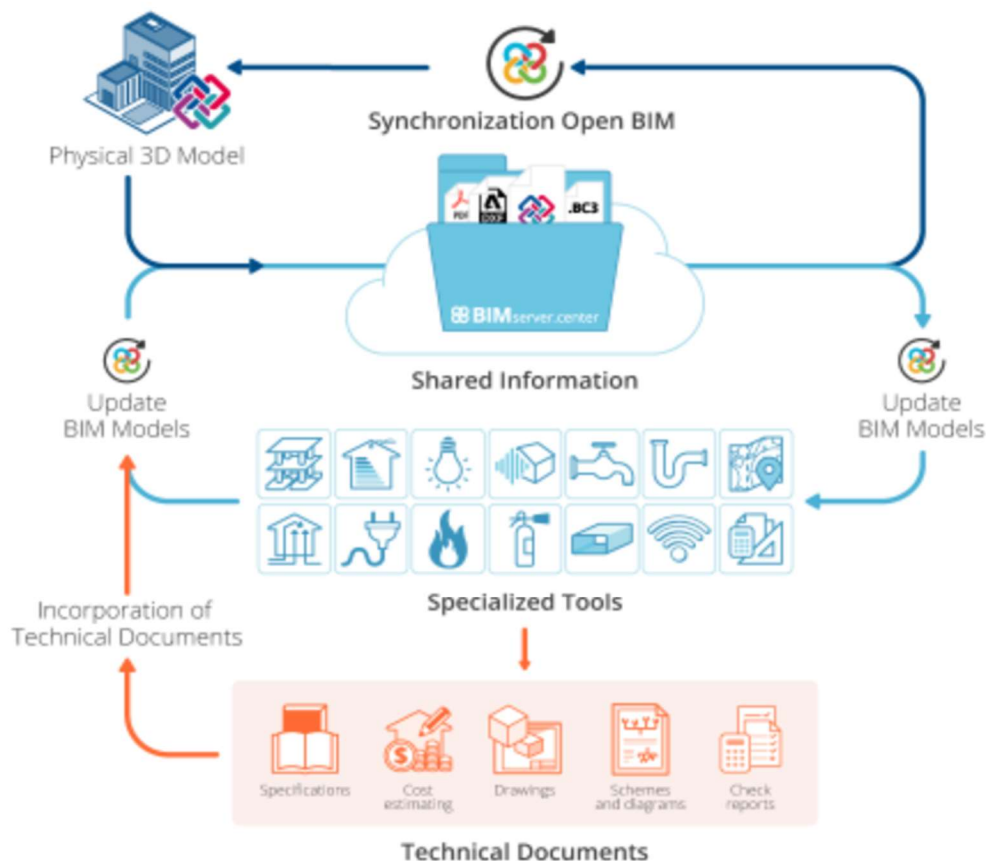


Fig. 1: OpenBIM workflow on BIMserver.center

The stages or actions considered in the proposed workflow for the development of a project are:

1. Starting a BIM Project: The situation and location of the project are selected and started with a standard format file of a geometric model generated by a modelling programme.

2. Using specialised applications to solve the project: Technicians will use specialised tools to solve each of the disciplines involved in the project by linking to a BIM model in the cloud.
3. Updating the BIM model through specialised applications: Once the technicians develop their work in each discipline, they export their solutions to the BIM model by adding layers of information.
4. Consolidating the BIM model: As the project develops, the information corresponding to the BIM model increases thanks to the standard format files generated by the specialised applications.

3. Project on BIMServer.center

All the aforementioned disciplines involved in the project are in a common collaborative environment in the BIMserver.center cloud.

Each specialist is responsible for a particular discipline and will use specific tools for developing their work by exporting files containing their solutions to the platform.

BIMserver.center is the natural result of this collaborative workflow, as the need for direct communication arises between all the specialised applications we use for the development of the project, allowing us to share, manage and update all the project files in the cloud. This makes it possible to centralise and manage all the files of a BIM project in real time, as well as manage the log-ins of the different technicians involved. It is also a meeting place for engineers, architects, builders, manufacturers and, overall, all professionals and institutions linked to the world of architecture, engineering and construction, allowing them to work together to develop projects and exchange information and services. A representative diagram of how the BIMserver.center platform works can be seen in Fig. 2.

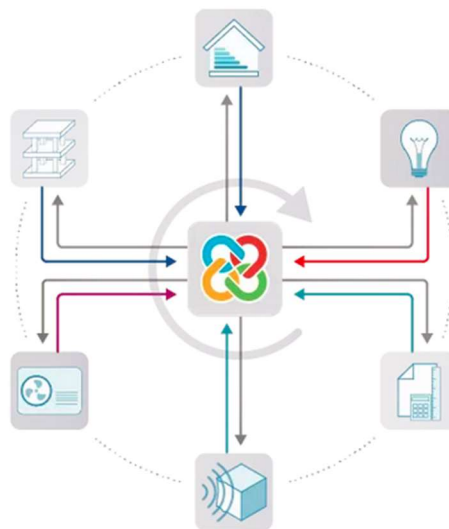


Fig. 2: Schematic diagram BIMserver.center

4. OpenBIM workflow in structural steelwork construction

Focusing on steel structure construction projects, we can define the workflow within the OpenBIM ecosystem that allows us to go through its different stages, from the definition of its

geolocation to its fabrication at the workshop. In Fig. 3 this workflow is shown in a representative way, through different specialised applications that make it easier to deal with each and every one of the stages from design to construction.

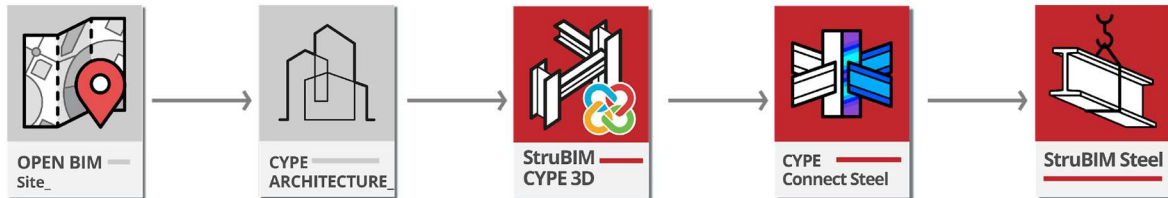
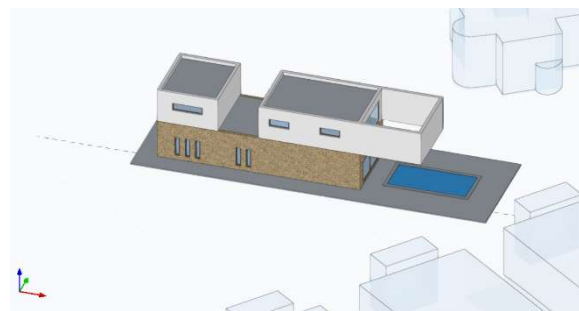


Fig. 3: Workflow of steel structure construction

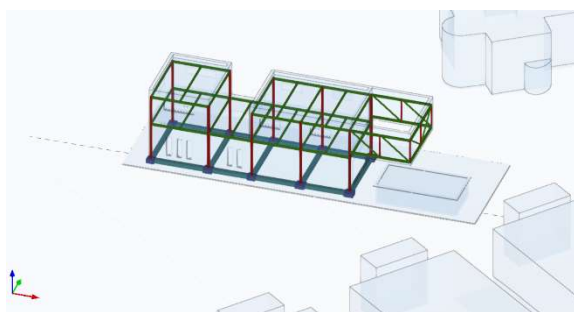
In each of the stages, the BIM model is enriched with the information provided by each of the specialists involved in the project, as shown in the example in Fig. 4 (single-family house). By working with specialised applications, and with complete control of the design models, the responsibility of each person involved in the project development is perfectly defined.



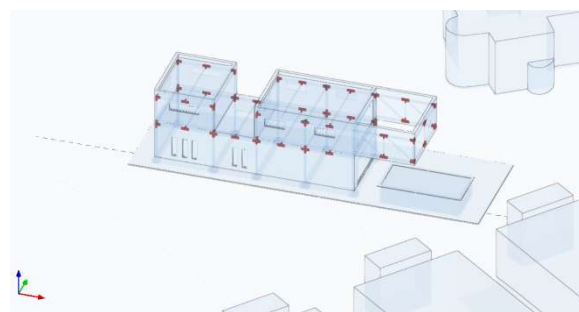
a) Location and Geolocation



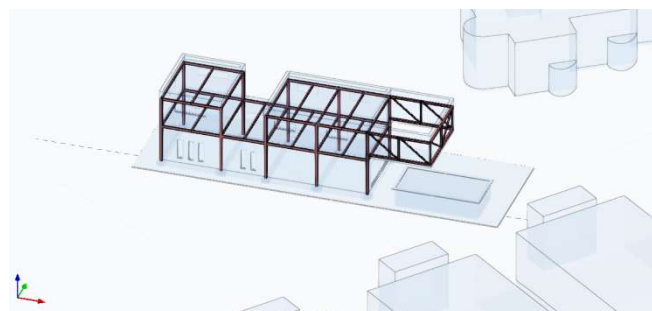
b) Architecture



c) Structure



d) Definition of joints



e) Precision steel structure model

Fig. 4: Workflow of steel frame construction of a single-family house

As shown in Fig. 4, the following phases can be identified:

1. Location and geolocation: In this phase, the initial conditions of a BIM project site are defined including its geolocation, topography of the land according to its surroundings and the cadastral location.
2. Architecture: The next step will be the generation of an architectural model that defines the geometry of the building. In the OpenBIM workflow, this architectural model can be generated by any software tool that is able to export this model in a standard format.
3. Structure: Once the architectural model has been defined, the design and analysis of the structure and dimensioning of the sections is carried out.
4. Design of joints: In this phase, once the dimensions of the sections and the internal forces to which they are subjected are known, the joints of the steel structure are designed.
5. Detailing: Once the structural analysis has been completed, which includes the design and analysis of the corresponding joints, the precision model of the structure that will be manufactured at the workshop to be assembled on site will be defined.

5. Structural design and analysis in OpenBIM workflows

5.1 Architectural design

Once the project site has been defined, the first step will be to carry out the architectural design of the building, generating a geometric model of the building that will be used as the basis for the rest of the disciplines of the project. In Fig.5, the architectural model corresponding to the example of a single-family house is shown.

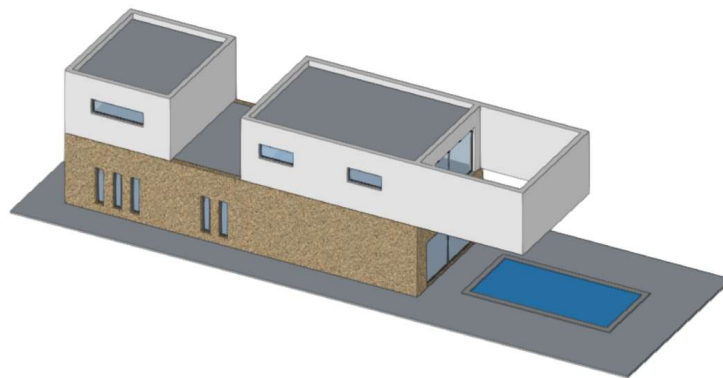


Fig. 5: Architectural design

One of the advantages of the presented collaborative workflow is that it allows the architectural design, in which the geometry of the building and its constructive elements are defined, to be decoupled from the specific definition of structural elements such as columns, beams, footings and floors.

5.2 Definition of structural elements

Once the architectural model of the building has been generated, using this as a basis, the specialist can then define the structural elements that will become the building skeleton. The pre-dimensioning of these elements is always based on the experience and knowledge of the

technician in charge of this task, who will subsequently make the necessary adjustments according to the results of the analysis.

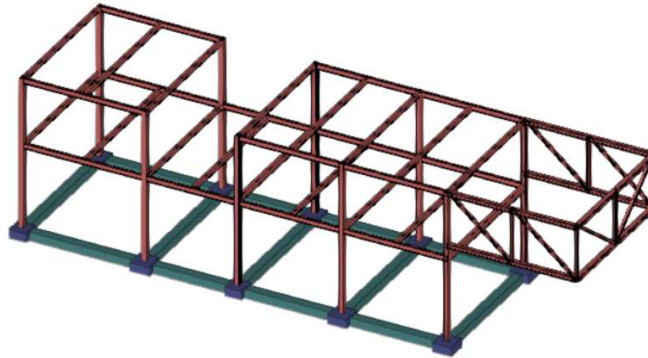


Fig. 6: Definition of structural elements

Fig.6 shows the definition of the structural elements of the single-family house. These elements have been designed with the previous architectural model as a reference. The decoupling of these phases allows the different agents developing the architectural and structural design of the building to work with specialised tools according to their needs.

5.3 Structural analysis

The next phase is to analyse the building structurally. For this purpose, an analytical model based on the structural model will be generated. The structural analysis consists of obtaining the effect of the loads to which the structure will be subjected in order to check the ultimate limit states and the serviceability limit states. This analysis must be carried out for each design situation using appropriate analytical models that consider the influence of all the variables involved.

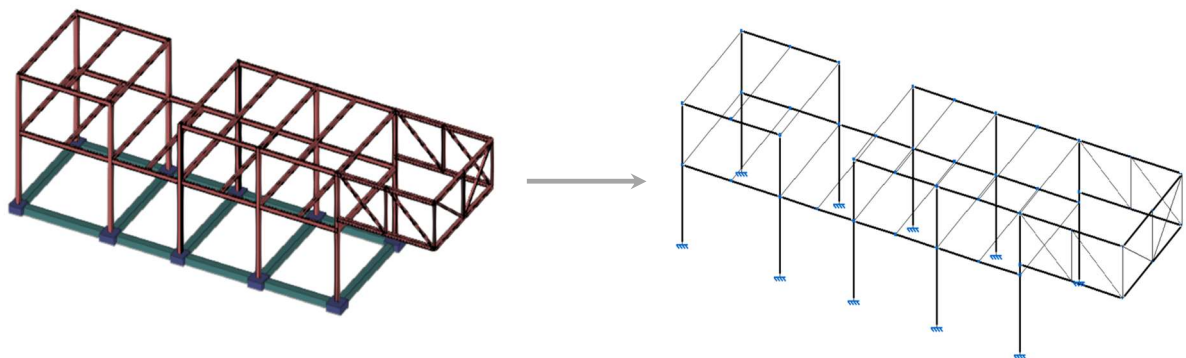


Fig. 7: Analytical model generation

Fig. 7 shows the generation of the analytical model of the building taking into account the structural design of the building.

5.4 Designing joints

Once the analysis of the structure has been carried out and the steel sections to be used have been determined, the design of the connections between the different structural elements is carried out, taking into account the stresses for each situation in the project.

Joint design is one of the most complex problems in structural engineering. One of the ways to approach this problem is by using Finite Element Modelling [3].

CYPE Connect is a specific application for performing this task. The internal engine used for the Finite Element Method analysis OpenSees [4], a world-renowned programme developed by the University of Berkeley.

As shown in Fig. 8 and 9, the connections at the nodes of the steel structure must be perfectly defined geometrically in order to proceed with the analysis.

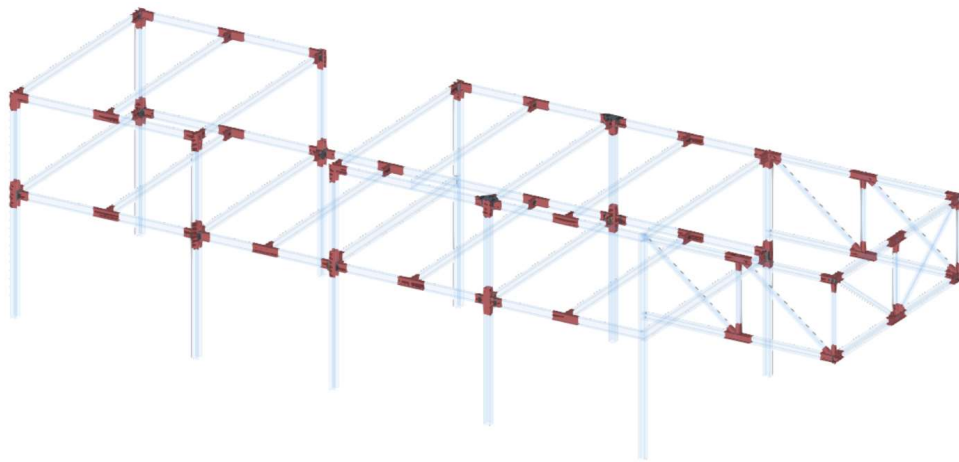
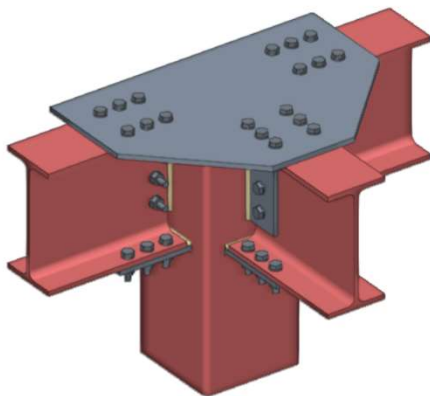
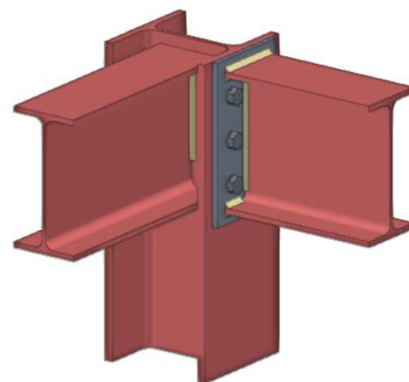


Fig. 8: Geometric definition of joints



(c) Example joint 1



(d) Example joint 2

Fig. 9: Examples of geometrical definition of joints

Subsequently, once the internal forces at the ends of the steel sections obtained once the analytical model of the structure has been solved or by analysing the joints individually by applying specific forces, the finite element analysis of the connections is carried out.

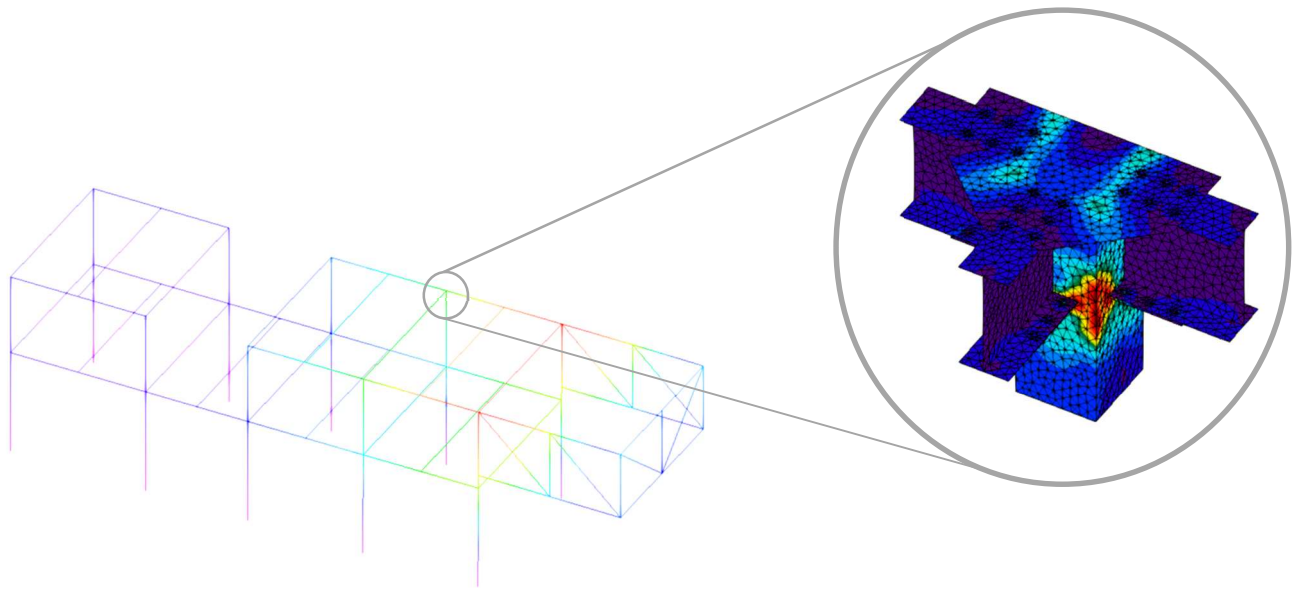


Fig. 10: Joint analysis taking into account the internal forces from the analytical model

Fig. 10 shows the Von Mises stress contour plot for one of the joints of the structure.

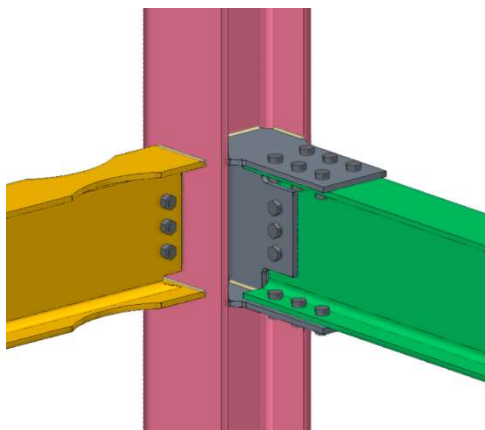
6. Detailing and fabrication in OpenBIM workflows

Once the structural analysis has been completed and all the regulatory requirements have been met, the last phase of detailing will be carried out in which, based on the sections of the structure and the joints that have been designed, a precision model is generated. In this phase, the elements that make up the structure are detailed exactly, taking into account all the structural information of the project with the aim of obtaining a model that will be manufactured at the workshop. All the operations to be carried out on sections and plates, such as cutting, drillings, edge preparation, marking, etc. shall be detailed in this model. Additionally, the welds and bolts that will join the different elements will be included in a precise manner.

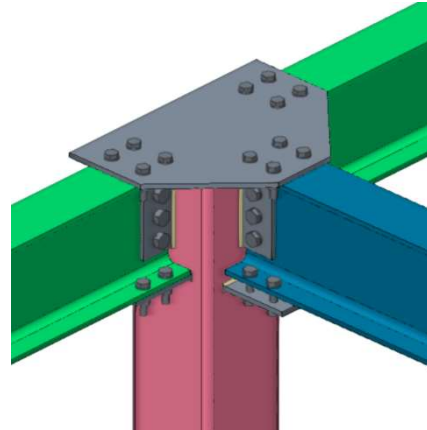
StruBIM Steel is a specific application, for this purpose it is integrated into the OpenBIM workflow. In Fig. 11 and 12, a representation of the precision model that will be fabricated at the workshop is shown.



Fig. 11: Precision model of a steel structure



(c) Detail 1



(d) Detail 2

Fig. 12: Details of a precision model of a steel structure

The StruBIM Steel tool also allows computer numerical control (CNC) fabrication files, in DSTV and STEP format to be exported. An example of exporting to these files is shown in Fig.13.

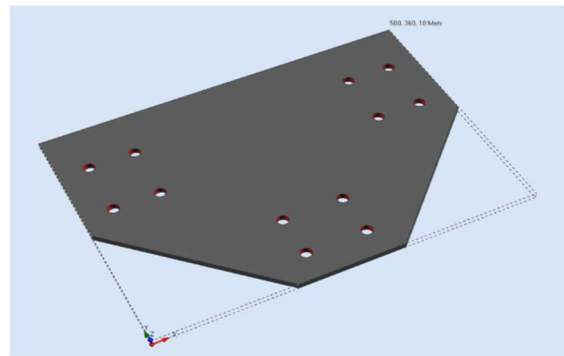
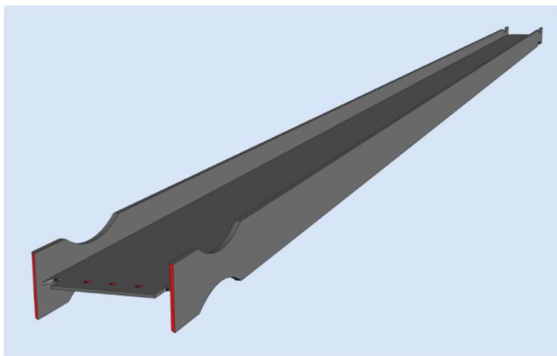


Fig. 13: Export of files in a format suitable for CNC manufacturing

This phase is the final stage of the steel structure construction workflow. Starting from the definition of the site and location of the project, layers of information have been added until a precision model of the steel structure is created, whose elements will be manufactured directly at the workshop, reflecting an industrialisation of the construction process.

7. Conclusions

This work has presented a workflow that allows a steel structure construction project to be developed, addressing each of its phases through specialised tools and managing the project files through a collaborative platform in the BIMserver.centre cloud. The solutions presented can also be extrapolated to other project disciplines: thermal or acoustic studies, MEP system design, energy efficiency studies, installation of manufacturer systems, etc.

One of the great advantages of this collaborative flow is that it is open, i.e. the specialised tools used to solve each of the disciplines of the project do not have to be tied to a single software vendor as the transmission of information occurs through files in standard, open and public digital format.

Additionally, the OpenBIM technology implemented allows the processes related to designing a building project to be carried out in a more optimised way in terms of quality control and resources used. The models shared on the platform make up the BIM project whose information, both geometric and technical, is incorporated into the different models according to the needs of each speciality, by means of automated processes after the designer's approval. The automation implemented reduces human error as it eliminates the need to manipulate the information through semi-automatic or even manual exchange processes. Furthermore, there is greater control of all the project information as it is collected in a common collaborative environment in the cloud, allowing the entire project development process to be monitored and any possible problems that may arise in stages prior to execution on site to be detected, reducing both time and costs.

References

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