

## **STRUCTURAL DESIGN WITH OPENBIM: FROM THE ARCHITECTURAL MODEL TO THE STRUCTURAL ANALYSIS WITH A STATE-OF-THE-ART CALCULATION ENGINE**

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### **Abstract**

OpenBIM is a universal approach to collaborative design, construction and maintenance of buildings. This technology allows a transparent and open workflow, facilitating the participation of all intervening technicians in a coordinated and simultaneous way, regardless of the software tools they use. The process of calculation and structural design can be integrated into the OpenBIM workflow without complicating or modifying the way of working that has traditionally been carried out. To this end, CYPE has recently created applications integrated in the OpenBIM flow to analyze and design structures such as StruBIM Analysis, in addition to adapt the existing ones. StruBIM Analysis is a new software to calculate the structure, that is to say, it obtains nodal displacements, sectional forces of one-dimensional elements and shell forces by means of FEM analysis. StruBIM Analysis integrates OpenSees as its calculation engine. OpenSees is a well-known framework developed by University of California: Berkeley, which performs complex calculations efficiently. This calculation engine has the data entry through code and the result output without graphical interface. However, thanks to the integration of OpenSees in an OpenBIM workflow, calculating non-linearly building structures with a dynamic analysis with integration over time will be possible in a user-friendly and reliable way.

### **1. Introduction**

Open BIM is a global proposal to achieve user collaboration in the design, execution and maintenance of buildings, based on an exchange of information using standard formats (IFC) and an open workflow. By using IFC format, which is standard and public, and not linked to a specific developer, the durability of the work that has been carried out is guaranteed, since it does not depend on the applications that have been used. Even the own data files of these applications, from a durability point of view of the project, are set aside as auxiliary files,

because the generated IFC provides the final information of the project. At the same time, it allows real and efficient communication amongst users, since these formats can be read and generated by the vast majority of applications used in project development.

Cype has recently integrated OpenSees [1] within Open BIM workflow. OpenSees [1] is a well-known framework to perform linear or non-linear analysis, developed at University of California, Berkeley. Its use is widespread all over the world mainly to simulate seismic behavior in structures. Cype has integrated OpenSees [1] as calculation engine for StruBIM Analysis, StruBIM Design and StruBIM Foundations. These programs are in charge of analyzing, designing and checking structures, including their foundations. To fulfill this, Cype has extended OpenSees [1] in some ways and one of them is creating two new finite elements, which will be explained in the following sections.

## **2. Open BIM workflow**

The phases of Open BIM workflow are displayed in Figure 1. A BIM Project starts with an IFC file which must be generated based on a 3D geometrical model produced by any architectural modelling software. This geometrical model is uploaded to a web platform called BIMserver.center which allows direct communication between all the users and applications that participate in a project. Next, all the applications that are compatible with the Open BIM workflow import the IFC model. All intervening agents receive the same geometry and architecture. Each specialized application imports the geometrical model and exports an IFC file with the results. This way, the BIM project is enriched and completed. Thus information of the BIM model increases using the IFC files generated by all the applications and defines the complete BIM project. This process is called consolidation of the BIM project. This information consolidation allows for the complete project to be generated, as a whole, and therefore detect, any possible interferences between the solutions that have been adopted. Besides, during the whole process, if any changes are made to the initial model, all the applications can undergo an updating process. This guarantees that no information is lost.

The IFC format files do not include specific information that makes up the project; all the data is generated and stored in the specialized applications. In other words, each member only shares the results and adopted solutions, whilst the data that has been introduced, the work methodology and intermediate results remain in the private domain of the specialist. By working in this way, the size of the files is significantly reduced, since each member is only in charge of the part of the project which s/he is responsible for. The information in IFC format, which forms the project, exclusively defines the project, and therefore, the specific tools and programs used to create it are auxiliary elements that can be changed or eliminated during the life span of the project.

When the project designer is faced with a design problem, he/she usually has to evaluate different solutions or proposals. As alternative options are rejected and decisions are made, more detailed work is carried out on them, to achieve greater definition. In the Open BIM flow, each analysis model is independent from the rest, so different solutions for the same field can

be proposed and defined, since the other models are not affected no matter what decision is made.

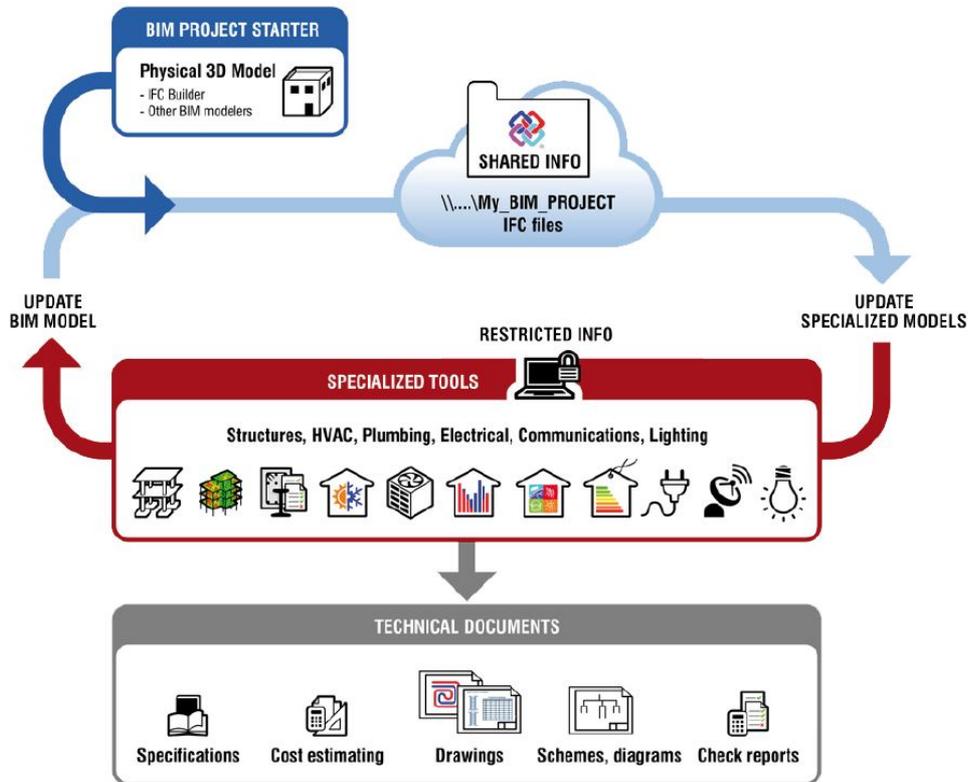


Figure 1: Open BIM workflow

### 3. Structural analysis and design in open BIM flow

The stages to carry out the analysis and design of structures are perfectly delimited (Figure 2): (1) create the structural model (based on the architectural or geometrical model); (2) generate the analytical model based on the structural model; (3) solve the analytical model; (4) design and check of structural elements; (5) generate layouts and reports.

#### 3.1 Generation, edition and analysis of analytical model

Cype has developed a program to generate, edit and perform structural analysis: StruBIM Analysis. This program forms part of StruBIM suite, which is a group of structural programs, each one related to one stage of structural design. Sequential version of OpenSees [1] has been used as calculation engine in StruBIM analysis (Figure 3). For this purpose several extensions have been implemented in OpenSees [1]: two new finite elements (one-dimensional and shell) [2-4], a new constraints manager, a new solver called MUMPS (Multifrontal Massively Parallel Sparse Direct Solver) [5], etc. Besides, multiple instances of sequential OpenSees [1] are used to solve several load cases at the same time.

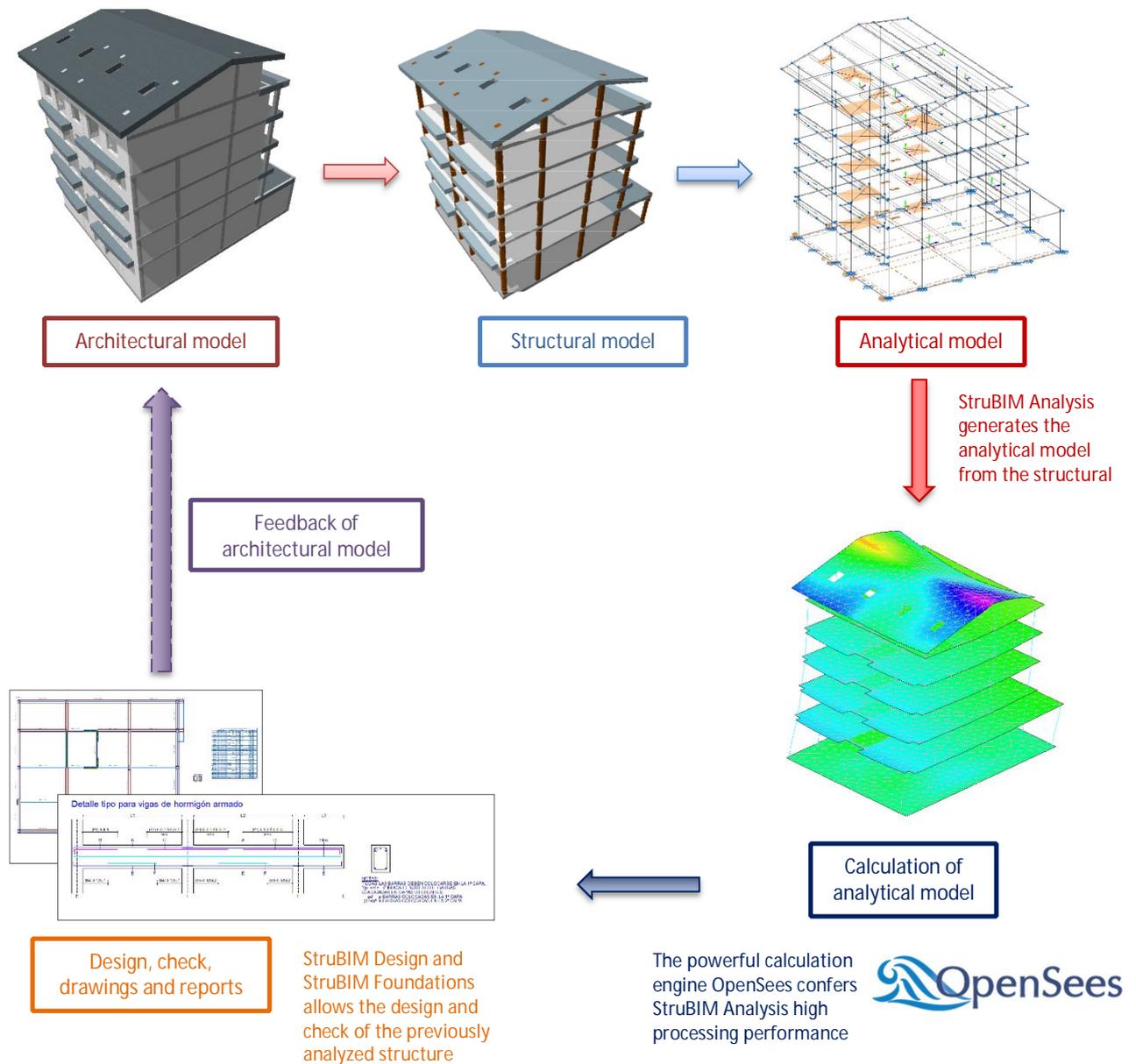


Figure 2: Structural analysis and design integrated in an Open BIM workflow

The main benefits that users can take from the workflow displayed in Figure 2 is that they will be able to use all the functionality of OpenSees [1] just importing the structural model into StruBIM. The structural model which derives from the architectural model can be made with any modelling commercial tool available on the market. User will be able to perform a complex non-linear analysis of an actual structure with OpenSees [1] with a minimum effort. This is unthinkable by coding the data input as OpenSees [1] itself requires.

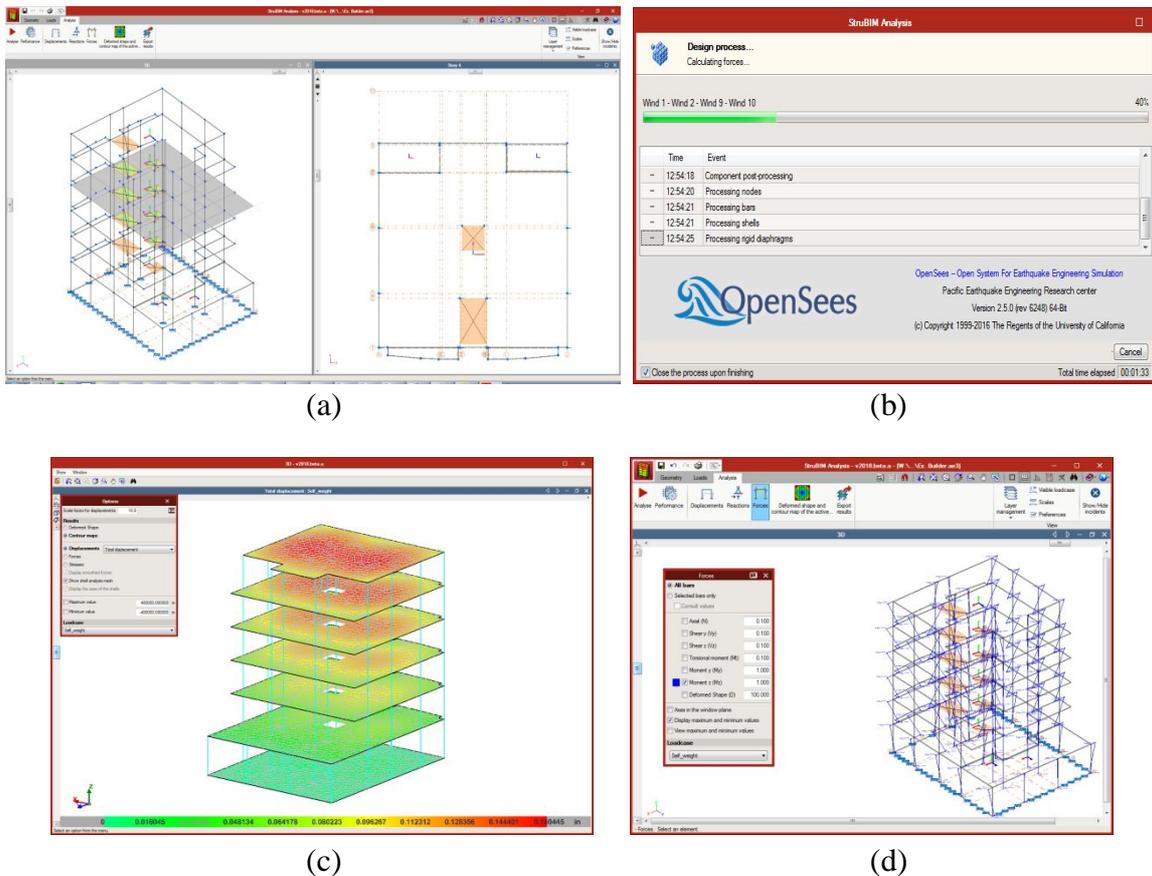


Figure 3: Structural analysis with StruBIM analysis plus OpenSees [1]: (a) Analytical model, (b) Calculating with OpenSees [1], (c) Deflections results, (d)  $M_z$  moments in columns

### 3.2 Design and check of structural elements

StruBIM Design is responsible for designing and checking columns, beams, slabs and walls according to ACI Codes. It imports the analytical model results from StruBIM Analysis or from an xml file with a specific format. Besides, it is able to manage a local analytical model of each floor to design tendons, slabs and beams. Analogously to StruBIM Design, Cype has created StruBIM Foundations to design foundation elements.

## 4. Conclusions

The following conclusions are drawn:

- In the Open BIM flow, users work with specific and highly specialized applications to solve each aspect of the project in detail. The relationship and interaction amongst all the applications is solved via including and integrating the BIM model composed of all the solutions adopted for each project area (consolidation process).

- Using open format interchange files, the applications are capable of reading all the information of the project and show it in an integrated way. Furthermore, with the consolidation process, users are able to detect any possible interferences between the adopted solutions.
- In the Open BIM flow, open formats are used at all times, which implies that any tool of any manufacturer can be part of the workflow in a simple way and, therefore, does not oblige users to have to modify their current working habits,
- Cype has recently integrated OpenSees [1] as calculation engine in its new suite StruBIM which is part of an Open BIM workflow. To fulfill this, Cype has extended OpenSees [1] in some ways and one of them is creating two new finite elements.
- OpenSees [1] itself requires the data input by coding. The main benefits that users can take from the integration of OpenSees [1] in an Open BIM workflow is that they will be able to use all the functionality of OpenSees [1] just importing the structural model into StruBIM. The structural model which derives from the architectural model can be made with any modelling commercial tool available on the market. User will be able to perform a complex non-linear analysis of an actual structure with OpenSees [1] with a minimum effort.

## References

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