



Take advantage of BIM for reinforced concrete structures

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SE6512 Structural engineers use many object-level design tools to effectively perform their designs. These tools can range from off-the-shelf structural design software to simple spreadsheets. As Building Information Modeling (BIM) adoption grows and general-purpose structural frame analysis software is being integrated with BIM workflows, connecting object-level design tools are not. There is an opportunity to drive BIM design information from these design tools in order to better streamline the engineer to BIM workflows. Come and learn how GRAITEC's Revit-based software will help engineers to get a real benefit from BIM.

Learning Objectives

At the end of this class, you will be able to:

- Start from an Autodesk® Revit® structural model and manage to get analysis results stored in Revit®, this being a starting point for going to rebar design.
- Complete structural Design assumptions.
- Use the BIM Designers technology for designing reinforced concrete members in Revit® (beam, column or footing) including detailed design reports.
- Get the 3D structural rebar automatically produced in Revit. From this 3D structural rebar, automatically produce the reinforcement drawings.
- Manage drawing revisions when a design changes are introduced.

About the Speaker



Starting his career as a structural draughtsman for a prominent engineering company in Southern Africa, Carl quickly worked his way up to DO Manager, and then Director of his own design company; developing practical skills born of real-world experience and a refined passion of adopting technology to eliminate repetitive tasks. Since moving to the UK in 2000, Carl has established a successful career within the Autodesk channel working with, and supporting both SME and major UK firms in the AEC and Infrastructure industry and gaining a wealth of industry knowledge and understanding of Autodesk's extensive portfolio in the process. This knowledge combined with his strong structural background and his passion for innovation and ambition to succeed, has resulted in quick succession through GRAITEC ranks and is now Graitec Product Strategy Director where he is using his skills to influence the future of construction technology to come.

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About the Co-speaker



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Introduction

There are many design tools used by structural engineers to effectively perform their everyday design tasks. Most of the time, in the existing workflow, they use standalone tools, sometimes linked or integrated with their 3D FEM analysis software but almost never linked with the CAD system. This break in the information workflow can be the source for a major bottleneck in the process resulting in wasted time and potential errors, especially in the dialog between the engineer and the draftsman.

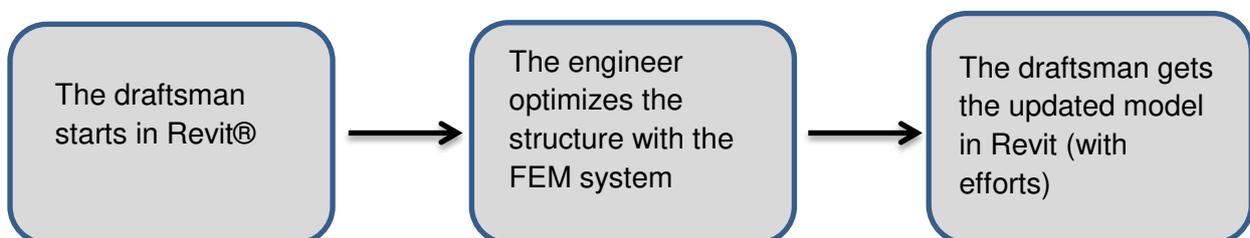
Building Information Modeling (BIM) is fast becoming the industry de facto. Noted for driving down project cost and errors whilst optimizing workflow and processes, BIM promotes early cross-discipline project collaboration and data sharing which ultimately leads to shorter project delivery times, increased accuracy and more effective and efficient designs.

The BIM workflow can be different depending on the company, on the people, on the projects... We believe that the industry is desperately in need of a technical solution which can fit with different workflows for the communication and data exchanges and bridge the gap between the engineer and the draftsman: who starts to work on a project first? Who is doing the member design? It could be the engineer, or the draftsman, or both, or vary depending on different applications or project types ...Regardless of which way or ways you work there always seems to be a gap resulting in the failure to successfully transfer, retrieve and reuse analytical data throughout the BIM project workflow.

We aim to show you that the BIM Designers technology from GRAITEC is designed to bridge this gap and provide a real solution to this problem. We will introduce a BIM solution which can fit with almost any workflow and retain the analytical data intelligence.

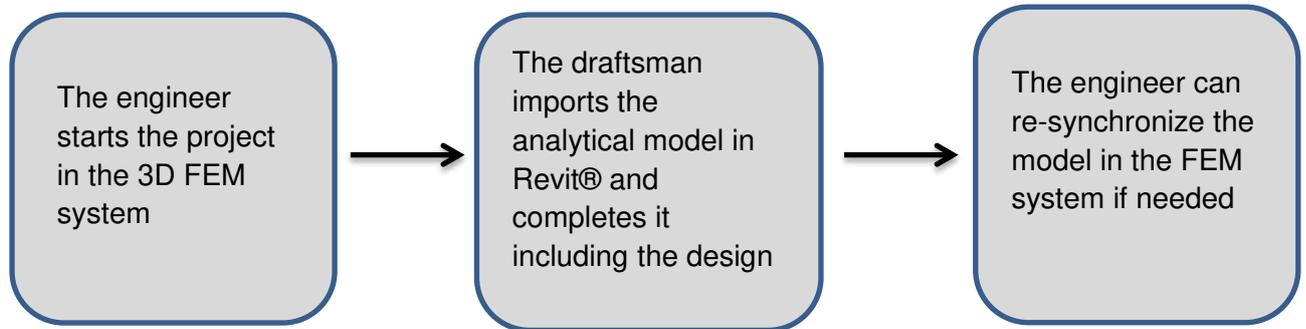
Again, there are several possible different workflows. Among them, we can identify two most commonly used:

- Workflow A: the project starts in Revit with the draftsman who creates the 3D geometry and creates the base Revit analytical model. At this stage; he exports the 3D model to the engineer for optimization and FEM calculation of the efforts. Then, the engineer sends back the model with efforts to Revit where the draftsman can create the drawings:



Workflow A

- Workflow B: the projects starts with the engineer working in the 3D FEM system where he creates a 3D analytical model, runs the FEM analysis and get the efforts on the elements. At this stage, he can export the model to Revit® where the draftsman can continue the modeling in Revit® and can exchange models with the engineer for additional member design.



Workflow B

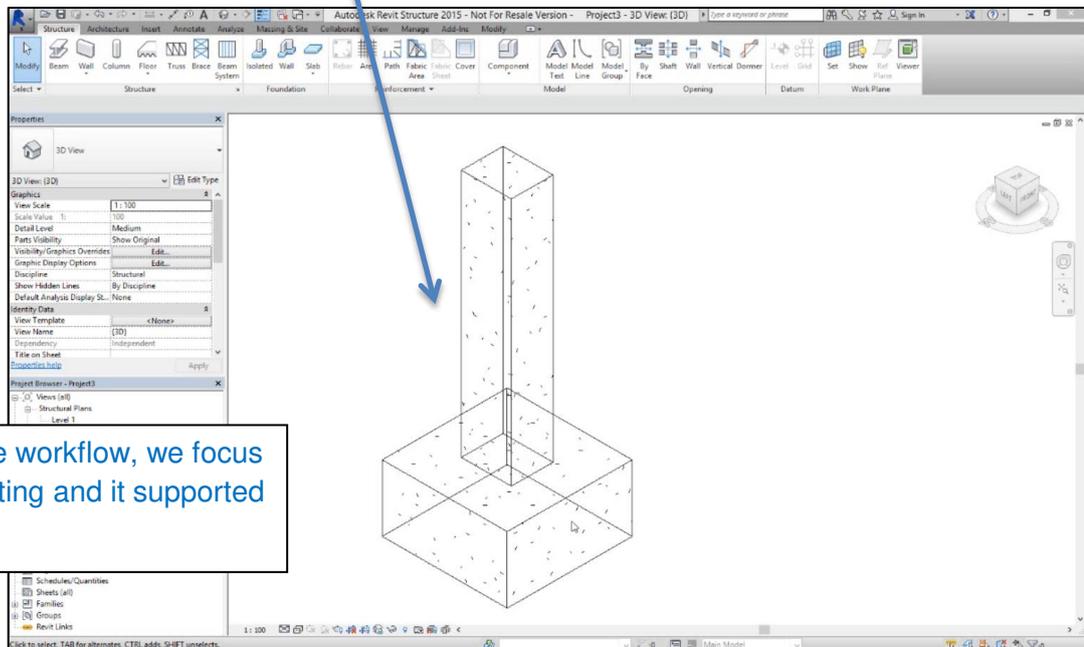
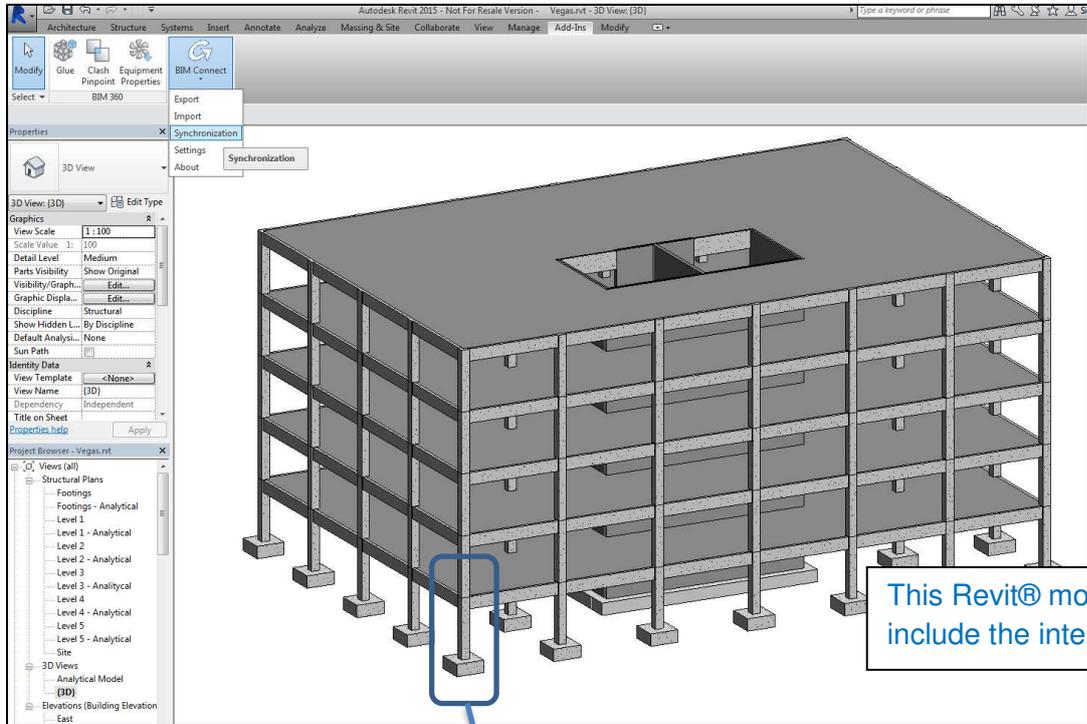
In this document, we will detail how the engineers and the detailers can communicate via an integrated model (not by sharing drawings, electronic or paper) but thanks to the GRAITEC BIM Designers 3D rebar technology. There are countless possible workflows adopted in the industry but based on practical experience we will demonstrate the workflow A described above.

Independently from the applied workflow, the objective is the same: automate the 3D rebar creation and the corresponding reinforcement drawings, make a change and update all the documents in one click!!!

Get real benefits from the power of the BIM with GRAITEC BIM Designers

Creating 3D rebar and reinforcement drawings in Revit

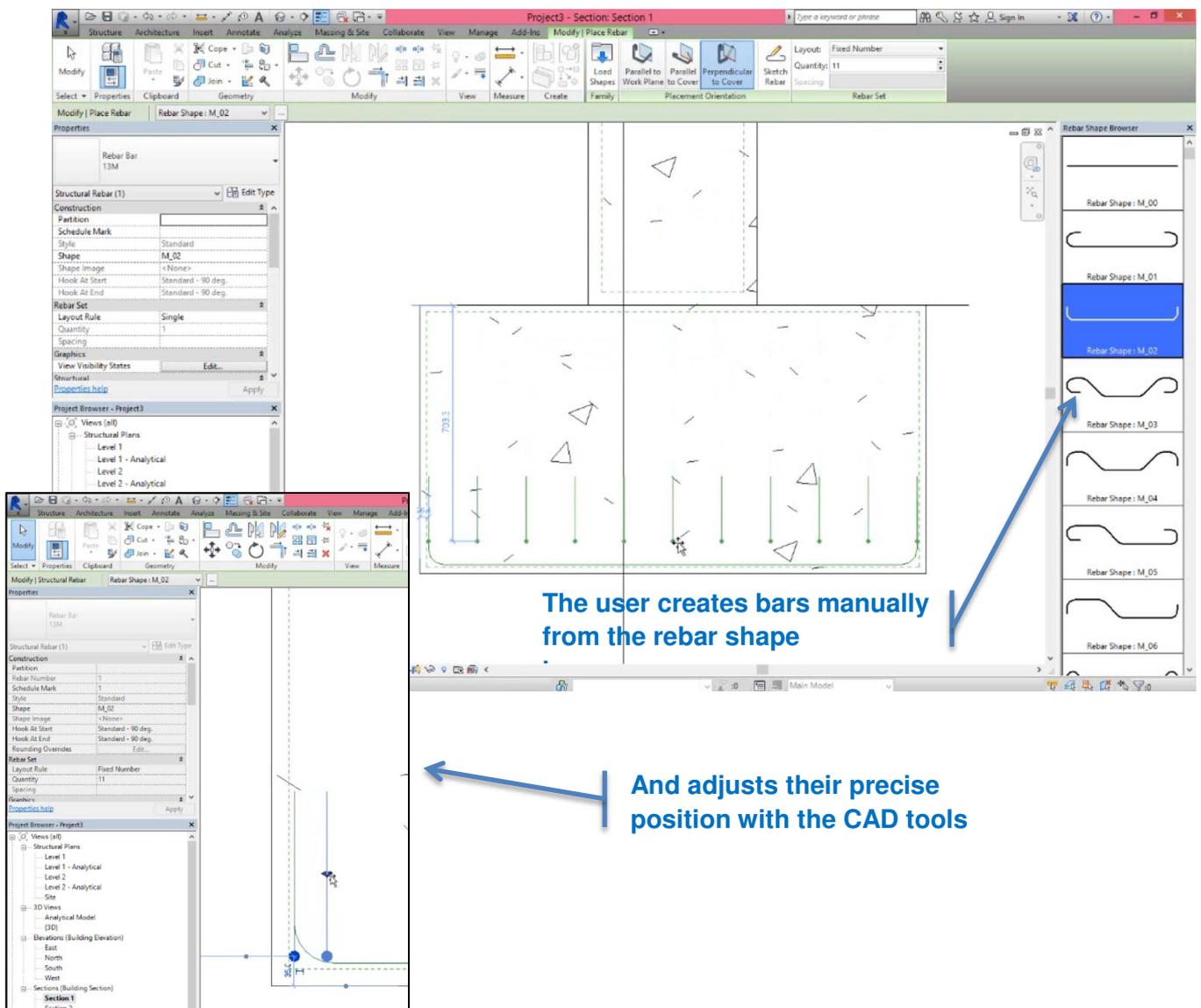
In order to quickly and easily answer this question and to demonstrate the full benefits of the BIM Designers, we should first take a look at the process of creating the reinforcement bars and drawings of an isolated footing using the standard Revit® tools:



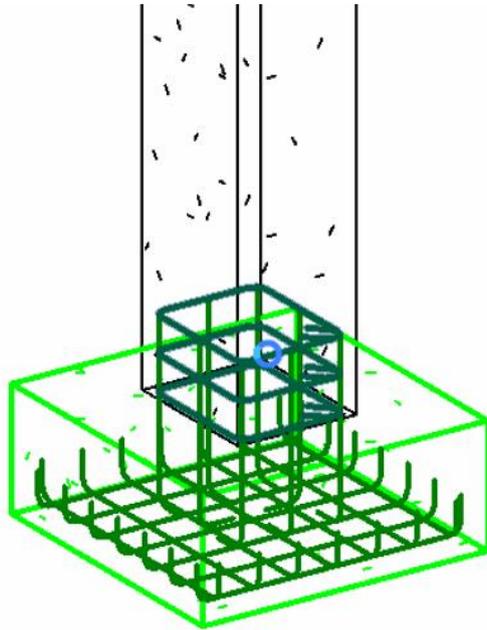
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Currently: to create the reinforcement bars in the footing, the Revit® user has to go through the following steps:

- Create the needed section views.
- Manually define the concrete cover from the properties of the element.
- Select a type of reinforcement from the rebar shape browser
- Define the distribution (numbers of bars or spacing) and place them manually in the model.
- This process has to be repeated for each of the reinforcement bars families of the element (bottom and top longitudinal reinforcements in both direction of the footing).



- Next the user creates the starting bars to link the footing and the column above, taking care of the accurate position of the bars considering the geometry of the column and the footing: anchor the vertical bars of the column in the footing, adjust the position of the column's stirrups to the top face of the footing...



Doing all those steps requires many clicks and can take anywhere between 10 minutes and half an hour depending on the footing and column geometry. Also it is important to consider that this method manually completes the 3D model independently from the engineers design. Of course, the time and the potential mistakes will depend on the experience of the user but we will demonstrate this process can be radically improved, making it faster and more secure.

Create 3D rebar and reinforcement drawings in Revit® using GRAITEC BIM Designers and starting with a Revit® model with analysis results

Tip: After installing the GRAITEC BIM Designers on top of Revit®, you get a specific GRAITEC ribbon from where you can access all the tools and utilities of the BIM Designers. Here simply click the 'Calculate' icon and the BIM Designer automatically creates the reinforcement cage for the footing.

Based on Workflow A now let's take a look at the same process using the BIM Designers:

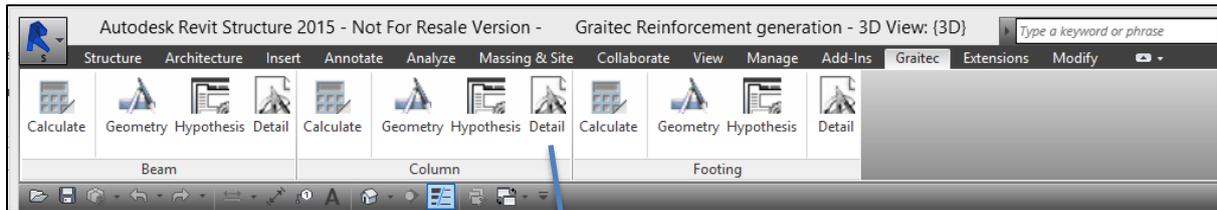
1. The initial model is created in Revit®, including the analytical model
2. This is sent to 3D FEM software (Advance Design in our example) for the internal forces calculation and optimization.
3. Then, the 3D FEM software saves the results as part of the BIM model and sends this back to Revit where the engineer can also take further design decisions (country code driven) using the BIM Designers inside Revit to finalize the design of the single elements.
4. Using the BIM Designer's running in Revit automate the 3D rebar creation and the corresponding reinforcement drawings and reports
5. Make a change and update the documents in one click!!!

In this workflow illustration, we are handling the FEM calculation part with Advance Design (which is the 3D FEM software from GRAITEC). It is important to understand and keep in mind that this workflow (including the BIM Designers tools) supports any kind of FEM software that links with Revit® or if the forces are added directly in the Revit Model manually.

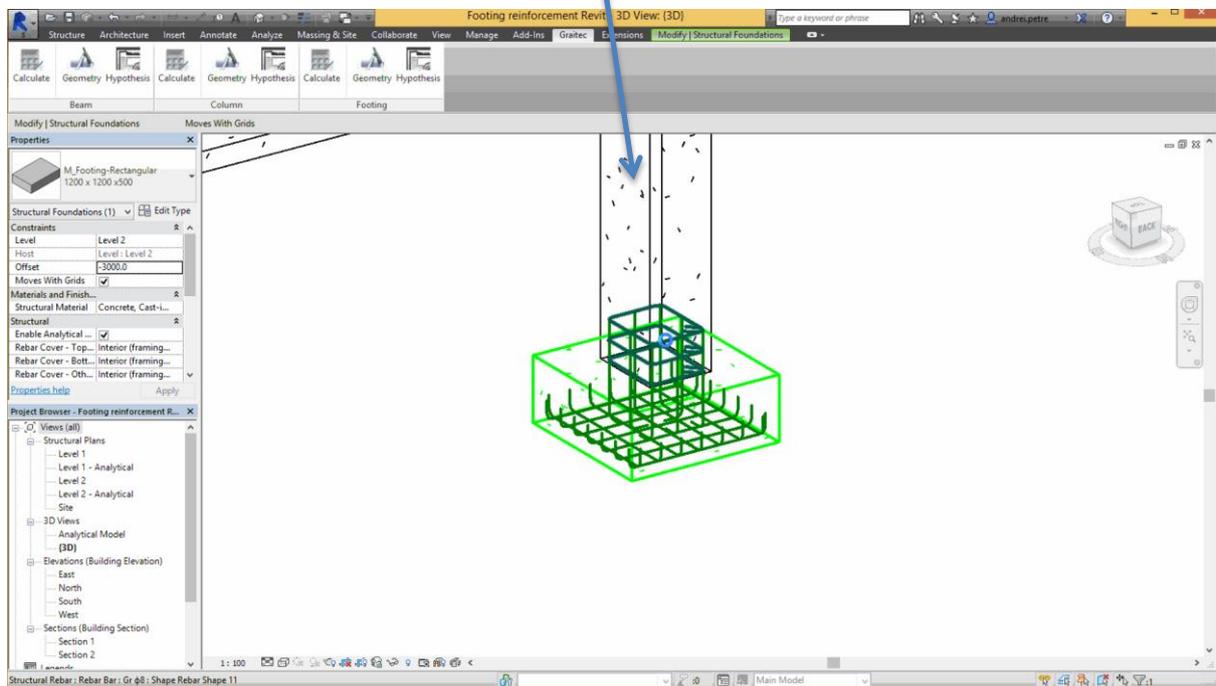
The draftsman starts working on the project creating a 3D model in Revit®. Most of the time, this 3D Revit model does not contain the loads, even if it is possible to define them manually in Revit, but does include a "default" analytical model (un-checked).

So, at this stage of the project, the draftsman sends the Revit model (the analytical model) to the engineer who will make a FEM calculation and optimization with Advance Design (or other FEM software). When this work is done, he can send back the model to the draftsman who will synchronize the changes in Revit and get the efforts on each member: this is the starting point for the member's design using the BIM Designers tools.

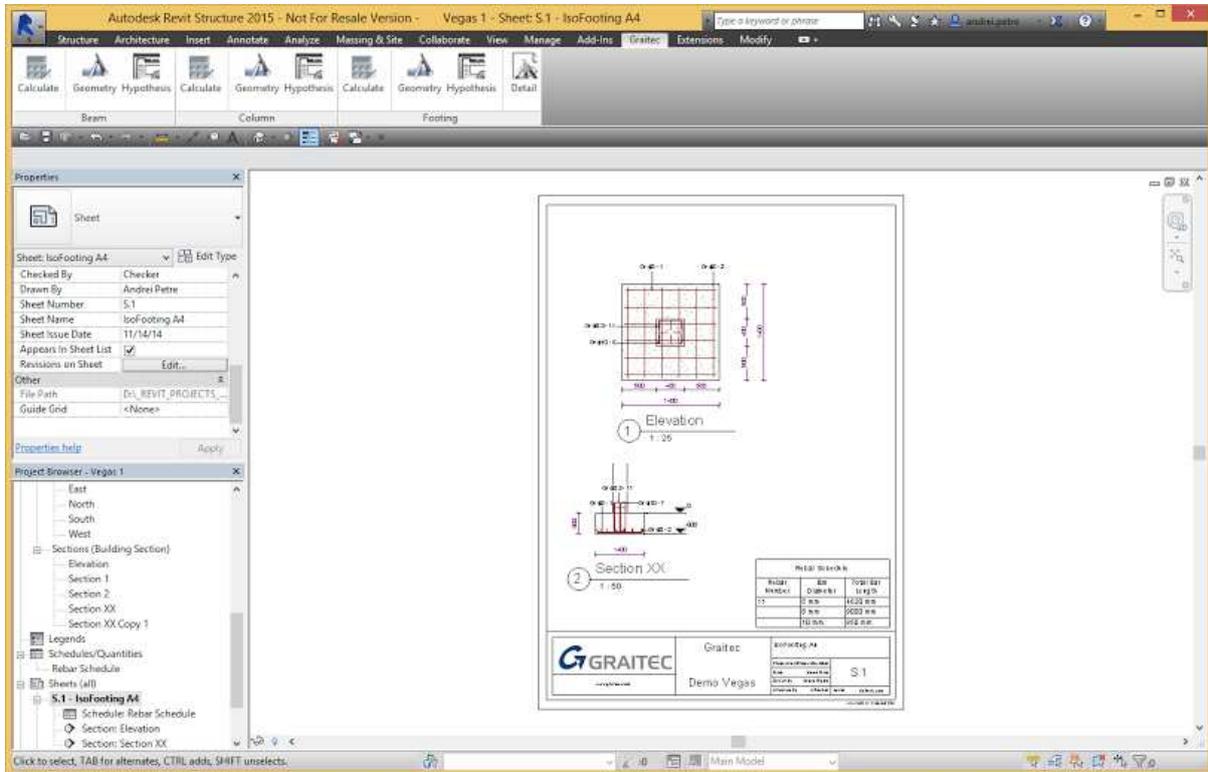
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The BIM Designers runs inside Revit® and designs and generates the 3D reinforcement according to country specific design rules - the Revit® model includes the internal forces



And with one additional click, you can get automatic reinforcement drawings:



There is no doubt about the potential performance and accuracy benefits of the BIM Designers to enhance your BIM workflow. Now let's take a look at the technical process that enables us to achieve this automatic result. But first we should understand what makes it possible to transfer the loads automatically from the structural analysis software to Revit, not only to speed up this process but store all the relevant data in one model.

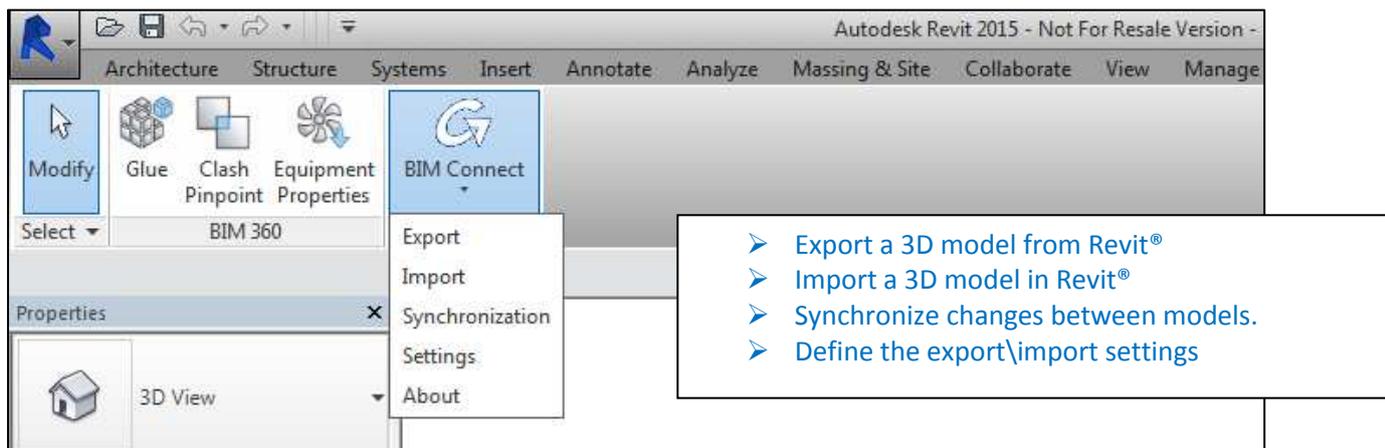
Sharing the Revit model with the structural analysis software (Advance Design)

Most of you already know the answer to this question and there is nothing new: several tools\plug-ins are available to link Revit and 3D FEM system, including the FEM calculation in the cloud with Robot.

In our example, we chose to use a 3D FEM software external to Revit® to make this workflow relevant to all companies: if you're not using Advance Design, just replace with your own FEM system (providing it links to Revit®), or apply the forces manually, and still get the BIM benefits from the BIM Designers tools. The BIM Designers tools are created to provide additional value to the existing tools you already have and complement your workflow.

Let's come back to our illustration: to export the model from Revit® to Advance Design, the draftsman uses Gritec BIM Connect Revit® plug-in (freely available from GRAITEC web site or from the Autodesk Exchange App Store).

When installed, the Revit user will get a specific ribbon in Revit with options to share the 3D model:



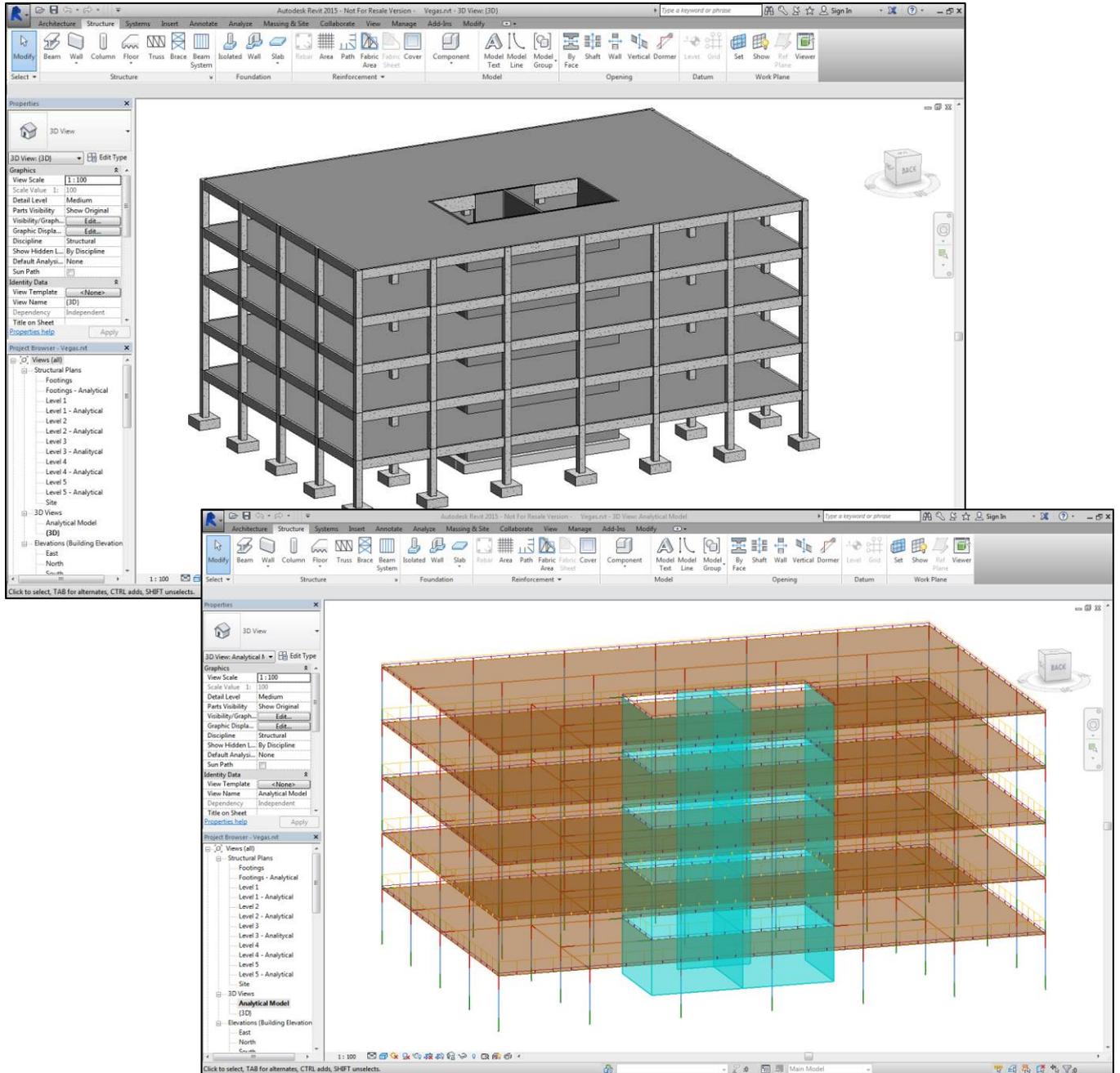
Powerful filtering options are available:

- The possibility to use a mapping database for sections and materials when linking Revit® and Advance Design. This database will be enriched real time every time the module is used!
- Options to export \ import the loads, in addition to the geometry: this option is really useful when the user wants to run a FEM calculation starting with a Revit® model on which the loads have been defined.
- Possibility to export only the Revit object which is defined as an analytical model.

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So, let's now apply this GRAITEC BIM Connect module to our example:

- We have a 3D model created in Revit® which also contains the analytical model:

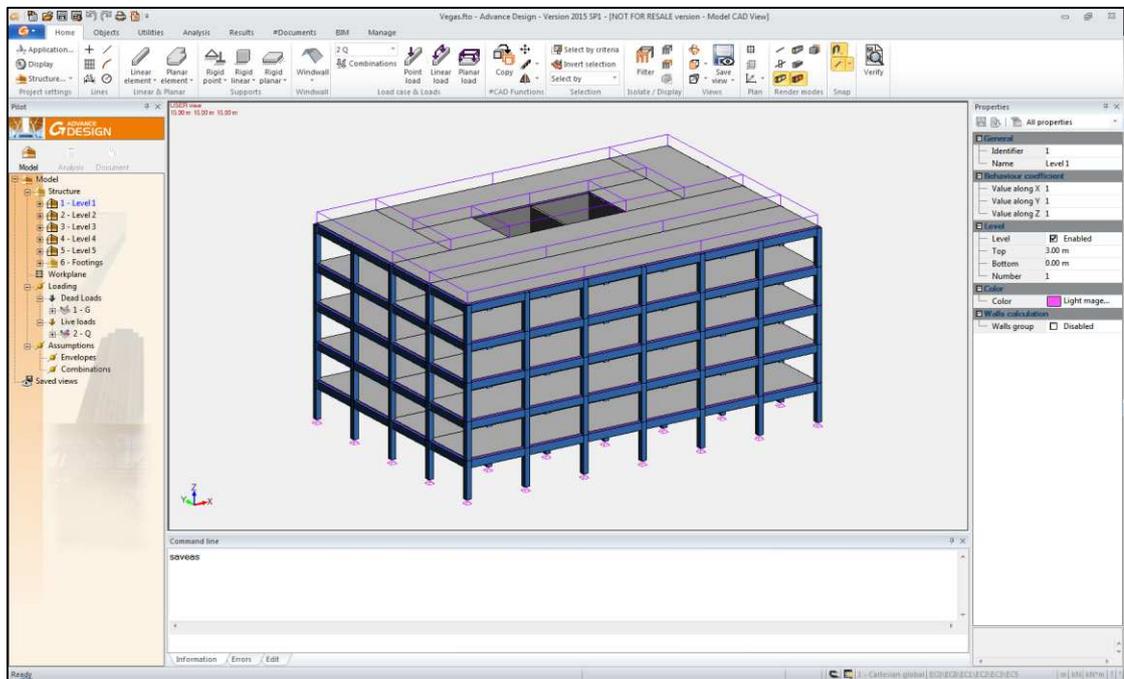


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- We export the model and ask to the BIM Connect centre to automatically run Advance Design:



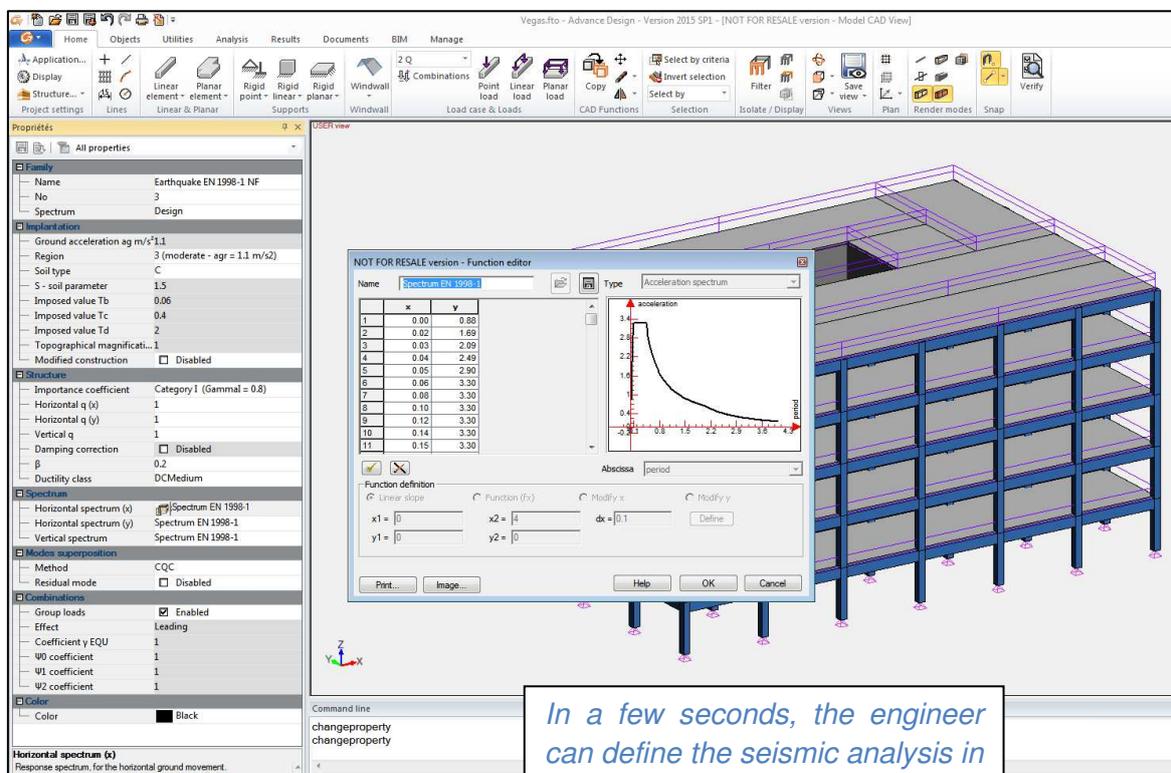
and we get the 3D analytical model in Advance Design:



Internal forces calculation with the 3D FEM system

At this stage of the workflow, the engineer has a 3D model in Advance Design which corresponds to the analytical model sent from Revit. He is in his environment with all the functionalities to tune the FEM model:

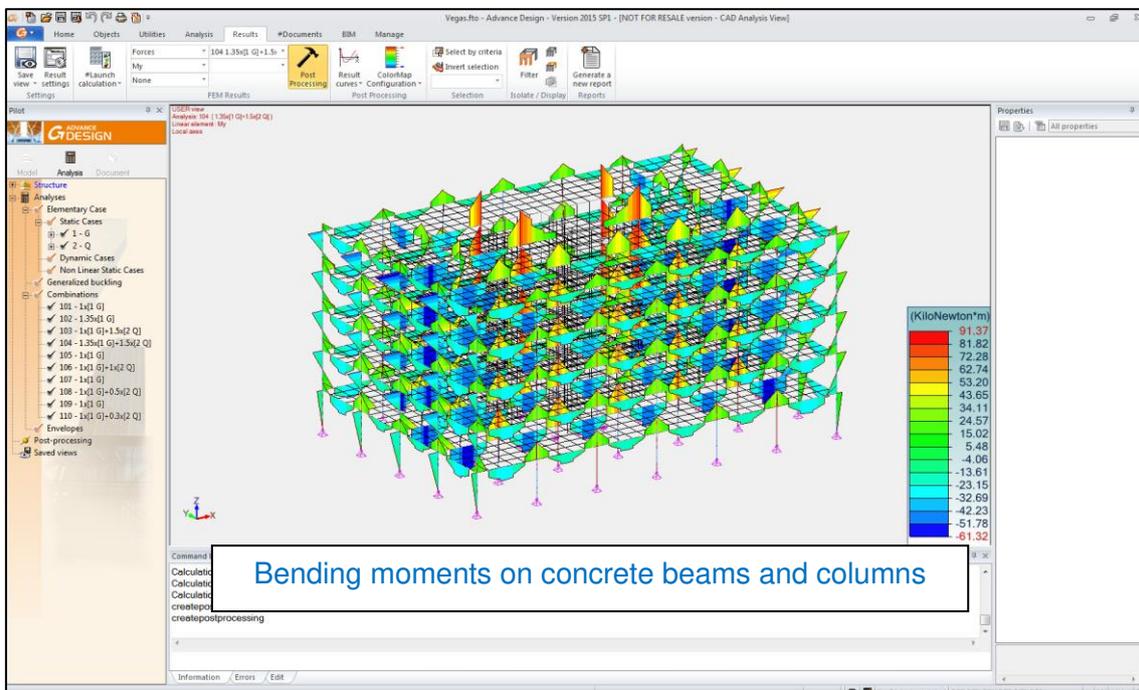
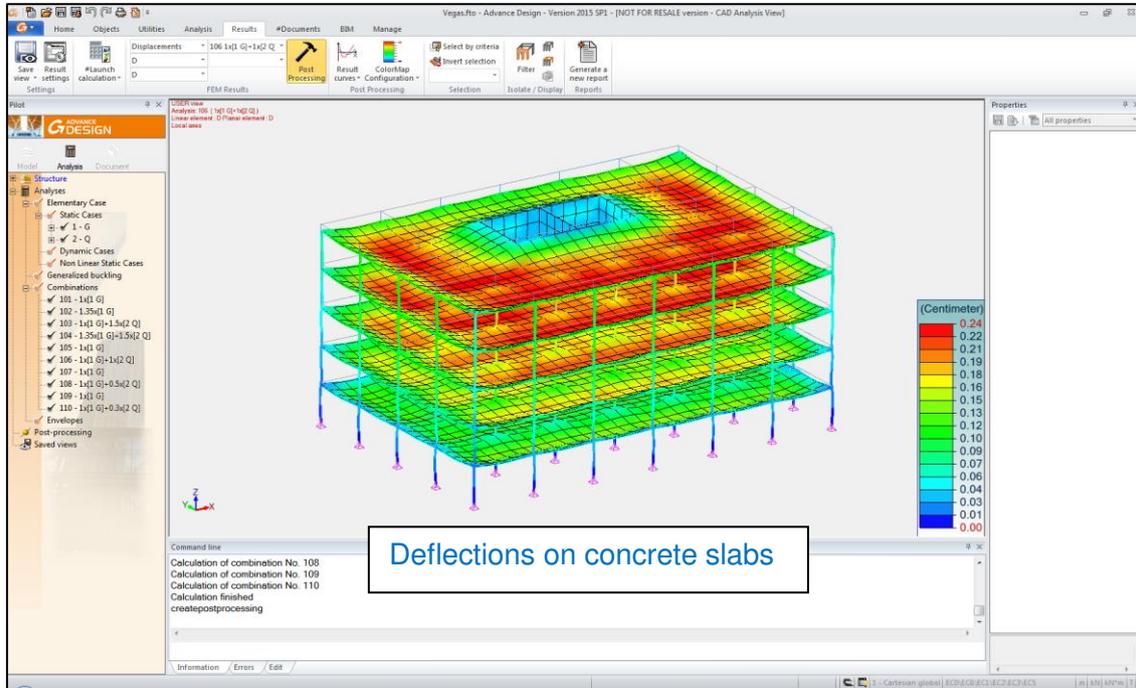
- He can obviously access all the properties of each member.
- He can define what kind of finite element he wants to apply: a beam with 6 degrees of freedom, a truss with only 3 degrees of freedom working in tension or compression, a tie, a cable...
- He can check and change the boundary conditions on the elements: rigid or semi-rigid links, elastic supports, articulations between slabs and walls...
- Set the meshing parameters.
- Define the loads, either manually or using the automatic generator for climatic and seismic loads:



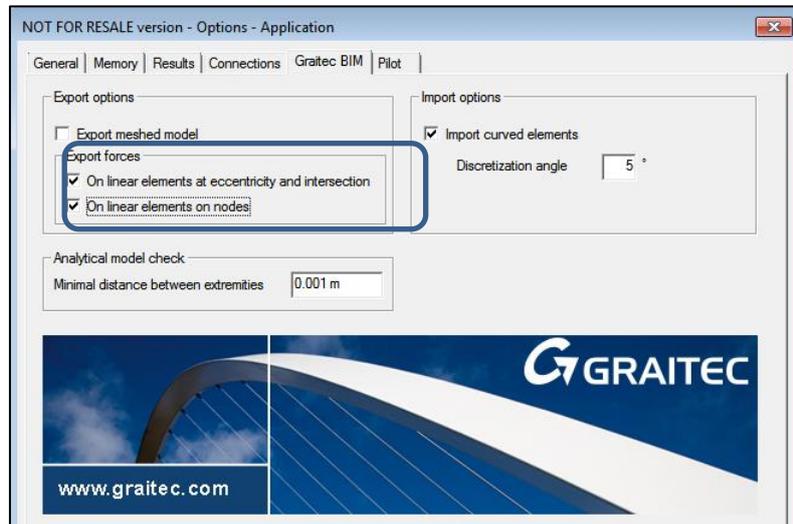
In a few seconds, the engineer can define the seismic analysis in Advance Design

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In Advance Design, the user can run a FEM analysis and get all the requested results (including the internal forces on all elements):

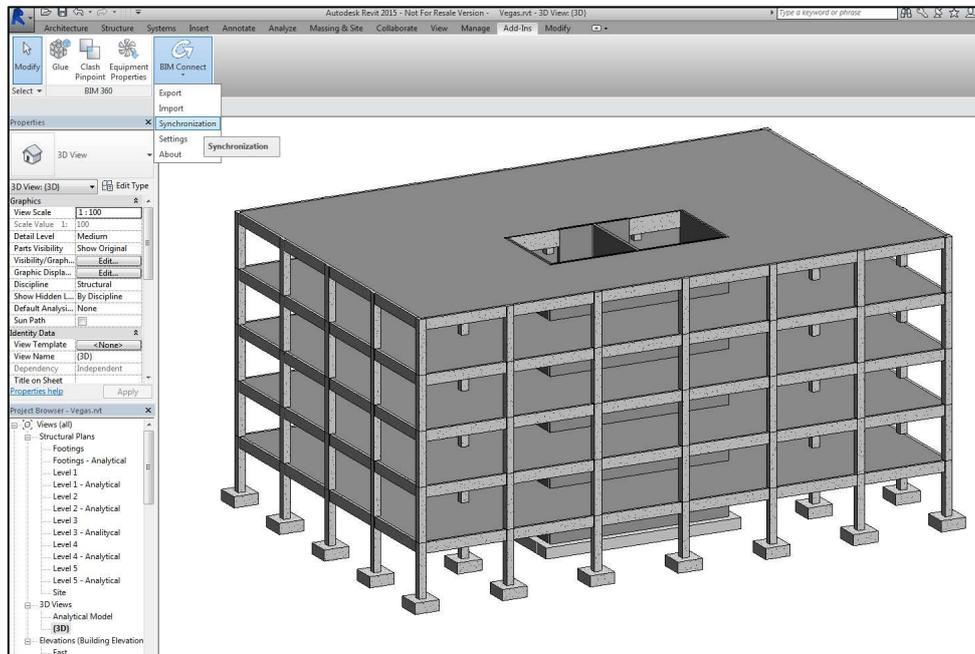


After the calculation, the Advance Design engineer can send back the model to Revit® (using the same file format), and include the internal forces:



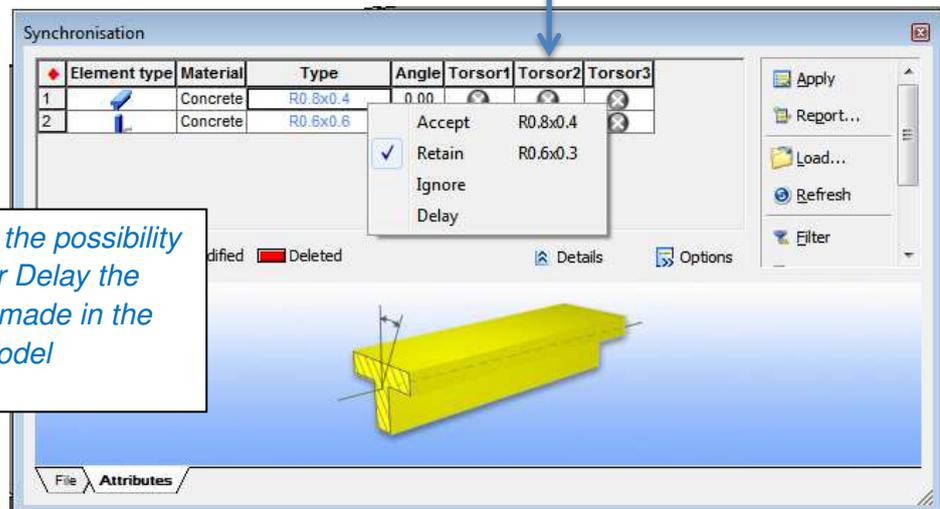
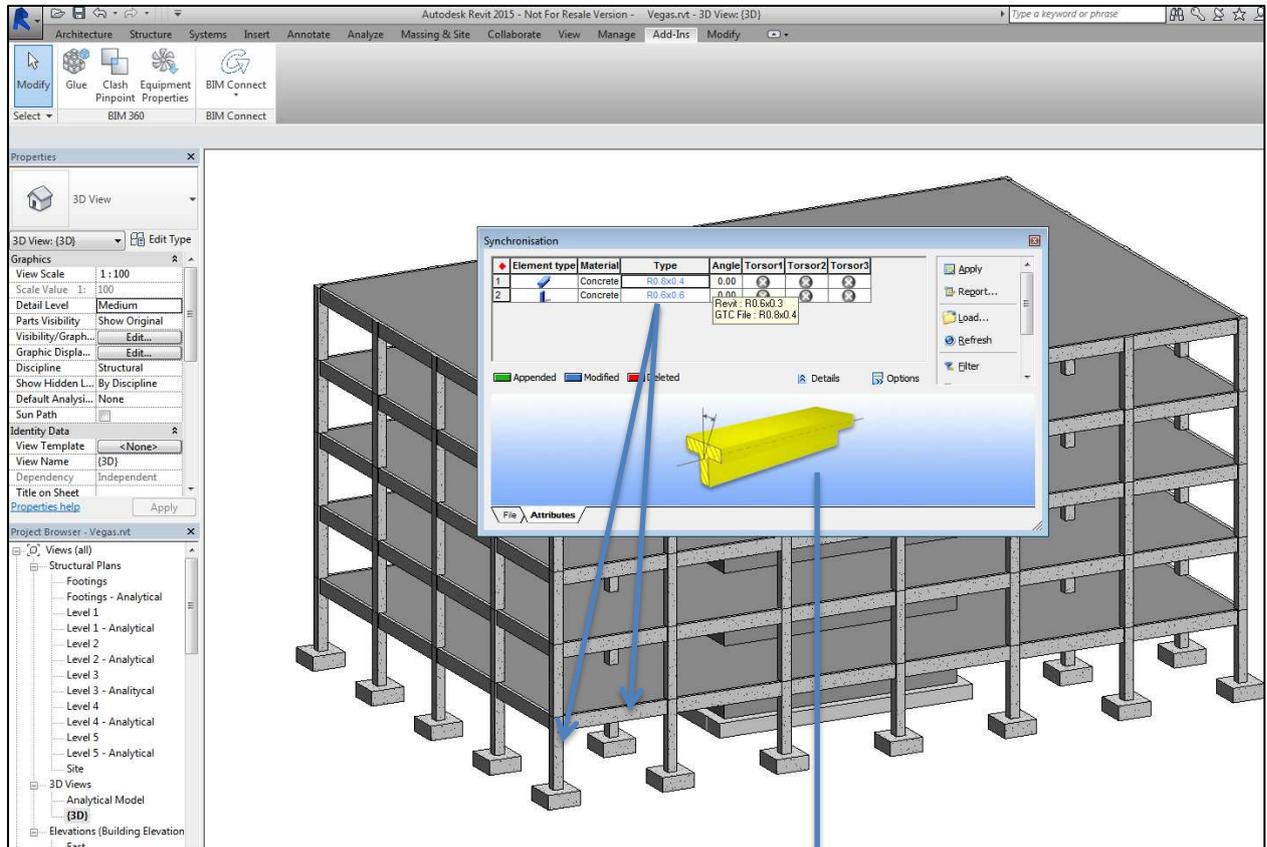
The synchronization mechanism

When the draftsman in Revit® and the engineer in the FEM system have already made one roundtrip, they continue to work in parallel on their own models. At this stage of the project, the synchronization mechanism is important to ensure a good communication to manage the change- synchronization in both models. The GRAITEC BIM Connect “Synchronization” option ensures the Revit® user is in full control of any changes to the 3D model and is able to manage modifications visually and intelligently.



Take advantage of BIM for reinforced concrete structures

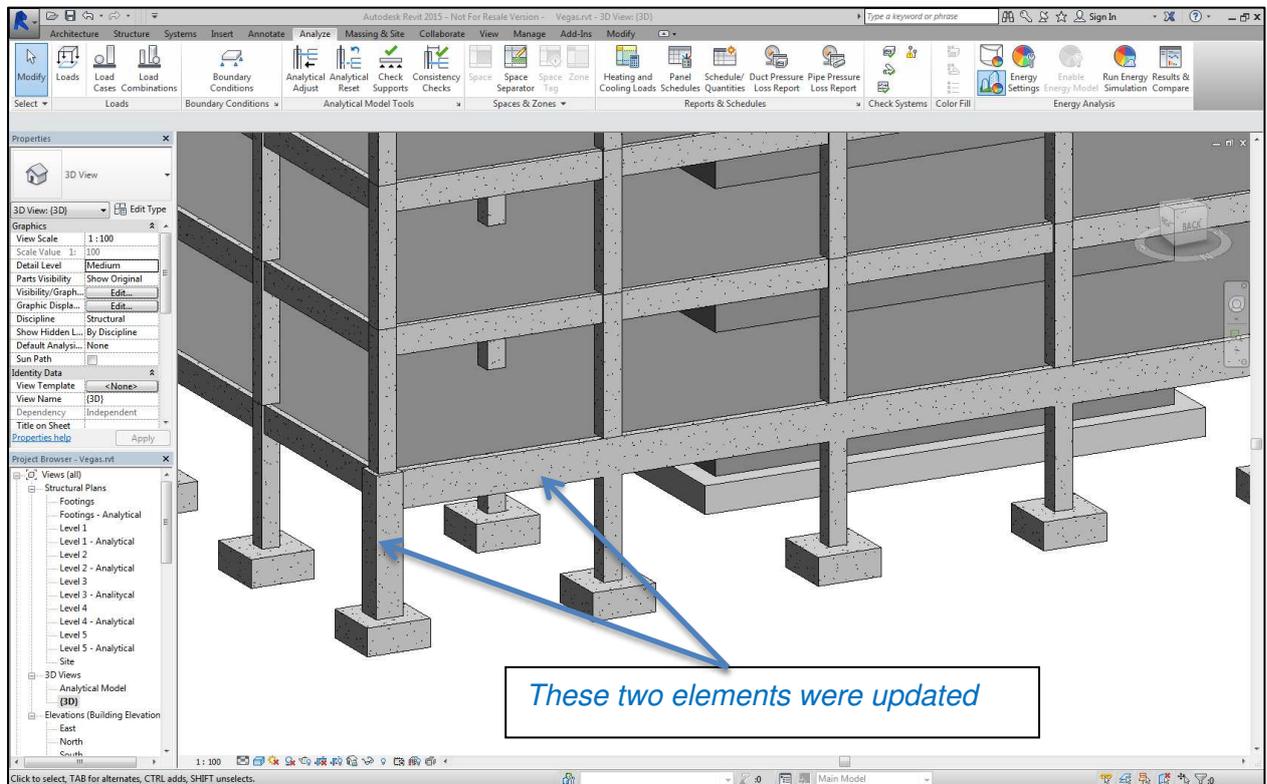
To illustrate the workflow, in Advance Design we changed the section of a concrete beam and a concrete column. When synchronizing the model in Revit®, we get the following messages informing us about the type of changes made and options on how we would like to apply them in Revit®



The Revit user has the possibility to Accept, Ignore or Delay the changes that were made in the Advance Design model

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If the modifications are accepted, the Revit model will be updated automatically:



This synchronisation mechanism is important to the integrity of the BIM workflow giving the possibility to handle quickly and safely the changes on the models during the different project phases.

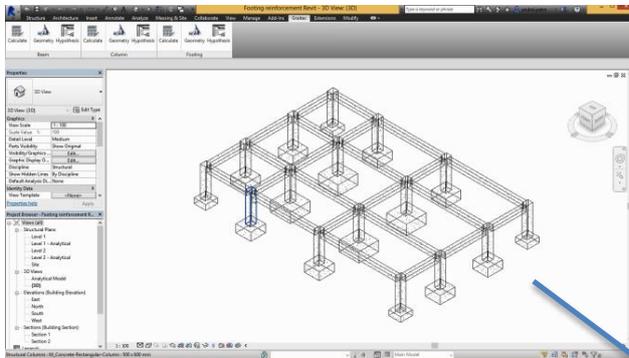
At this stage of the workflow, the draftsman has all the results in his Revit® model needed to handle the member's design.

Technical details on how the BIM Designers work!

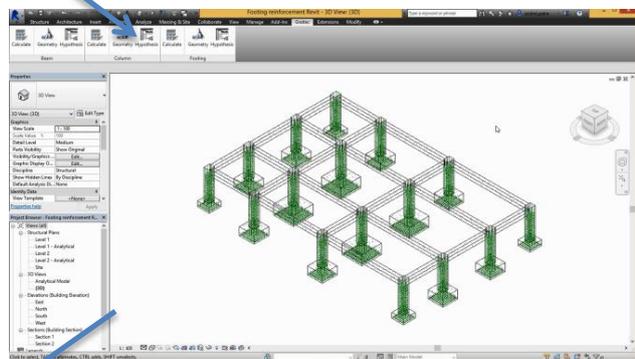
Few words about the BIM Designers concept...

GRAITEC BIM Designers are the next-generation software for automation, optimization and interoperability. Combining analysis, intuitive modelling, automatic drawing and report creation, GRAITEC BIM Designers are crafted to deliver exceptional performance and design accuracy across multiple BIM and Analytical software applications.

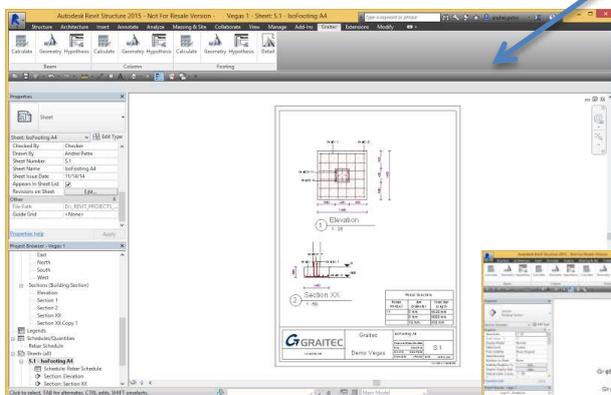
With easy to use intuitive modelling tools, comprehensive built-in analytical assumptions covering a wide spectrum of uses, and customizable outputs, GRAITEC BIM Designers not only add analytical capabilities to Revit®, but also automate the creation and design of the 3D rebar models, produce fully detailed documents, and simplify and support a complex multi-discipline model sharing BIM exchange workflow.



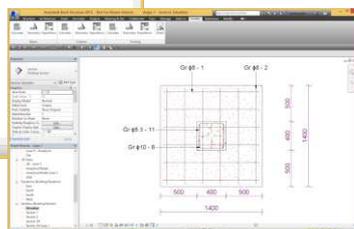
3D model in Revit®



Automatic 3D rebar generation



Automatic reinforcement drawings



Working across multiple software platforms, including GRAITEC Advance Design®, Autodesk Advance Steel® and Autodesk Revit®, GRAITEC BIM Designers enable users to utilise the same model and analytical data simultaneously across all supported applications!



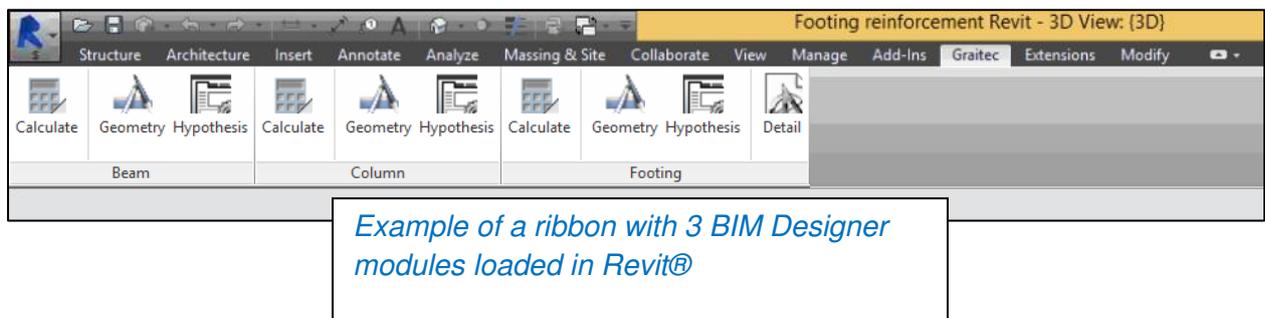
Complete Structural Design assumptions

The only way to automate the reinforcement creation is to embed the design capability directly in the BIM application: this is the differentiating principle GRAITEC is introducing with the BIM Designers modules working on top of Revit®.

Considering the previous steps, the Revit model includes the forces on each element originating from the FEM calculation.

The initial Revit® model however does not include any structural design assumptions: this is what is introduced with the BIM Designers. In this technical section we will be focusing on reinforced concrete footings, columns and beams.

When the user selects an appropriate element in the Revit 3D model, they can access the corresponding icon on the GRAITEC ribbon from where they can manage the geometry of the element and the associated concrete assumptions:



Tip: In order to fully appreciate how the BIM Designers can improve your workflow of the design of the reinforced concrete structures, it is important to keep in mind that GRAITEC BIM Designers are multiplatform. This means that different people in an engineering company can use the same design modules and share the corresponding model and data, even if they are working in different application: in Revit®, in Autodesk Advance Steel, in Advance Design, or even in as a standalone solution...

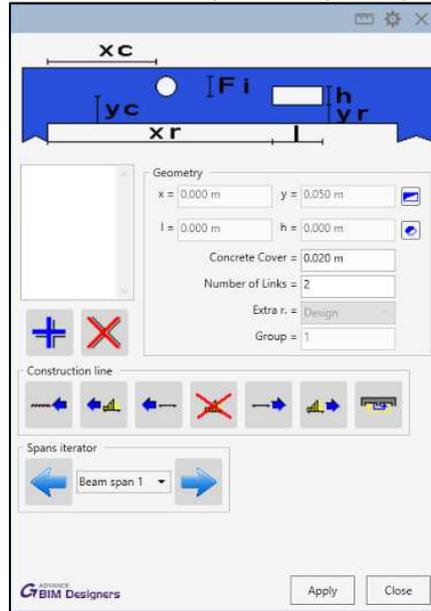
This flexibility makes the system adapted to different workflows depending on your company's preference, process, and workflow or project type, for example:

- The engineer (or the draftsman) wants to create and manage the concrete design directly in Revit® (this is the workflow we described previously in this technical note). In such a case, we will see that the Revit user has the possibility to enter the loads manually or re-use the internal forces calculated by the FEM application. (again as described in a previous chapter).
- Alternately the engineer could import the Revit model into Advance Design (as described above) and use the native tools or the same BIM Designers in the FEM application to take design decisions and validate the design. Then, transfer the project to the draftsman who, re-using the same data in Revit, produces the final drawings (as the bars are already generated by the BIM Designers in Advance Design).

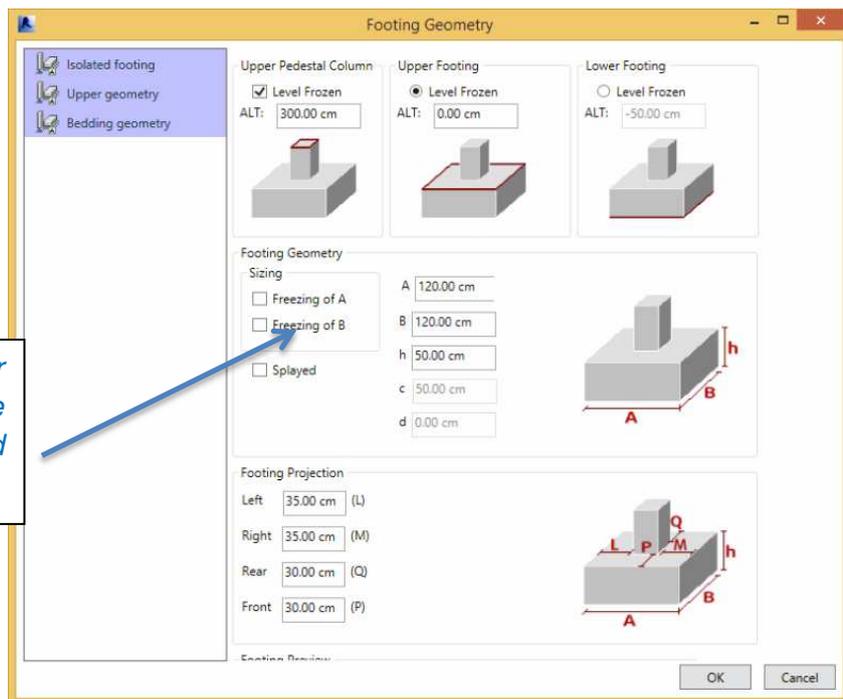
Why a supplementary dialog to manage the geometry?

Obviously, the geometry of the member is defined in the Revit model but when thinking about the design, there are numerous reasons to modify the geometry:

- The user wants to define specific geometry important for the concrete design not yet defined in the Revit® model: for example, an opening on a concrete beam:



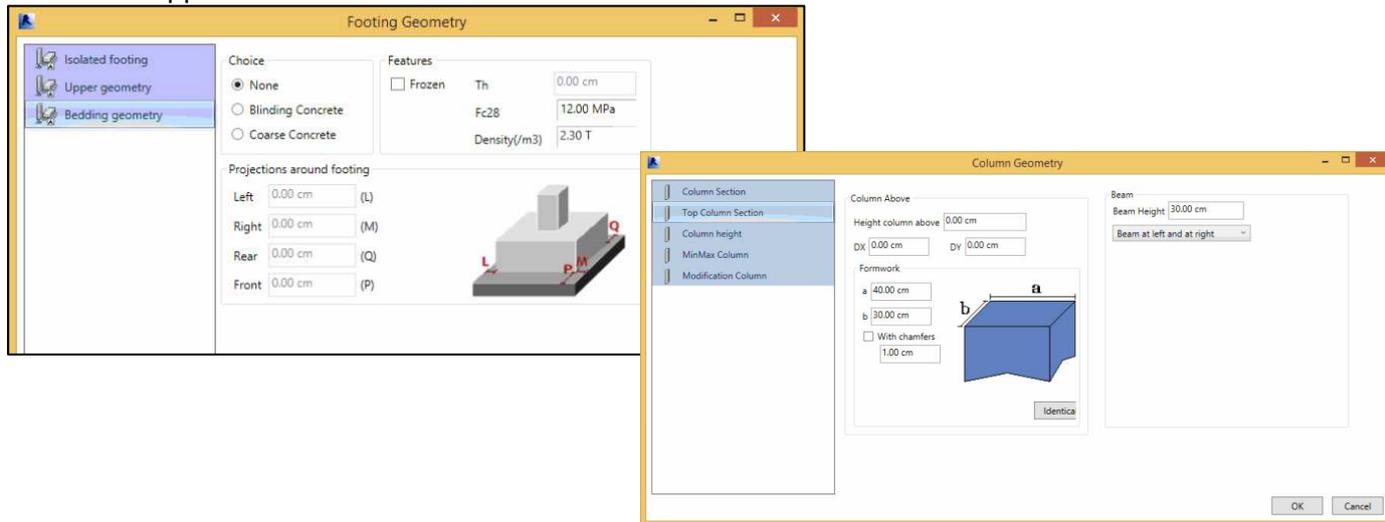
- Consequently the engineer or the draftsman may decide to optimize the dimensions of the element automatically with the corresponding BIM Designer module: in such a case, they can drive the pre-dimensioning by defining the parameters of the element which can be changed:



Here, we can see that the user decided to not freeze the dimensions of the isolated footings in both directions

When changing the initial Revit geometry, for any reason, the BIM Designer module is able to update the Revit model creating the new corresponding sections type. This is very important having in mind that the BIM Designers modules are built to help the Revit user to take design decisions.

- Another case is for example the definition of the bedding geometry for a footing or the upper elements for a column:



The definition of the structural design assumptions!

The unavoidable step, before being able to run a structural design session, is to define the structural design assumptions.

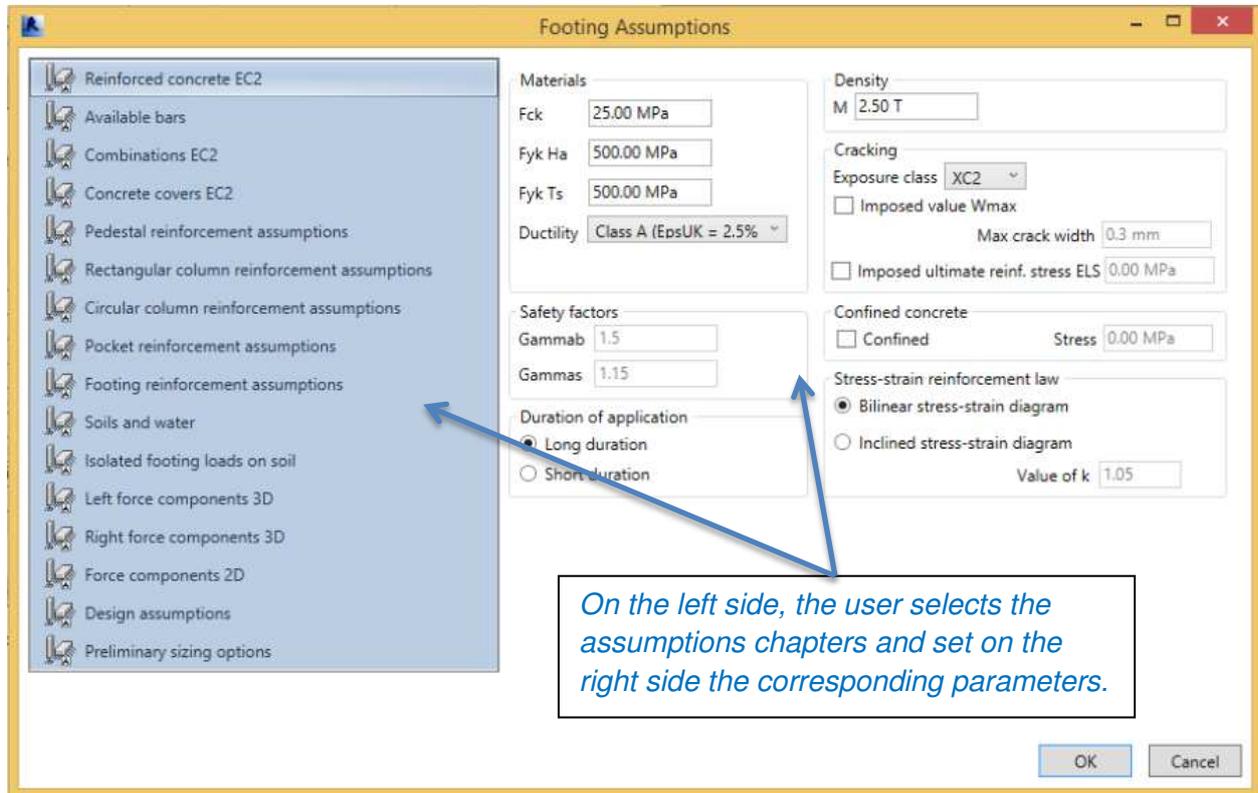
Here, we cannot make an exhaustive list of all the design parameters; it would be too long and dare I say boring! But we can split those assumptions in two different families:

- The design codes assumptions
- The constructive dispositions for the automatic placement of the bars inside the concrete members.

Of course, both assumptions families are country code dependent (Eurocodes with different national appendixes, US codes, Canadian codes...) and that's raises the question of country compliancy. It is a hard task for a software editor, especially when speaking about design and automatic drawings, to localize any application for different countries. That's why the BIM Designers are built on a parametric technology! => We will see this in detail later in the document.

As above when selecting an element, the user can access the icon to call the assumptions dialog depending on the type of selected element (concrete beam, column or footing).

Here is the example of the assumptions dialog for the footings:



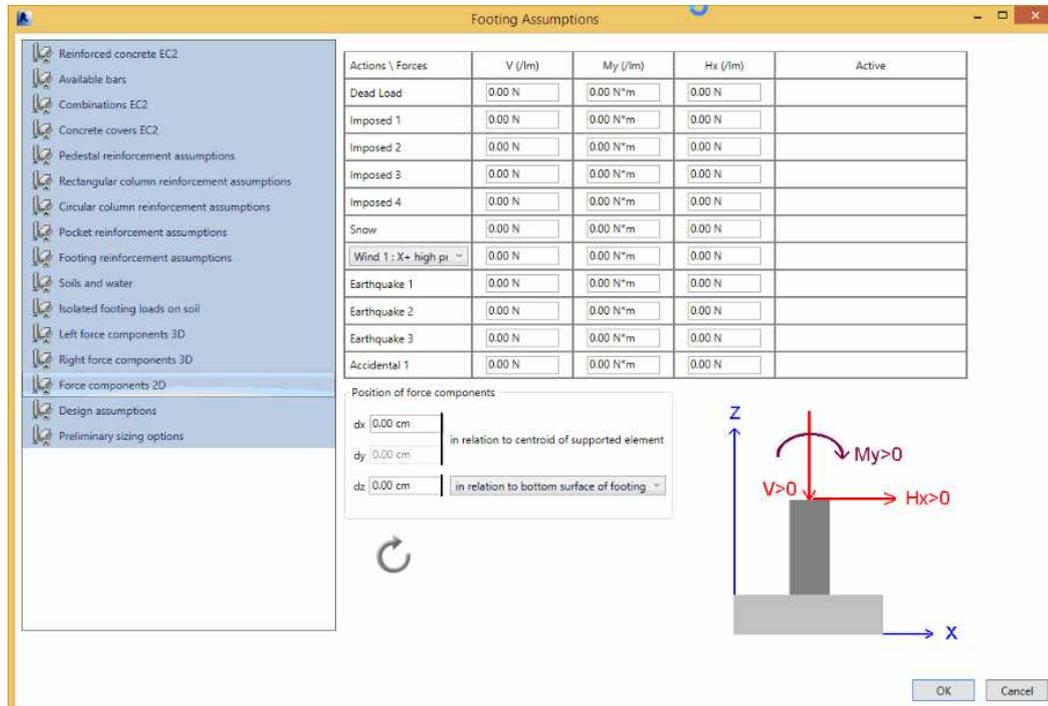
We can see here many assumptions required for the concrete design:

- Reinforced concrete assumptions depending on the code (here above is the EN1992 dialog).
- Available diameters to be used in the automatic 3D reinforcement rebar:

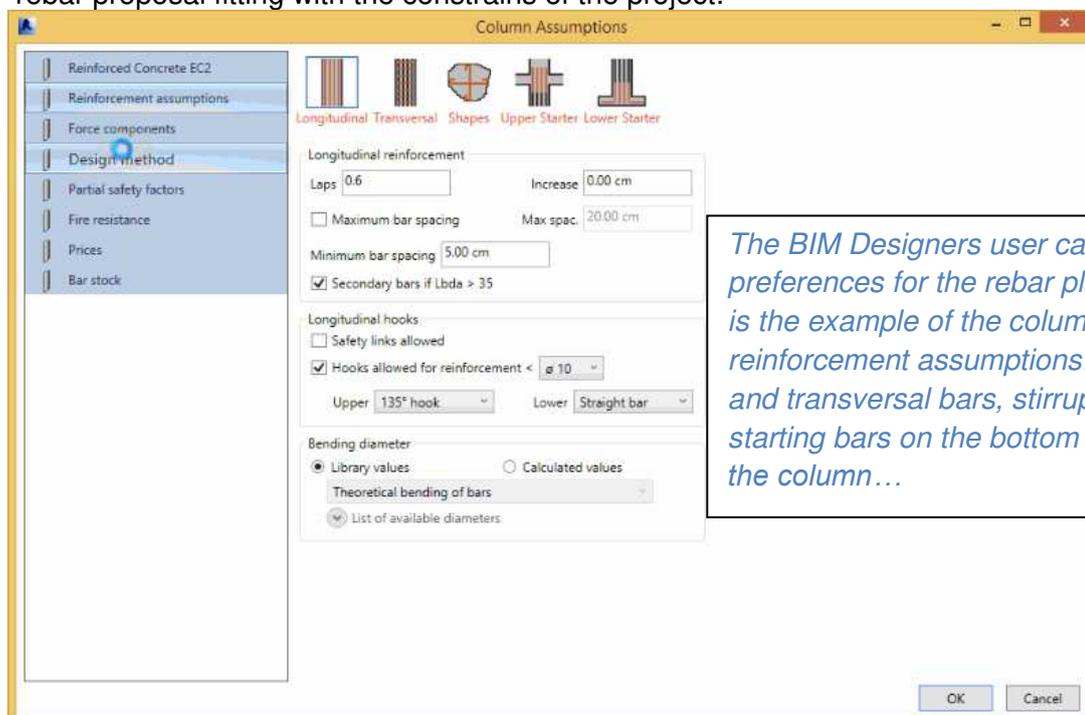
Available bars		Diameter	Section	Bending radius of reinforcing bars [m]		
Longitudinal	Transverse	[mm]	[cm²]	Longitudinal	Transverse	Bent-up
<input type="checkbox"/>	<input checked="" type="checkbox"/>	6	0.28274	0.063	0.032	0.1
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	8	0.50265	0.08	0.04	0.125
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	10	0.78539	0.1	0.05	0.16
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	12	1.13097	0.125	0.063	0.2
<input checked="" type="checkbox"/>	<input type="checkbox"/>	14	1.53938	0.16	0.08	0.2
<input checked="" type="checkbox"/>	<input type="checkbox"/>	16	2.01061	0.16	0.08	0.25
<input checked="" type="checkbox"/>	<input type="checkbox"/>	20	3.14159	0.2	0.1	0.32
<input checked="" type="checkbox"/>	<input type="checkbox"/>	25	4.90873	0.25	0.125	0.4
<input checked="" type="checkbox"/>	<input type="checkbox"/>	32	8.04247	0.32	0.16	0.5
<input checked="" type="checkbox"/>	<input type="checkbox"/>	40	12.5663	0.4	0.2	0.5

Take advantage of BIM for reinforced concrete structures

- Assumptions for loads and combinations with the possibility, as we saw before, to impose external loads or re-use the FEM results exported from Advance Design to Revit (or from a cloud calculation done from Revit).



- And also constructive dispositions assumptions in order to get a 3D reinforcement rebar proposal fitting with the constrains of the project:



The BIM Designers user can define his preferences for the rebar placement. Here is the example of the column reinforcement assumptions: longitudinal and transversal bars, stirrups shapes, starting bars on the bottom and top part of the column...

Design reinforced concrete members in Revit

As mentioned previously, the objective of the GRAITEC BIM Designers is to embed the design into Revit® which is the primary BIM application. This way of working is raising an important question: *how can the user trust the automatic reinforcement provided by the BIM Designers?*

Of course, there is a graphical control when visualizing the 3D reinforcement rebar but it is not enough. The design codes (Eurocodes, US codes, Canadian codes) impose a set of verifications to be done and this is an important responsibility for the engineering companies.

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Steel grade
(NF EN1992-1-1 / Section 3 / Annex C)

B500A - $f_{yk} = 500 \text{ Mpa} - k = 1.05$
 $f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{500}{1.15} = 434.78 \text{ Mpa}$
 Ductility class: A - $\epsilon_{yk} = 25\%$ - $\epsilon_{yd} = 0.9 \times \epsilon_{yk}$
 $E_s = 200000 \text{ Mpa}$
 Density: 7.85 T/m^3
 Horizontal elasto-plastic diagram

c) Concrete covers
 Exposure class (§4.2) Class XC2
 Structural class (Table 4.3N) Class S4
 Concrete cover (§4.4.1)

Nominal concrete cover - C_{nom}				Minimal values		Tolerance			
Top (mm)	Bottom (mm)	Right (mm)	Left (mm)	$C_{min,s}$ (mm)	$C_{min,i}$ (mm)	ΔC_{dev} (mm)	$\Delta C_{dur,y}$ (mm)	$\Delta C_{dur,xt}$ (mm)	$\Delta C_{dur,add}$ (mm)
35	35	35	35	16	25	10	0	0	0

$C_{min,s}$: Minimal value for adherence (§4.4.1.2 (3))
 $C_{min,i}$: Minimal value for durability (§4.4.1.2 (5))
 ΔC_{dev} : Execution tolerance (§4.4.1.2 (P))
 $\Delta C_{dur,y}$: Durability margin (§4.4.1.2 (6))

The user is able to get detailed design reports directly in Revit®

Thanks to the BIM Designers, the user can create a detailed design report directly in Revit®: he will get all the design details in a technical document, including all the formulas and the corresponding articles from the standard, the numerical applications, the corresponding graphics...

Nothing is magic without the preparation and the 3D reinforcement rebar is not coming from the hat!!! Every bar, every result can be justified.

In the BIM workflow, it will also make easier and more efficient communication between the draftsman and the engineer. If the draftsman is using the BIM Designer modules in Revit to automate the 3D rebar creation, he will be able to send (on demand) a detailed calculation report to the engineer for a proof check.

This workflow can be applied on a single element or on an entire building: the design is done on the fly when selecting the 3D rebar creation. Of course if a change occurs in the model, (geometry or design assumption changes) the design is updated on the fly and the user can produce an updated design report.

Importantly all the results, including the design results for each member, are saved in the Revit model. The Revit objects are include additional properties linked to the design and the users can come back to previous design results when he wants. => This is an important advantage of BIM for reinforced concrete structures, making the general workflow more flexible and efficient. Everything is saved in the same place...

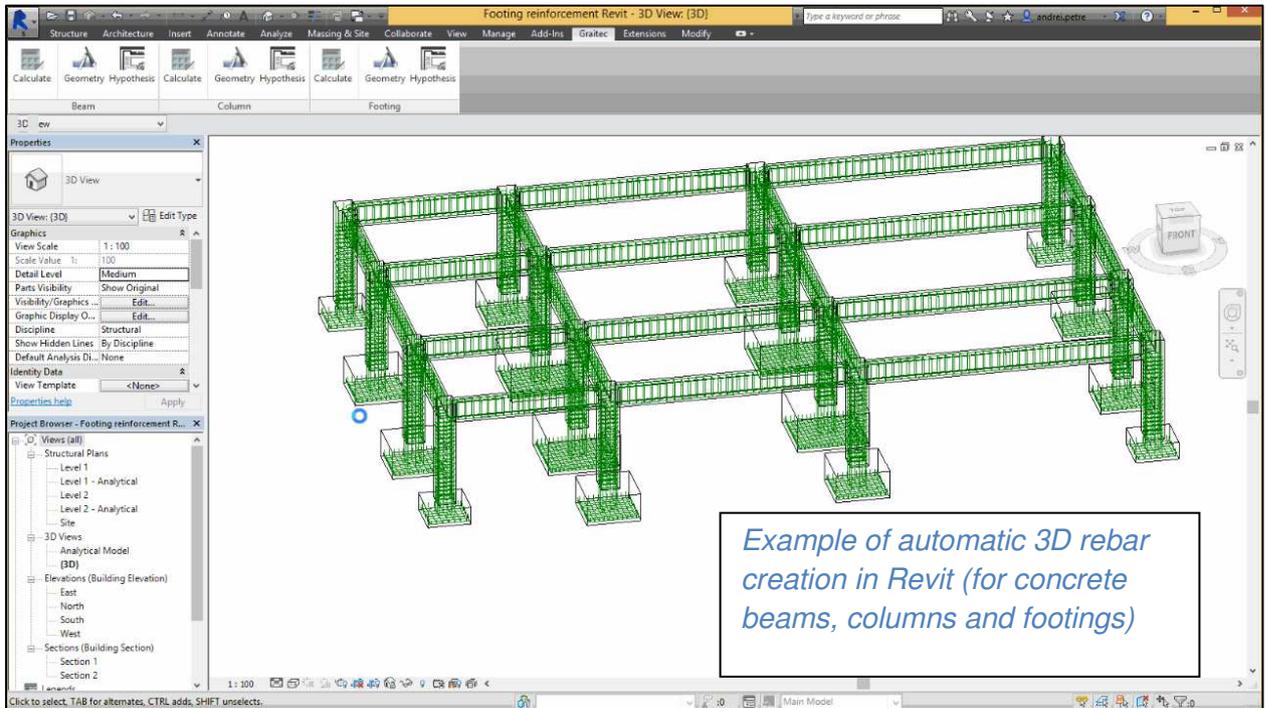
The calculation notes are created and saved in a file. The BIM Designers add an additional user parameter to each structural element, to store the document's URL published in the cloud A360. This is the way to have the design validation glued to the object and stored in the A360 documentation, helping to share the information between all the actors of the project.

In case of big projects (with multi-users), it is also possible to export, from the 3DRevit model, different members to be designed using the same BIM Designers modules but in standalone mode: in such a workflow, the BIM Manager using Revit can dispatch the design job among several people using the BIM Designers modules outside Revit and reimport the data after work.

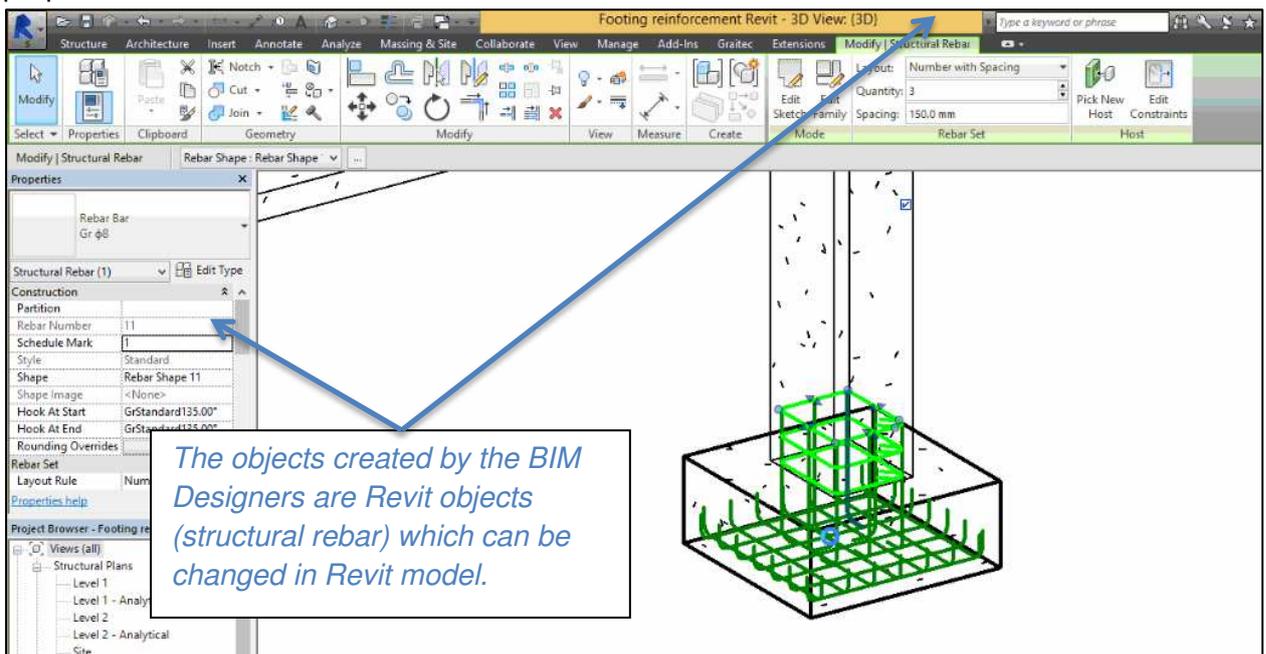
Get the 3D structural rebar

The automatic 3D rebar generation

At the end of the design process handled by the BIM Designers, the user will automatically get the 3D reinforcement rebar, considering all the design assumptions and the constructive dispositions defined above:



The created bars are native Revit objects which can be changed through the default Revit properties and functionalities:



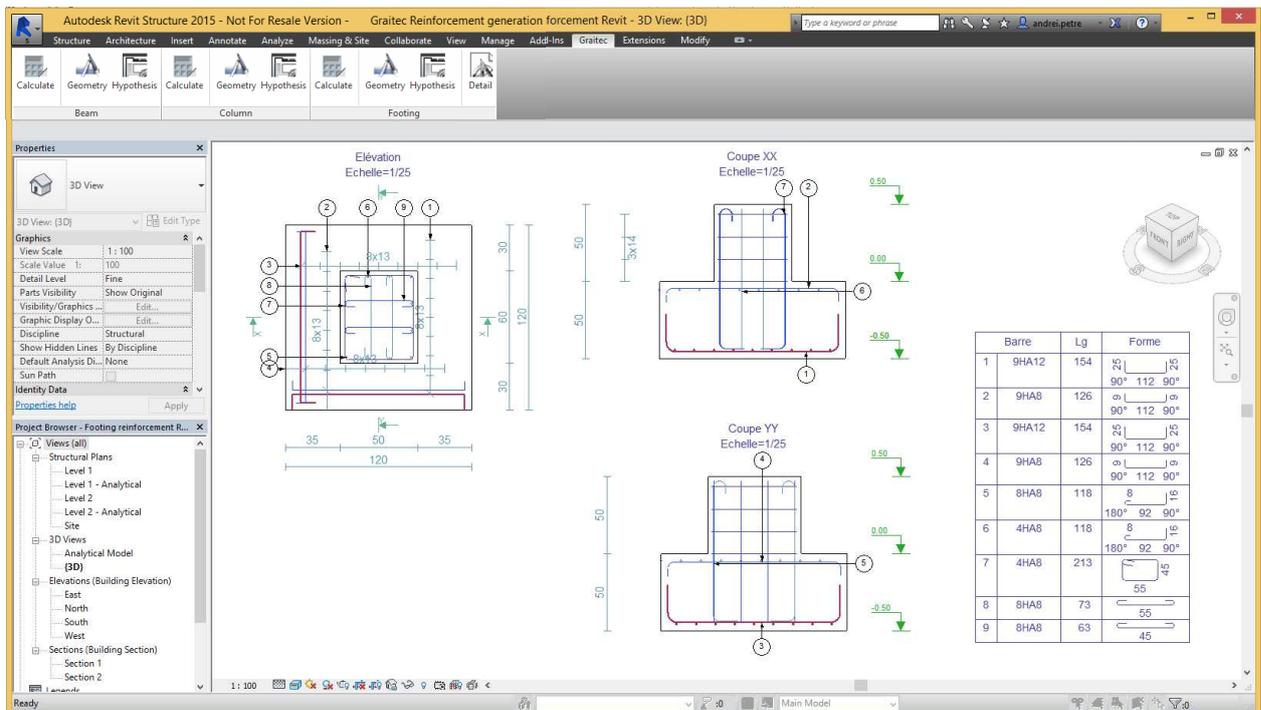
And the automatic drawings creation!

The reinforcement drawings creation is also automated with the BIM Designers. Starting from the 3D reinforcement rebar, the application is able to create the needed sections views, place annotations and dimensions, produce bar schedules, bill of quantities... and consolidate all those views in a drawing sheets.

This process relies on the Revit templates similar to the ones used in Revit to produce manually. Then, when assigning another template to an existing drawing, the user automatically gets another updated drawing.

This technology is also able to easily manage the drawing updates when a design change is introduced!!!

They do not need to be recreated or updated manually: no error and more productivity!



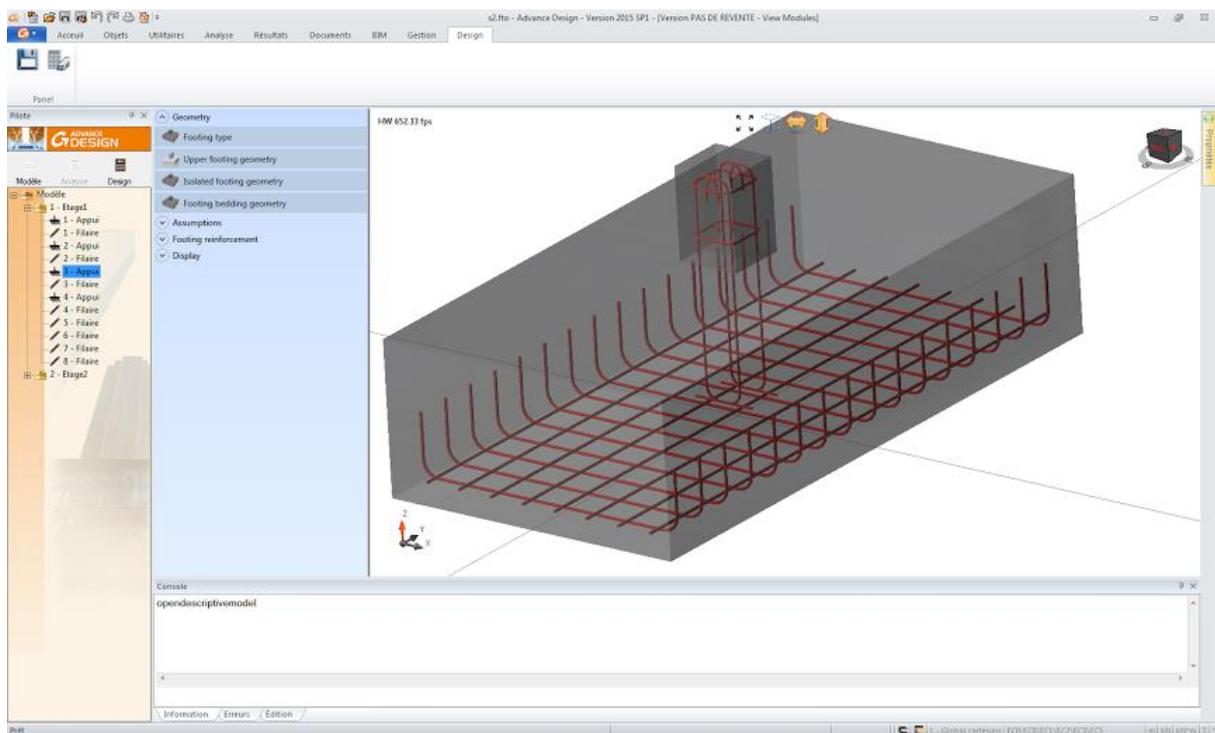
BIM Designers running on the 3D FEM system

We just described a possible workflow where the member's design is done in Revit®, either by the engineer or by the draftsman.

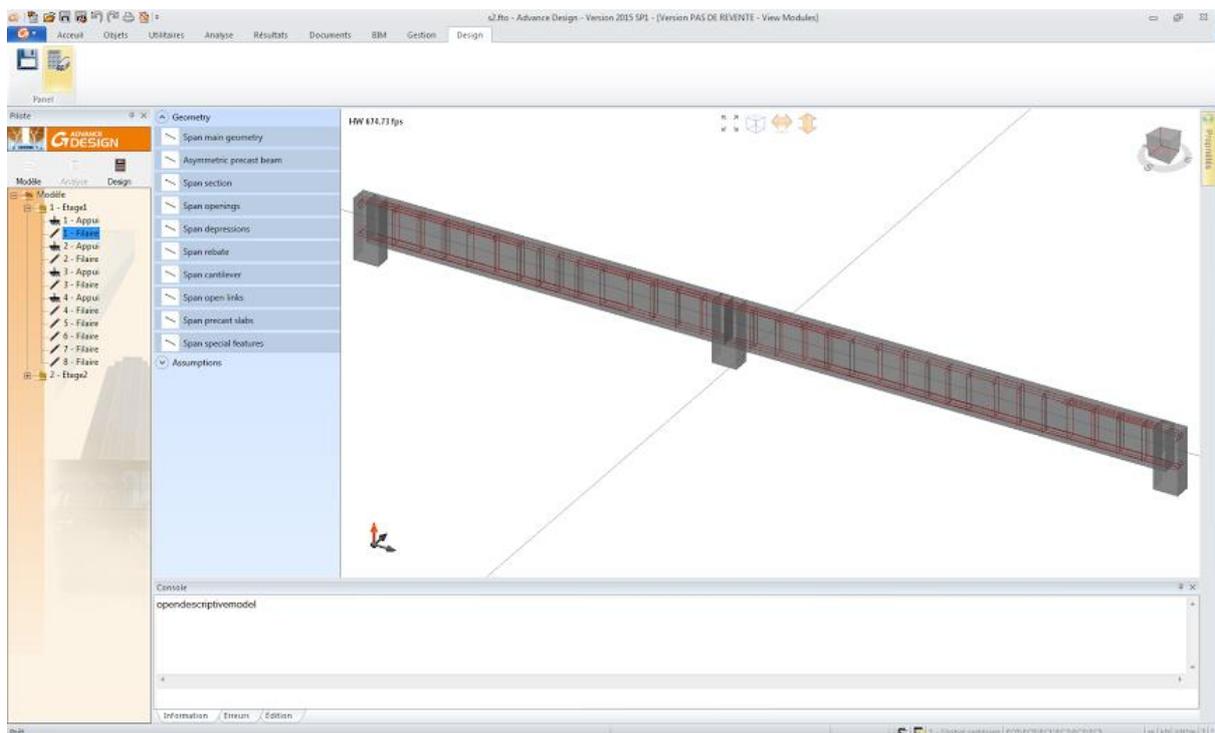
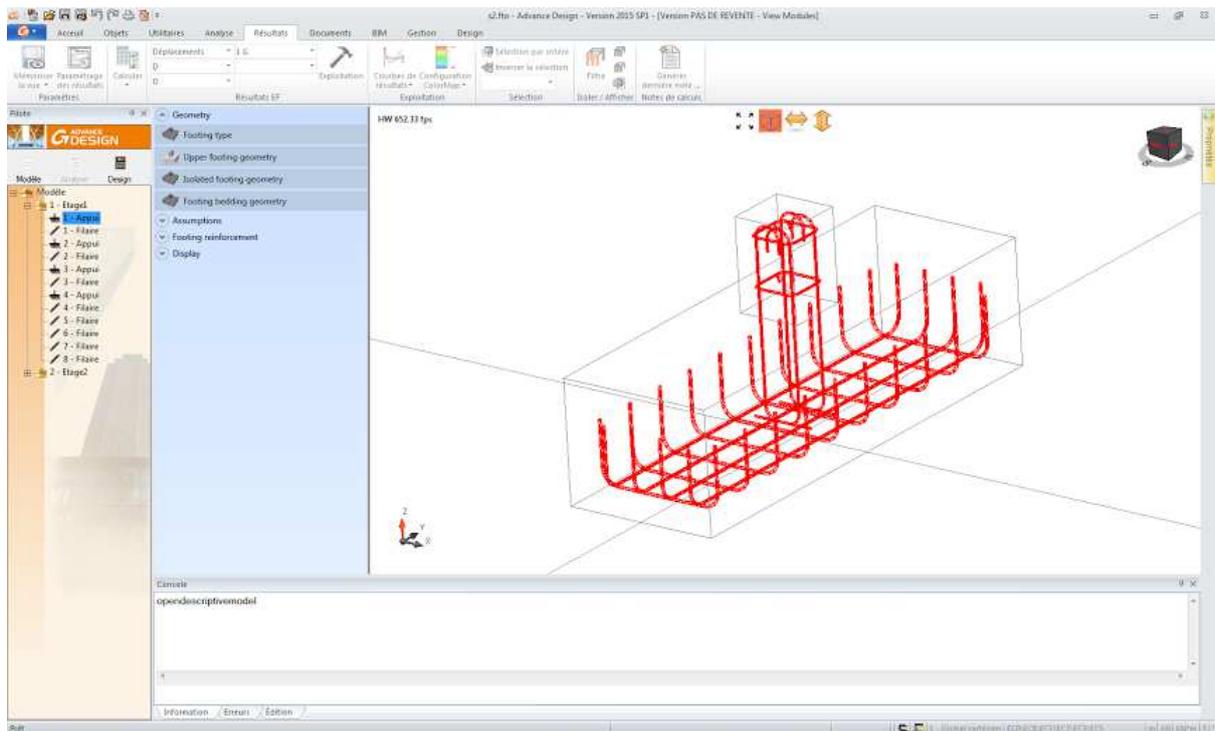
In some companies, the engineer may want to use their analysis and design software to handle the member's design, take the corresponding decisions and send back the information to the draftsman. This can depend on the company, but can also depend on the project complexity inside the same company.

That's why GRAITEC decided to develop the BIM Designers to be the 1st multi-platform design modules: the company working with the BIM Designers does not need to have (learn and know) different design tools depending on who is handling the design. The BIM Designers have the same dialogs, same assumptions and same reports working in a standalone mode, inside Advance Design or inside Revit®...

Here we can see a few pictures showing the same BIM designers tools running on Advance Design:



Take advantage of BIM for reinforced concrete structures



Of course, when the engineer has made a design sequence in Advance Design using the BIM Designers modules, he can send back the data to the Revit® user.

Tip: During the class presentation we will apply the same process to a more complex Revit model.

Conclusion

We hope that reading this document, you find out how to take advantage of BIM to design your reinforced concrete structures.

With the BIM Designers technology, it is clear we are trying to bring some disruptive changes that benefit the BIM workflow and the whole construction industry:

- Analysis results are part of the BIM model, relying on a real 3D BIM application which is Revit®
- Engineers take design decisions in the BIM Design application (Revit®)
- Engineers and detailers communicate via a 3D model (using the BIM Designers 3D rebar) and not only via drawings.
- Drawings do not need to be recreated when a design is changed.

GRAITEC BIM Designers technology is flexible enough to fit with different possible workflows. The objective is to provide tools with complementary added value, smoothing the transition from manual workflow to an entire BIM workflow.

With the power to automate and control complex manual processes, as well as bridge the 'analytical and detailed model data-sharing' gap between engineers and draftsman, the GRAITEC BIM Designers help you take advantage of BIM for reinforced concrete structures!

For further information, please contact:

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