Beyond the Box: Integrating Custom Structural Shapes, Analytical Models, and Revit Structure

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SE6666 Are you working on projects that require non-standard structural elements? Have you struggled with those shapes communicating across your analytical and Revit software models? This class will cover many things, including how to develop custom families that communicate bi-directionally between applications; how to properly map elements across models; how to develop an efficient, fluid, bidirectional workflow to avoid redundancy, increase coordination, and produce high-quality design documents and models; and how to integrate industry-standard third-party analysis tools (such as ETABS software) in a holistic workflow.

Learning Objectives

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

- Discover the procedure for developing a workflow between Revit Structure software and third-party analysis tools.
- Discover the steps required for creating bi-directionally enabled custom structural content.
- Understand organizational techniques for producing a clear, efficient design model and document set.
- Discover external tools available for efficiency and productivity gains.

About the Speakers

Raul is currently the Building Information Modeling (BIM) manager at Halvorson and Partners, a structural engineering firm in Chicago. Raul provides training and support, and he is involved on projects using Revit Structure software. Raul's experience expands over 25 years in the use of CAD and BIM applications. In his previous role as the digital design manager in the Chicago office of Skidmore, Owings, & Merrill LLP (SOM), he was responsible for BIM implementation, and he oversaw the implementation of digital design technology, visualization, and sustainable and building performance analysis applications. Raul has worked on various high-rise and high-profile projects around the world.

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Thomas works primarily as a structural engineer at Halvorson and Partners, but he also spends a considerable amount of time developing BIM software integration tools. He continues to look for new ways to increase office efficiency and bridge the gap between engineer and draftsman.

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Class Overview

The main idea behind Autodesk's Revit Structure has always been to provide structural engineers with a single application that can facilitate the analysis, design, and documentation of their projects from start to finish. Although Revit Structure provides some very powerful structural analysis tools, the stubbornness of structural engineers usually results in a disconnect between the analysis, design, and documentation processes. Whether it's due to the lack of trust in new/different structural analysis tools, or the fear of the initial loss of efficiency and/or aggravation usually associated with workflow changes, a structural engineer almost always refers back to their preferred structural analysis software package when beginning a new project.

One of the biggest improvements the Autodesk development team made to Revit Structure to address this issue was to include an Application Programming Interface (API). The addition of an API paved the way for structural analysis software companies to development integration tools that could communicate both with their structural analysis software and Revit Structure. These tools aim to bridge the gap between structural analysis software and Revit Structure by providing the functionality to import/export models to and from Revit Structure.

In this class we will demonstrate how Halvorson and Partners utilizes some of these integration tools in practice. We will describe the advantages of using third party integration tools as well as the challenges we encountered by doing so. We will also demonstrate how we use custom families to develop a bi-directional workflow to produce holistically integrated 3D Building Information Models and complete 2D design documents. Lastly, we will present tools that we have developed in-house to overcome some of the challenges and limitations of the commercially available products.

Commercially Available Workflow Tools Example : CSiXRevit

Computers and Structures, CSI, is the developer of ETABS, SAP2000 and other structural analysis programs. ETABS and SAP2000 are widely used in our office to design mid to super tall structures. We will be demonstrating the practical usages of the CSI developed "CSxRevit Add-in" which provides the functionality to import/export CSI models to and from Revit. The Add-in is available for Revit Structure 2013, 2014 & 2015.

Four different Workflows Supported

1. Export From Revit Structure to develop new ETABS Model
2. Export From Revit Structure to Update an existing ETABS Model
   (In this case you have the option of updating location of members, update the designs or update both)
3. Import from ETABS to Create a New Revit Project
4. Import from ETABS to Update an Existing Revit Project

Frame Section

1. ETABS first tries to map Revit Family sections in the loaded ETABS database by comparing section names. If it finds a match then that section is mapped. All geometric cross sectional properties are used from the ETABS section
2. If a Revit Family section cannot be mapped to an ETABS section from any of the property files, ETABS checks if it is a Revit parametric section. If it is a parametric section, ETABS creates an equivalent section and names it after the Revit family section.
3. If a Revit family section is not parametrically defined, then a new ETABS section named after the Revit family section is created with default ETABS section properties. At this point the user is given the option to add a new parametric section to replace that section or to load a new section from any other section property file(.XML) that is not in the properties file (.XML) list.

ETABS to Revit Translation

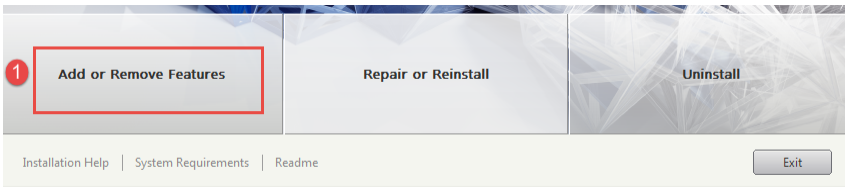
For this case study only structural frame elements were part of the import and export process.

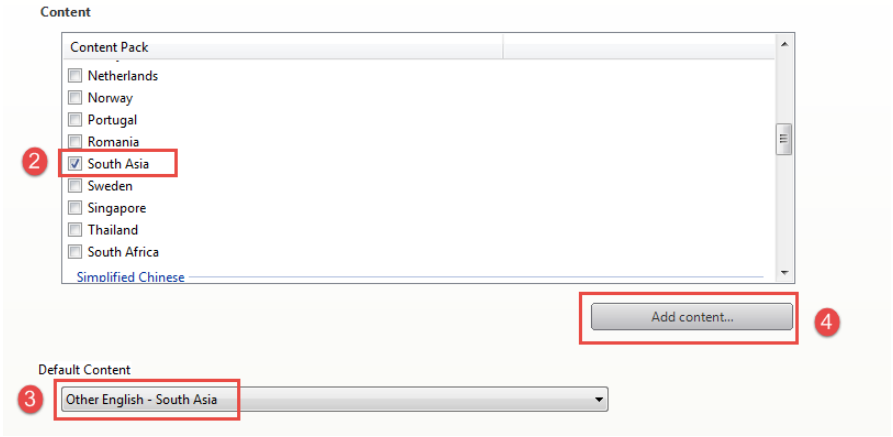
Developing Custom Families

Start with a typical Out of the box OOTB H-shape family from the Chinese Revit Structure library. If you are working on projects in China it is recommend to use the appropriate content for the region. For most typical projects rolled shapes will work just fine especially if integrating Revit with an analysis application. Chinese content is packaged with the Revit installation package. You will need to install it or have your IT support staff install it.
Make sure you install the correct content with English folder structure. The only Chinese content with English folder structure is the South Asia content. This is found in the installation content under Other English.

From the Control Panel under Programs > Programs and Features
For Autodesk Revit Structure 2014 it is under Add or Remove Features

For Revit Structure 2015 it is under Autodesk Revit Structure Content libraries



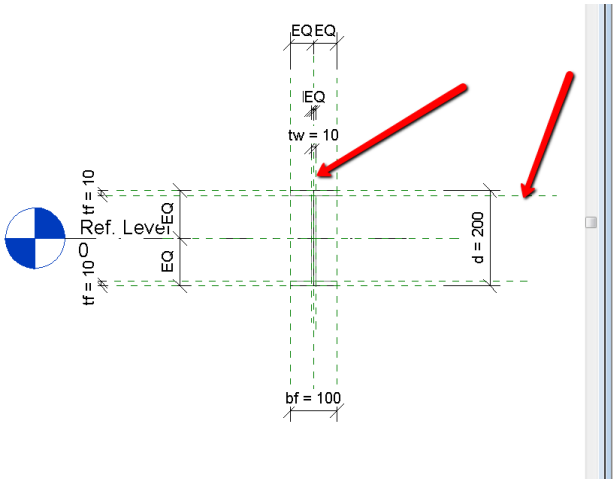


1. Add remove Features
2. Select South China checkbox
3. From the default content drop down list select Other English - South China
4. Click add Content.

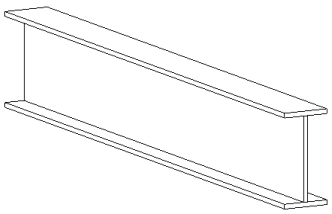
Content will be installed under C:\ProgramData\Autodesk\RVT 201x\Libraries\South Asia\Structure

For best practice open an OOTB family to begin creating a custom Built-up Plate family. There is also a family template “Metric Structural Framing - Beams and Braces.rft” that can be used. The template does not have predefined parameters.

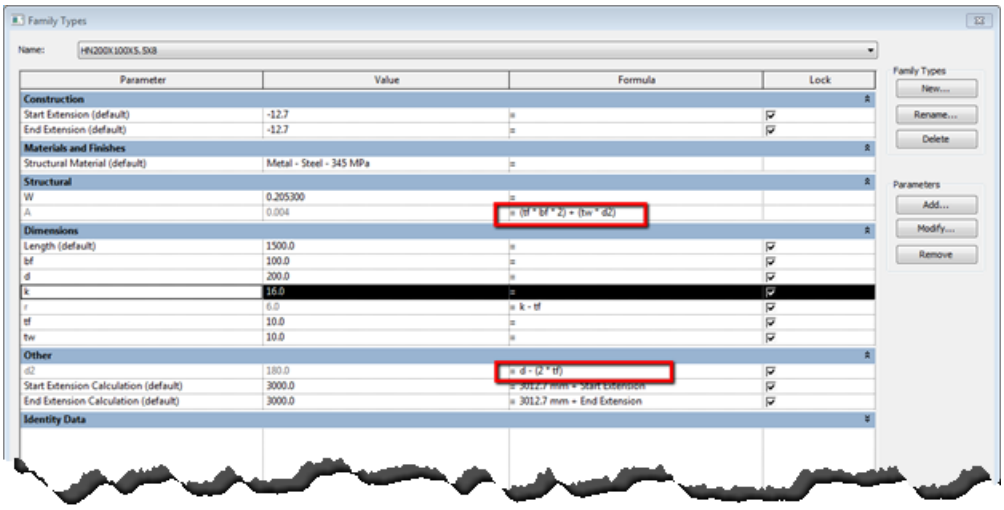
Use the medium and fine extrusions to develop the Built-Up Plate family. Add two reference planes for the top and bottom flange plate and 2 reference planes for the web thickness add a dimension for the web reference planes and assign the predefined tw parameter. Add dimensions for the top and bottom flange plates and assign the predefined tf parameter. The next step is to edit the sweep to create the top and bottom flanges. The Medium sweep was used for the top and bottom flanges and the fine sweep for the web thickness as sketch profiles. The original Line Stick Symbolic Lines were used. An advantage to start with an OOTB family is a time saving technique.



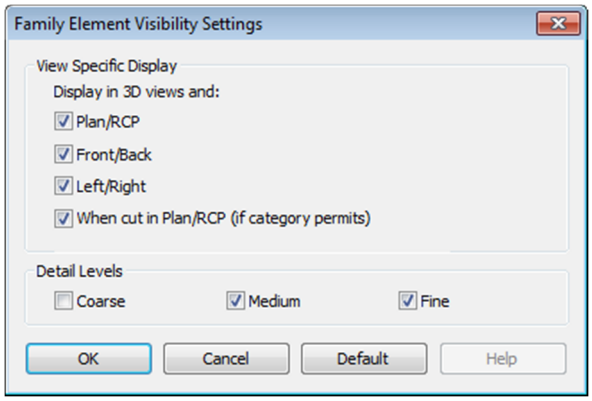
4 Reference planes added



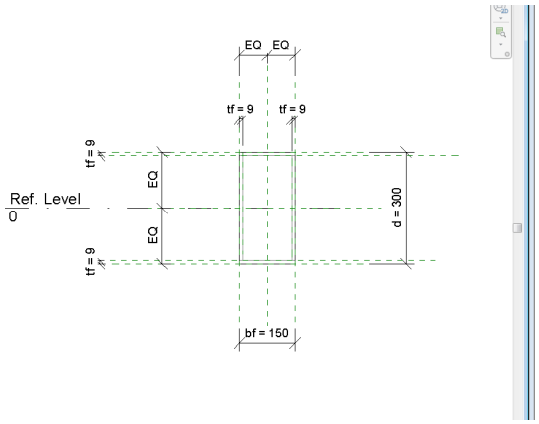
3D view of Buil-Up Shape family



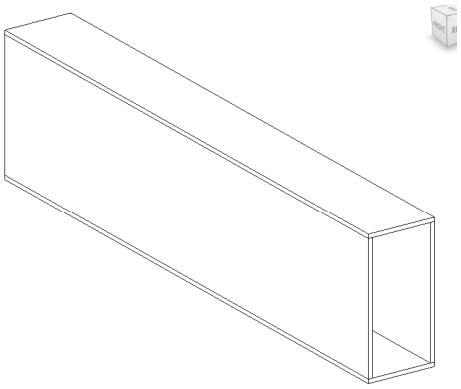
Add a family type parameter d2 with a formula d= d - (2 * tf) to subtract the top and bottom flange thickness. A formula was added for the area A = (tf * bf * 2) + (tw * d2). This can be used to calculate areas at a later time. Under Visibility Graphics modify the sweeps visibility settings to Detail Levels as Medium and Fine.



A similar process was used to develop a Built-UP Box Shape Custom Family started with an OOTB Tube family:

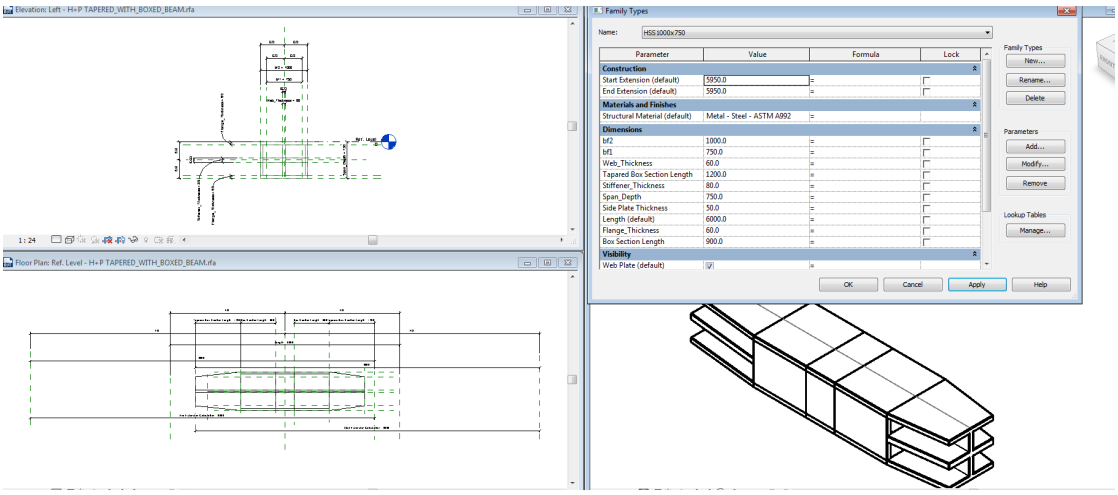


4 Reference planes added



3D view of Built-BOX Shape family

A column Built-Up Box shaped was developed using a similar process.



Views of Tapered Built up box shaped

This family has a little of everything. Tapered Section boxed shape with and without a stiffener plate or web plate.

Generating a Type Catalog file for custom families

To create a type catalog for the custom families follow the steps outlined below:

1. Open one of the custom families
2. In the family types create up to six new types

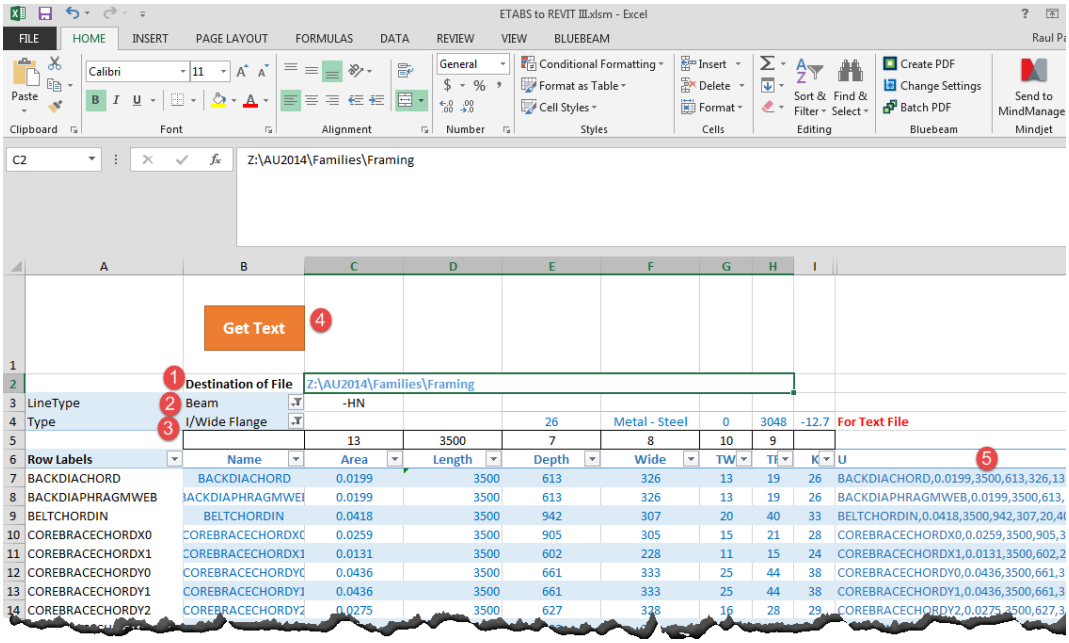
   Only parameters with values in the family will be exported to the type catalog file create a type catalog using the Export Family Types tool

3. Click File > Export > Family Types

The export creates a type catalog a file in the same directory where the family was saved and assigns the same name as the family but with a ".txt" extension.

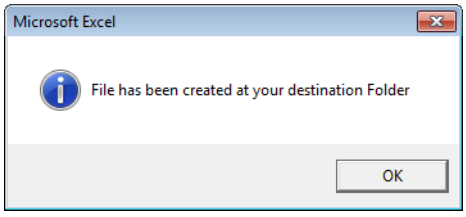
4. Click Save.
5. Open the .txt file in a text editor
6. The first line in the text file is the parameter declaration

With the type catalog saved you can use excel or a text editor of your choice to add additional family types. In this case study Microsoft Excel was used for our workflow to add additional family types.



The fields to generate type catalogs for the custom families were extracted from the ETABS generated section properties output file. A macro was used to filter and export only the values needed for each family type

1. Destination file
2. Filter the Family Name: (i.e. beam, Brace or Column)
3. Filter Section Property: (i.e. Tube, Box, Wide Flange)
4. Get Tex Button: Generates the catalog file
5. Exported values to the type catalog file



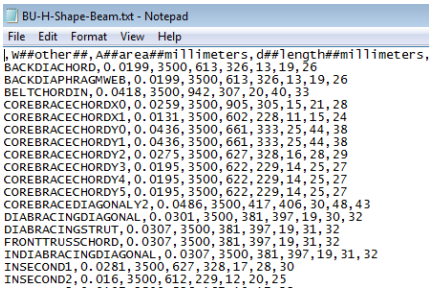


Image of the BH-Shape-Beam.txt file

List of Custom Families Created for this project

BU-H-Shapes
BU-H-Braces
BU-BOX-Shapes
BU-BOX-Braces
BU-BOX-Columns

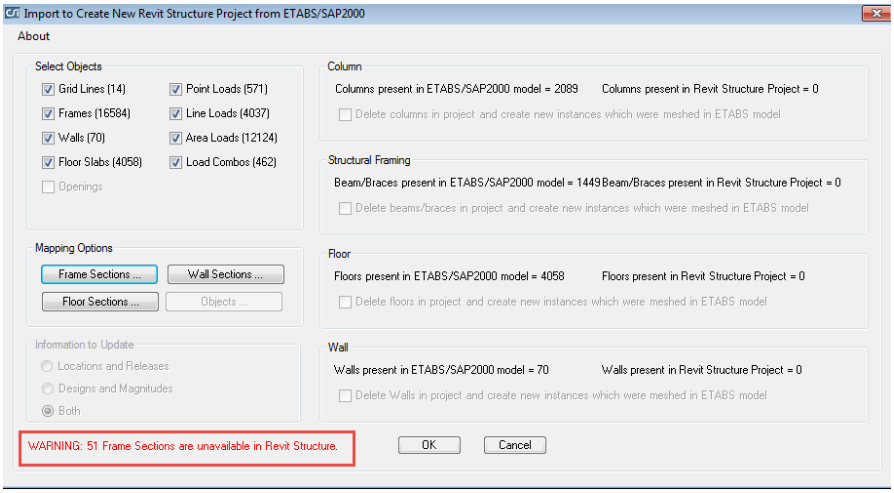
In-Place Families

ETABS does not support in-place-families and will not transfer from Revit to ETABS

Importing an ETABS Model into Revit Structure

Steps for Importing ETABS generated .EXR file

1. Pre load all custom generated family types into a new project
2. From the Add-Ins Tool > External Tools > Import to Create New Revit Structure Project from ETABS/SAP2000
3. Select the .EXR file to Import



For this import there were 51 Frame Section Warnings

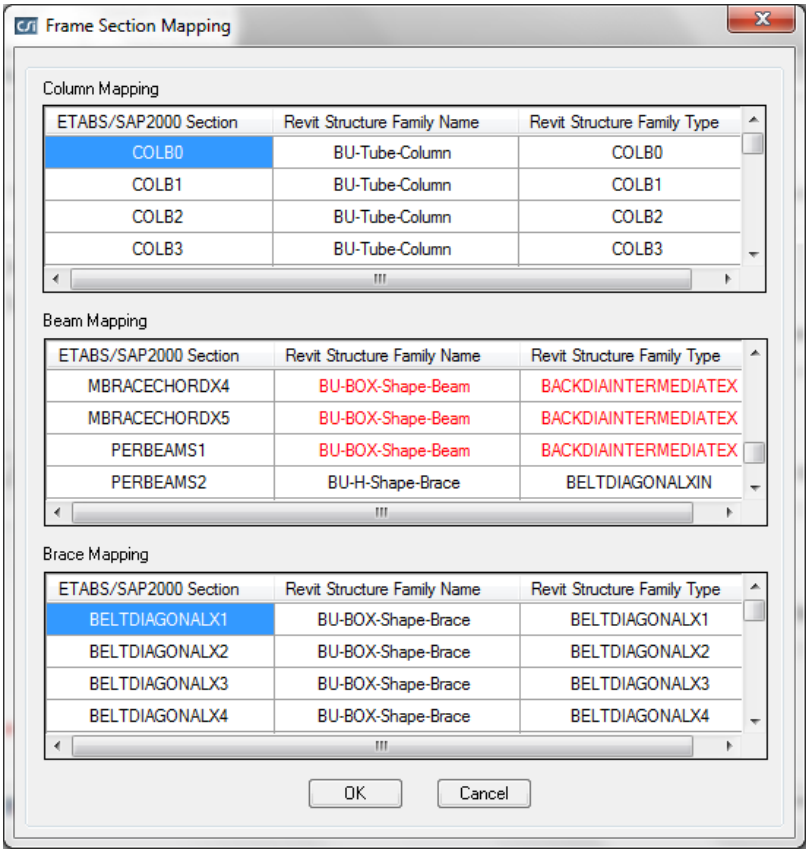


Image: Frame Section Mapping

Frame section mapping showing in red missing family types

You have two options:

1. Manually map the frame sections
2. Go back to the excel file to generate the missing frame sections and load them into the project

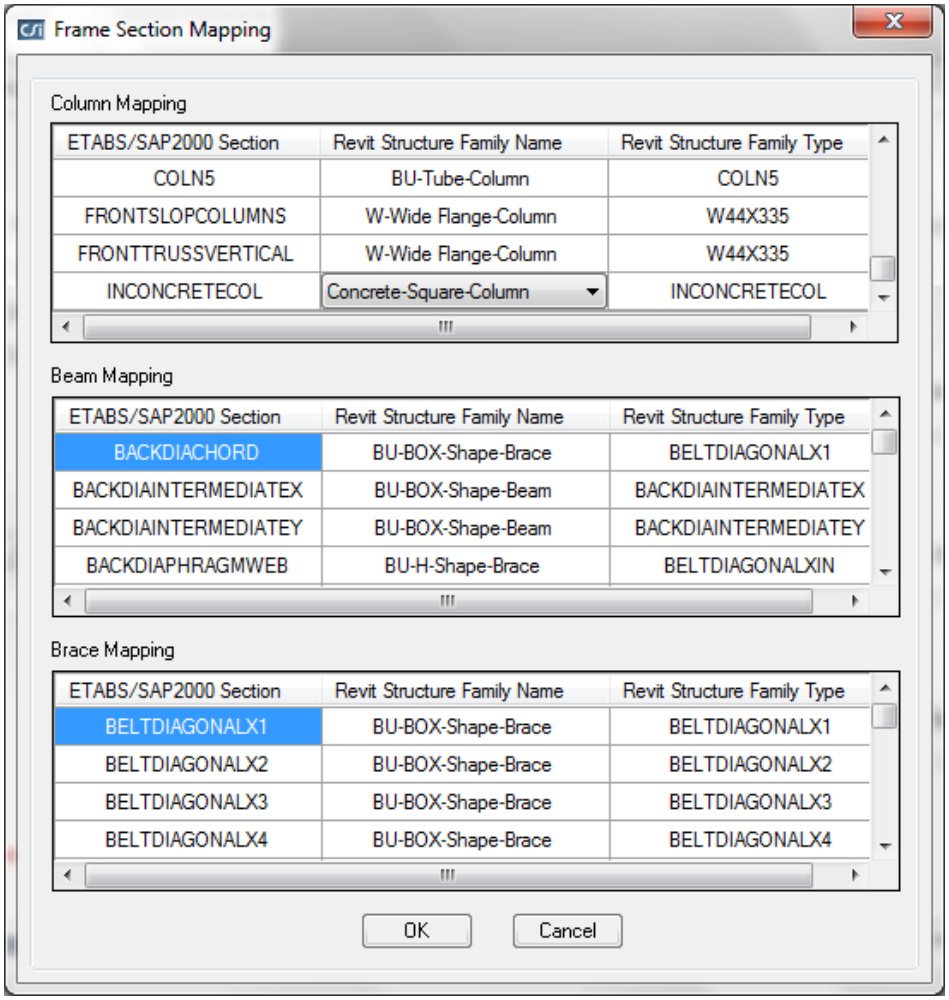


Image: Frame Section Mapping

After all sections have been mapped or reloaded into the project the model is ready to be imported

Sloping Columns

ETABS Model as Brace elements

Challenges

Creating Type Catalogs

Creating custom families and type catalogs is a time consuming endeavor. But with careful planning and leveraging the information from the ETABS out put file in conjunction with excel to extract only the information needed to create type catalogs this task is attainable.

X-Bracing

ETABS Splits X-bracing into 4 segments at intersection of frame elements. In Revit X-bracing is typically modeled as two frame elements.

Exporting a Revit Model to ETABS

Structural Columns and Framing:

Frame Sections:
The family type assigned to the Revit element is imported along with the whole family. ETABS converts the Revit family to an ETABS auto selection list

Insertion Points: In Revit, the beam insertion point is defined by the following two parameters:
Z-Direction Justification
Lateral Justification

Frame Section

The Mapping of Revit frame sections attributes depends upon their type

1. ETABS first tries to map Revit Family sections in the loaded ETABS database by comparing section names. If it finds a match then that section is mapped. All geometric cross sectional properties are used from the ETABS section
2. If a Revit Family section cannot be mapped to an ETABS section from any of the property files, ETABS checks if it is a Revit parametric section. If it is a parametric section, ETABS creates an equivalent section and names it after the Revit family section.
3. If a Revit family section is not parametrically defined, then a new ETABS section named after the Revit family section is created with default ETABS section properties. At this point the user is given the option to add a new parametric section to replace that section or to load a new section from any other section property file(.XML) that is not in the properties file (.XML) list.
4. Revit In-Place Families elements are not supported in ETABS and will not import from Revit.

Levels

Building Story

This is the datum level corresponding to a building functional story. In our workflow this is the top of the structural floor slab.

Structural Level

In Revit 2013 a structural level was introduced which identifies the level as primarily structural. In the OOTB Structural Template this parameter is disabled. We have enabled this parameter in our project template and assigned to their own Workset and labeled as T/Stl Level X.
All steel framing elements are hosted to the Structural Level

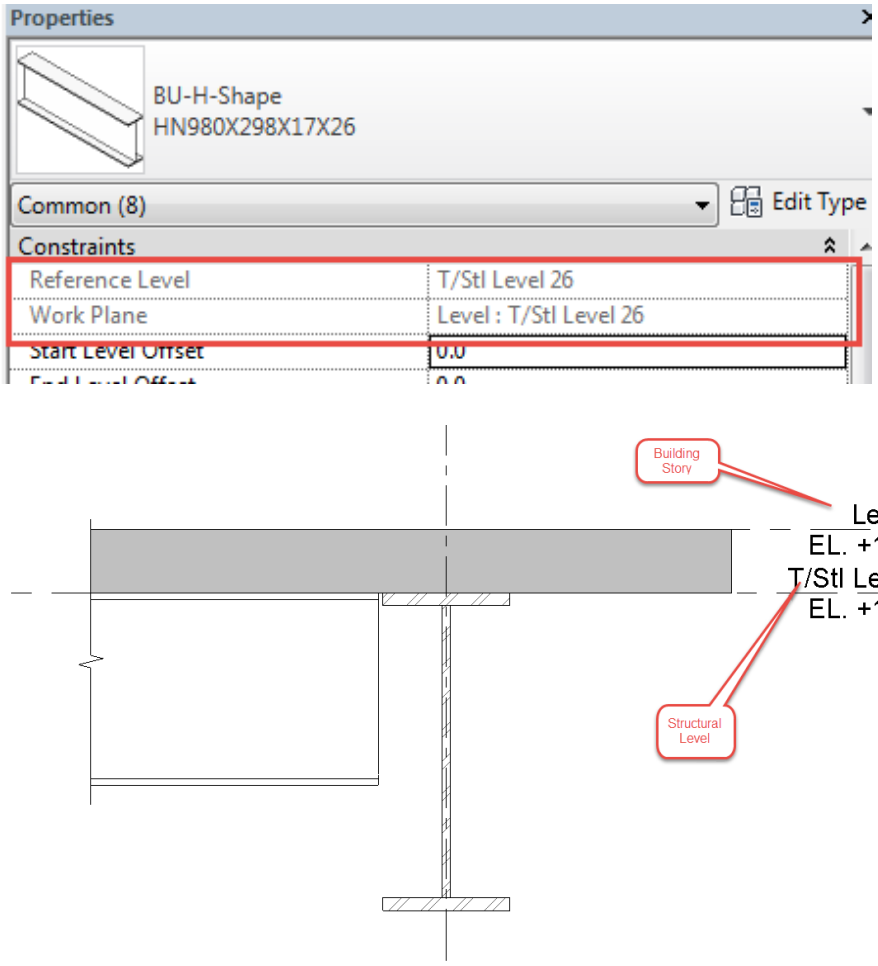


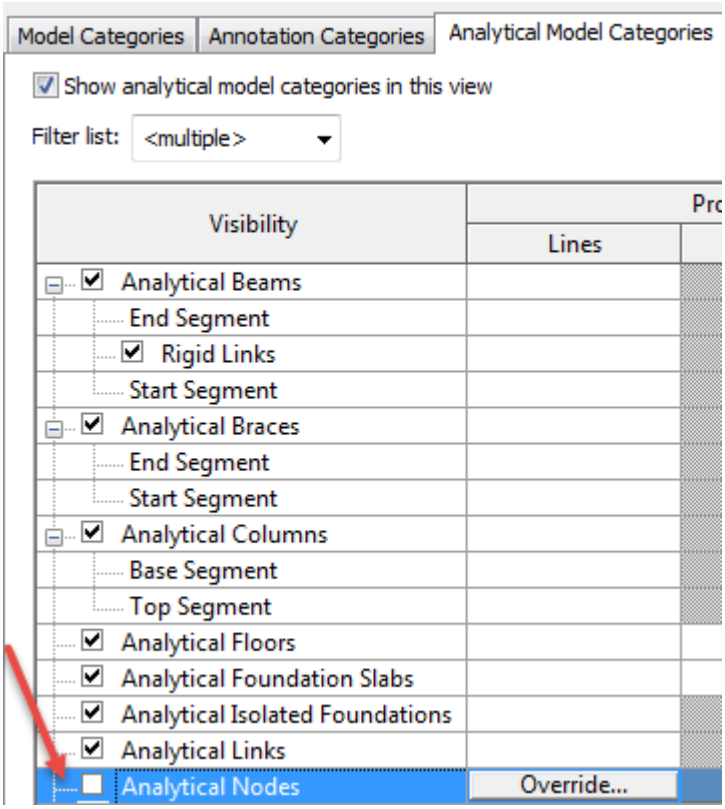
Image: showing Story Level and Structural Level

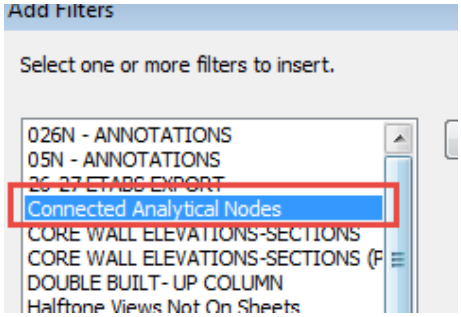
Analytical Nodes

Filters

New in 2014 analytical filters come preloaded in the Structural template.
Tip! When upgrading your company template as best practice is to start with a clean OOTB template to take advantage of enhancements.
Prior to Exporting from Revit it is recommended to review all nodes and make sure they are analytically connected. In a 3D view add the two Analytical Node filters and assign a color to each one.

Under visibility graphics turn on Analytical nodes





From the Filters tab add the two filters Unconnected Analytical Nodes and Connected Analytical Nodes for our case study two colors were used:

1. Green was assigned to connected nodes
2. Red was assigned to unconnected nodes

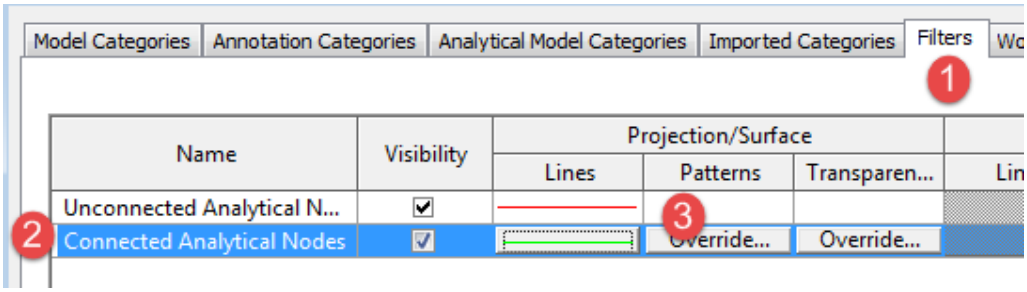


Image: Showing Color Coded Filter

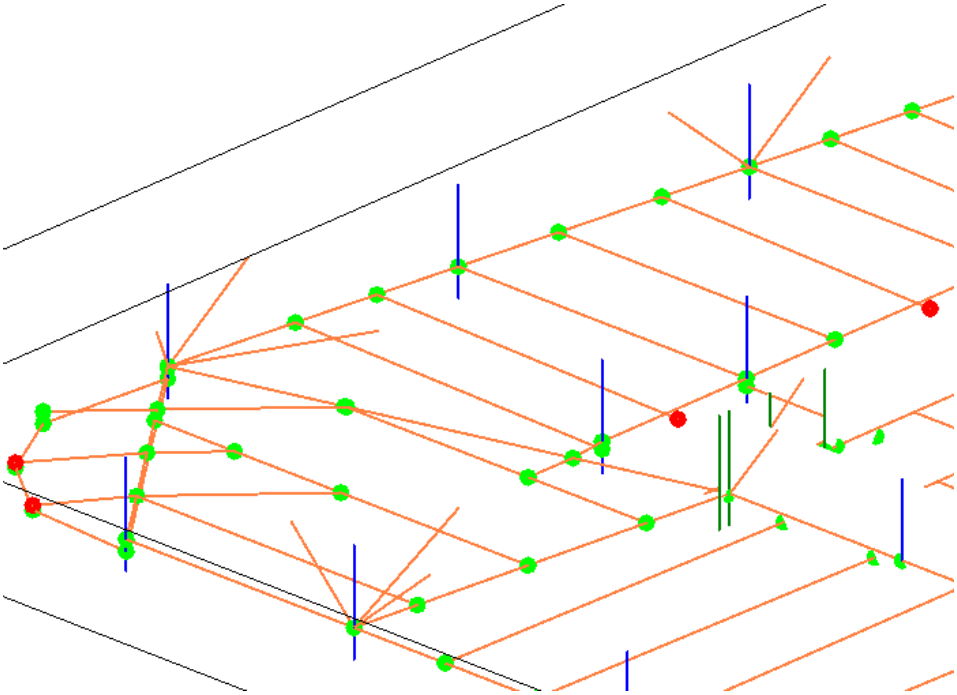


Image: showing Connected green and Unconnected Analytical Nodes

Manually connect all unconnected nodes. For the most part connecting the graphical element will fix the unconnected nodes. Another Method is by selecting the analytical element and using the Analytical Adjust button from the anlytical model tab. This can be a tedious process depending on the number of unconnected nodes that exist in your project. With proper planning you can have a clean model to export to an analysis application.

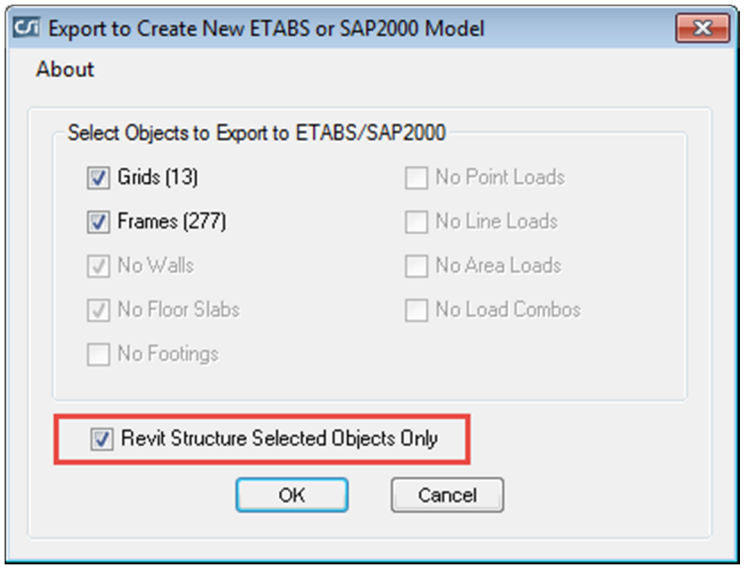
By performing the steps outlined above you will have a cleaner model to export.

RevitStructureBlog: has a video demonstrating the use of these filters and assigning color to them
https://www.youtube.com/watch?v=J2_iddaJzLg

Exporting a Revit Model to an EXR file

For this process two levels of framing were selected along with the Grid lines

1. From the Add-Ins menu
2. Under External Tools > Export to Create a New ETABS/SAP200 Model



3. In the Export to Create a New ETABS/SAP200 Model check Revit Structure Selected Objects Only Click OK

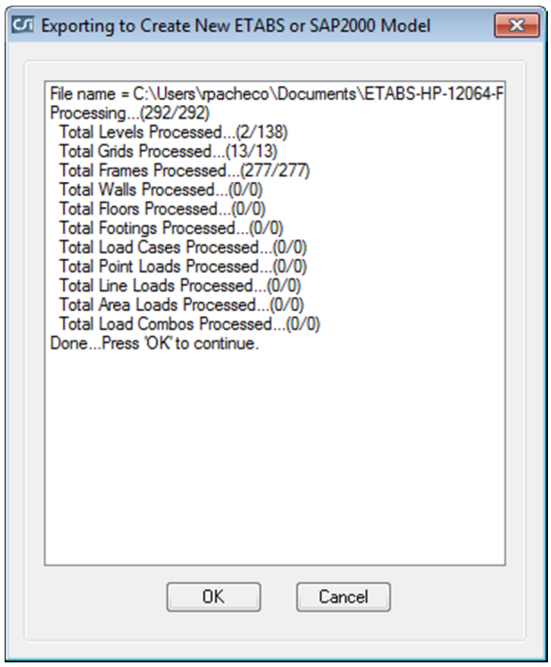


Image: displaying elements processed

4. The file will be save with an .EXR extension to be imported into ETABS

Linked Models:

Revit Models with Linked Structural Models will not export to an EXR file. You will need to export linked models separately.

Import EXR file into ETABS

For this Case Study a Chinese Steel Section Database was used using the Built-in Settings in the image below:

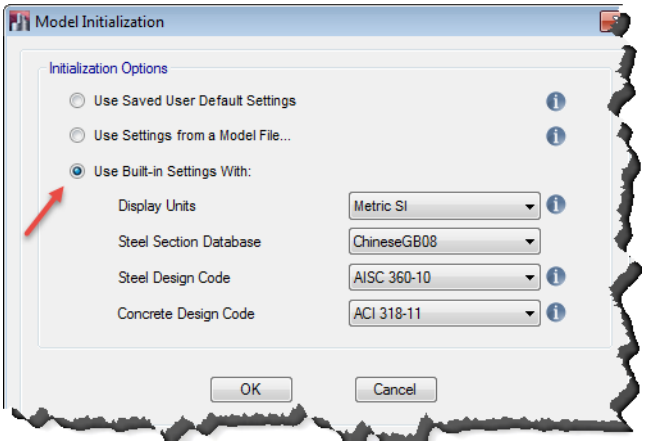


Image: Model Initialization

Import > the Revit Structure.exr file into the ETABS model
The first dialogue box you will get is the Revit Data Overview/Control dialog box
With warnings. There are a total of two warning for Material and 32 for Frame Sections
At this point you have two options

1. Select the edit button to define equivalent fame sections in ETABS
2. Select Import Mapping file

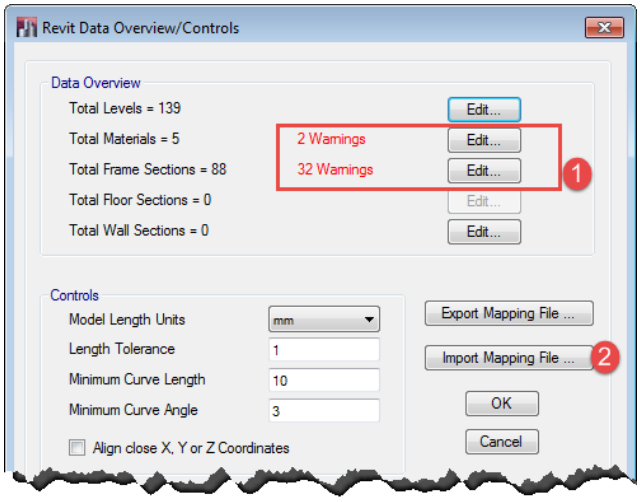
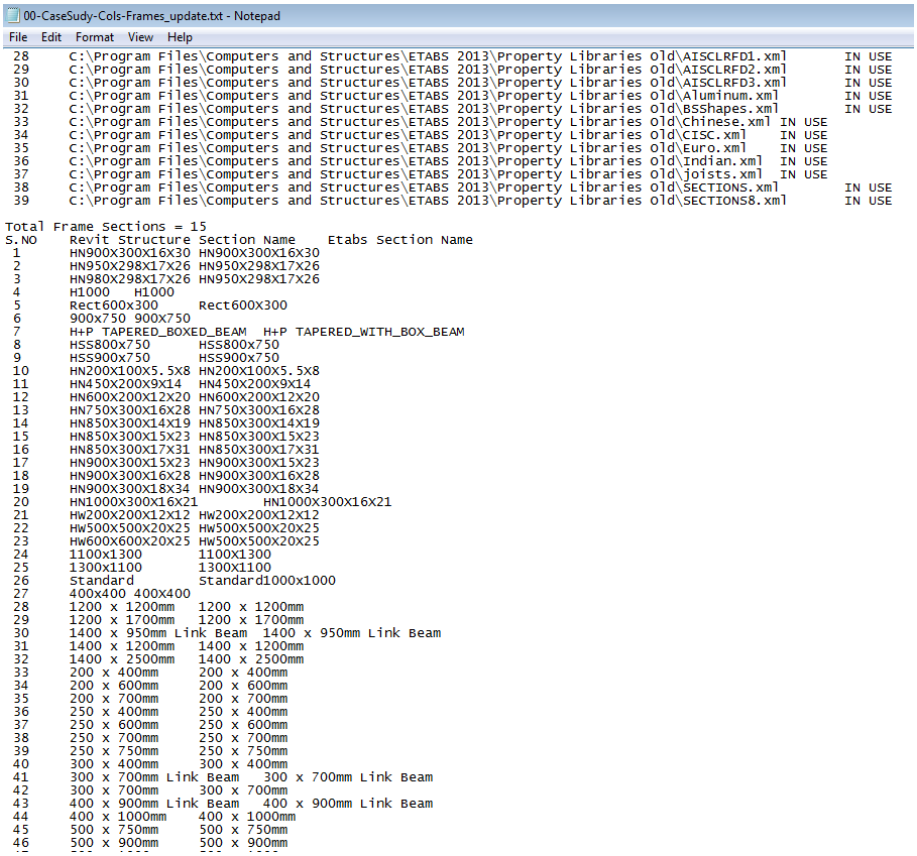


Image: Revit Data Overview/Controls

Mapping file

Mapping file with section properties
Revit Structure Section Name ETABS Section Name



```
00-CaseSudy-Cols-Frames_update.txt - Notepad
File  Edit  Format  View  Help
 28     C:\Program Files\Computers and Structures\ETABS 2013\Property Libraries Old\AISCLRFD1.xml       IN USE
 29     C:\Program Files\Computers and Structures\ETABS 2013\Property Libraries Old\AISCLRFD2.xml       IN USE
 30     C:\Program Files\Computers and Structures\ETABS 2013\Property Libraries Old\AISCLRFD3.xml       IN USE
 31     C:\Program Files\Computers and Structures\ETABS 2013\Property Libraries Old\Aluminum.xml        IN USE
 32     C:\Program Files\Computers and Structures\ETABS 2013\Property Libraries Old\BSShapes.xml        IN USE
 33     C:\Program Files\Computers and Structures\ETABS 2013\Property Libraries Old\Chinese.xml IN USE
 34     C:\Program Files\Computers and Structures\ETABS 2013\Property Libraries Old\CISC.xml    IN USE
 35     C:\Program Files\Computers and Structures\ETABS 2013\Property Libraries Old\Euro.xml    IN USE
 36     C:\Program Files\Computers and Structures\ETABS 2013\Property Libraries Old\Indian.xml  IN USE
 37     C:\Program Files\Computers and Structures\ETABS 2013\Property Libraries Old\joists.xml  IN USE
 38     C:\Program Files\Computers and Structures\ETABS 2013\Property Libraries Old\SECTIONS.xml        IN USE
 39     C:\Program Files\Computers and Structures\ETABS 2013\Property Libraries Old\SECTIONS8.xml       IN USE

Total Frame Sections = 15
S.NO    Revit Structure Section Name    Etabs Section Name
 1      HN900X300X16X30 HN900X300X16X30
 2      HN950X298X17X26 HN950X298X17X26
 3      HN980X298X17X26 HN950X298X17X26
 4      H1000   H1000
 5      Rect600x300     Rect600X300
 6      900x750 900X750
 7      H+P TAPERED_BOXED_BEAM  H+P TAPERED_WITH_BOX_BEAM
 8      HSS800X750      HSS800X750
 9      HSS900X750      HSS900X750
 10     HN200X100X5.5X8 HN200X100X5.5X8
 11     HN450X200X9X14  HN450X200X9X14
 12     HN600X200X12X20 HN600X200X12X20
 13     HN750X300X16X28 HN750X300X16X28
 14     HN850X300X14X19 HN850X300X14X19
 15     HN850X300X15X23 HN850X300X15X23
 16     HN850X300X17X31 HN850X300X17X31
 17     HN900X300X15X23 HN900X300X15X23
 18     HN900X300X16X28 HN900X300X16X28
 19     HN900X300X18X34 HN900X300X18X34
 20     HN1000X300X16X21        HN1000X300X16X21
 21     HW200X200X12X12 HW200X200X12X12
 22     HW500X500X20X25 HW500X500X20X25
 23     HW600X600X20X25 HW500X500X20X25
 24     1100x1300       1100X1300
 25     1300x1100       1300X1100
 26     Standard        Standard1000x1000
 27     400x400 400X400
 28     1200 x 1200mm   1200 x 1200mm
 29     1200 x 1700mm   1200 x 1700mm
 30     1400 x 950mm Link Beam  1400 x 950mm Link Beam
 31     1400 x 1200mm   1400 x 1200mm
 32     1400 x 2500mm   1400 x 2500mm
 33     200 x 400mm     200 x 400mm
 34     200 x 600mm     200 x 600mm
 35     200 x 700mm     200 x 700mm
 36     250 x 400mm     250 x 400mm
 37     250 x 600mm     250 x 600mm
 38     250 x 700mm     250 x 700mm
 39     250 x 750mm     250 x 750mm
 40     300 x 400mm     300 x 400mm
 41     300 x 700mm Link Beam   300 x 700mm Link Beam
 42     300 x 700mm     300 x 700mm
 43     400 x 900mm Link Beam   400 x 900mm Link Beam
 44     400 x 1000mm    400 x 1000mm
 45     500 x 750mm     500 x 750mm
 46     500 x 900mm     500 x 900mm
```

Sample mapping file

A predefined a mapping file was created using Microsoft excel and exported to a text file. You can use a text editor of your choice.

Note: This file can resides in the same location as your project or on your company server for use on other projects.

After importing the mapping file the warnings were reduced to 2. For best practice is recommended that you predefine all your custom shape in the mapping file to reduce or eliminate warnings.

CSiXRevit documentation states that if a frame section is not found ETABS will try to create an equivalent section.

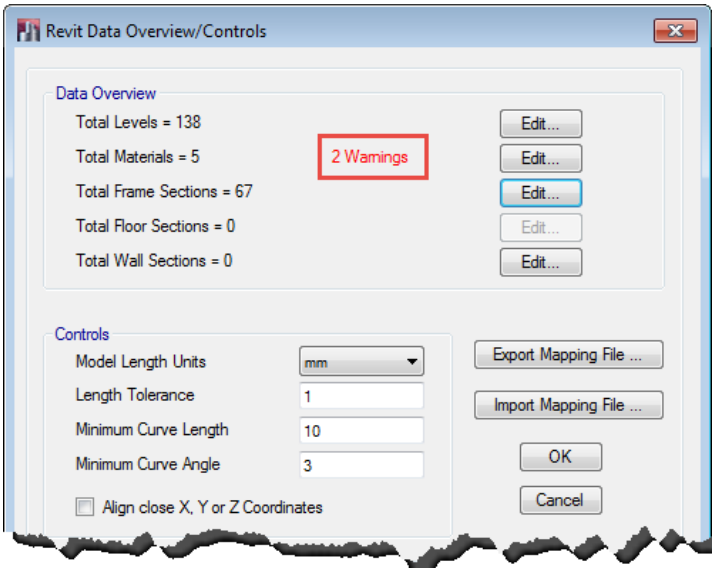


Image: Revit Data Overview/Controls

For the Material warnings since there were only two they can be manually mapped by selecting the edit button and choosing the appropriate material type. Material can also be mapped at the end of the mapping file under Total Material Assignment section.

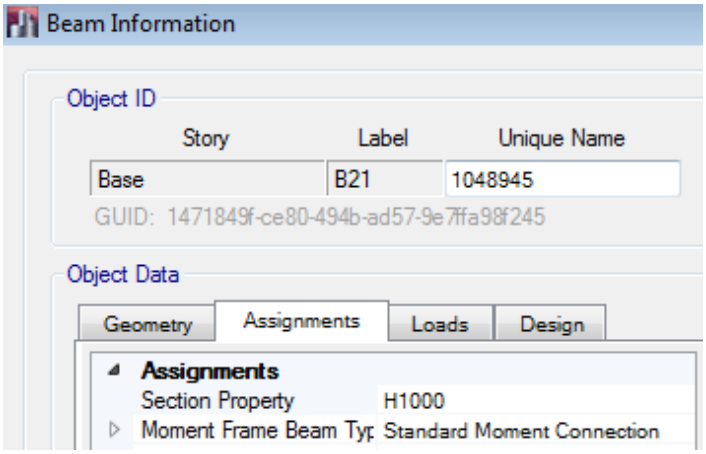
```
 106     HW500X500X20X25 HW500X500X20X25
 107     HW600X600X20X25 HW600X600X20X25

Total Material Assignments = 2
S.NO     Revit Structure Material Name   Etabs Material Name
 1       Concrete - Cast-in-Place Concrete       4000Psi
 2       Metal - Steel   Metal - Steel - 345 MPa
```

Image: Mapping file Showing Total Material Assignments Table

Round Trip

For this case study only a few framing elements were changed to import back into Revit

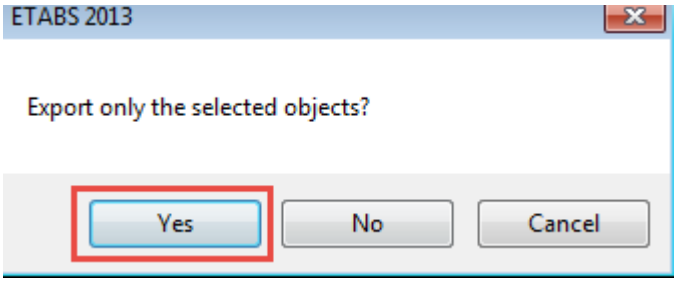
Partial Import from ETABS to Revit
Changed frame types in ETABS for a partial import to Revit
A built-up section was change to a box section
Floor framing section properties were changed from HSS900x298 to a Built-up H1000 section property



Partial export of only frame elements changed

File > Export > Revit Structure.exr file

When prompted to Export only the selected objects click ok



Before importing the ETABS to Revit Partial Update the edge frame elements were tagged as HN980X298X17X26

After the ETABS to Revit partial update was completed tags automatically updated to a Built-up shape H1000

Challenges

Framing at the same level as floor slab

Groups do not export

Revit Framing Elements in Groups do not export to ETABS

Ungroup all groups prior to using the CSiXRevit Export to ETABS

Structural Levels & Story Levels imported: When Levels were not selected as part of the export process the CSiXRevit Exports both the Story Level and the Structural Level to the .EXR file resulting in some frame elements showing up in the Story Level and Some in the Structural Level. Even when frame elements were hosted to the Structural Level.

Even when only Structural Levels were slected and not the story levels when exporting from Revit to ETABS. This did not prevent framing elements from importing to ETABS into multiple Levels.

H+P Software Suite

Description

The H+P Software Suite is a collection of in-house software tools deployed by means of a Dashboard Application, an Excel Add-in, and a Revit Add-in.

Embedded at the heart of the H+P Software Suite is an API framework that encompasses the functionality of all the modeling applications used within our office.

Structural Analysis Applications

RAM Structural Systems
ETABS
SAP2000
Strand7

Documentation Applications

Rhinoceros/Grasshopper
Revit

Goals

- Must be efficient. No repeated code. No unnecessary hard drive read/write operations.
- Must be scalable. Adding new functionality cannot break old functionality.
- Importing/Exporting Models
  - Must be able to send any model from any application to any other application.
  - Information should not be unnecessarily duplicated. No global database with "master" information.
  - Must be able to compare models to one another both before and after import/export operations.
  - Must support "nodes", "lines", and "areas".

Revit Specific Goals

- Very little effort must be required to extend functionality to future versions of Revit.
- Tools must be available from outside of the Revit Interface.
  - Since we don't have access to the proprietary file formats that these programs use, we must start instances of the programs in order to read model information.
    - As a result, we may need to start separate x86 and x64 processes to access two models simultaneously; each of which may use a program built for a different architecture.
  - This is also necessary to run automated tools that may not require user interaction. Model maintenance tools, for example.
- Must be tailored to our structural analysis and documentation style.
  - For example, there must be an understanding that steel floor framing may be modeled differently in a Revit model than it will be in a structural analysis model.
  - As another example, there must be an understanding of what link beam modeling techniques are used in each program.
- Importing/Exporting
  - Revit specific information must not be lost when importing updated information.
  - Whatever gets imported must get exported. If we change the information in Revit to reflect a more documentation oriented standard, we must not lose the original information.

- We must keep track of any unexpected changes Revit might make to each element that we import.

In order to meet these goals, we have developed custom families with custom parameters, and custom Revit Add-ins that facilitate the assignments of these parameters.

Workflow Demonstration

- Import an ETABS 2013 Model to a new Revit 2014 model.
  - Note any changes that Revit made to our imported information.
- Make documentation specific changes in the Revit 2014 model.
  - We must do this without losing the analysis model information in case we want to re-import or export.
- Re-import an updated version of the ETABS 2013 model into Revit 2014.
  - We must do a location based search for each element in Revit and then make sure its information is up do date. We also create new elements that didn't exist before, and delete elements that no longer exist.
- Compare Revit 2014 Model to ETABS 2013 Model in Excel.
  - It's always good to compare models to make sure our tools are behaving the way we expect them to.
- Export Revit 2014 Model to Strand7.