BES473682-L

Automate Structural Analytical Modeling Workflows in Revit

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Learning Objectives

- Learn how to constantly check your structural analytical representation assumptions while dealing with changes in Revit.
- Learn how to check and assure the connectivity of the structural analytical representation in Revit.
- Learn how to identify and filter the structural model changes so you can automate the impact for analytical representation.
- Learn how to automate the relationship between physical and analytical models using Dynamo.

Description

Creating the analytical representation of the structural model in the Revit environment can be seen as the easy part. The ability to constantly check your assumptions while dealing with the analytical representation, ensuring connectivity during creation and editing, to be notified when something has changed—especially when you're not the structural engineer—is the one that modifies the project. These can be tedious and time consuming. In this class, you'll learn how to have an analytical model that constantly reflects the structural model, and how to automate the process and integrate the structural analysis in the Building Information Modeling (BIM) models.
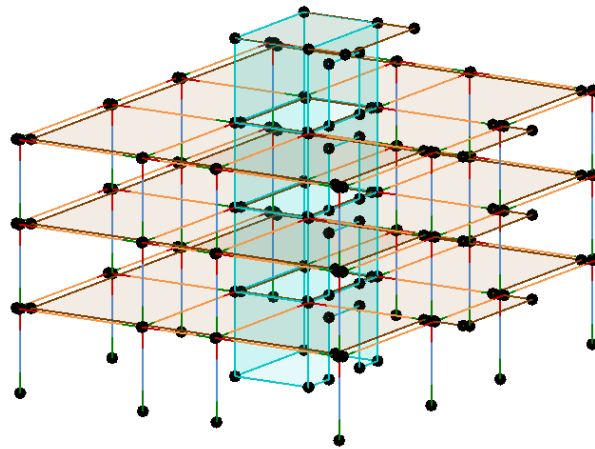
Speaker(s)

Catalin is a former Autodesk customer, currently Autodesk employee, working in constructions field for over 19 years, going through several branches of the industry, from junior unskilled worker to formwork specialist, storekeeper, project coordinator, project manager, CAD designer, structural designer. Joined Autodesk since 2014 as Quality Analyst. Currently, Product Owner for one of the teams that develops Revit and Advance Steel structural features. He is specialized in structural modeling and detailing.

Mihai has been working in the construction industry for over 13 years, going through several branches of the industry, from working in the production of aluminum windows, construction cost estimations, junior project planner, construction work supervision and quality assurance engineer in the software industry. Joined Autodesk in 2013, through the acquisition of Graitec, he is currently working as a Sr.QA Analyst for one of the teams that develops Revit and Advance Steel features. He is specialized in structural modeling and detailing.

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Introduction

The analytical model is a simplified 3D representation of the structural physical model. It consists of those structural components, geometry, material properties and loads, that together form an engineering system.

In Revit software, the analytical model can be created automatically as the physical model is built.
- Analytical Elements are derived from the correspondent physical object.
- There's a 1:1 relationship between the physical element and its analytical representation.
- Analytical Elements are in a continuous relation with the correspondent physical objects
  - Cannot be created without the correspondent physical objects
  - Cannot exist without the correspondent physical objects
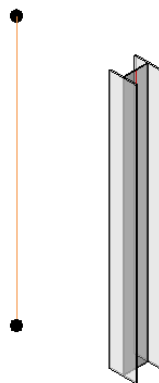
Revit analytical representation of structural elements:
- Analytical Column
- Analytical Beam
- Analytical Brace
- Analytical Floors

- Analytical Walls
- Analytical Isolated Foundation
- Analytical Wall Foundation
- Analytical Foundation Slab
- Analytical Line within In-Place Family
- Analytical Surface Opening
- Node
- Boundary Conditions
- Analytical (Rigid) Link
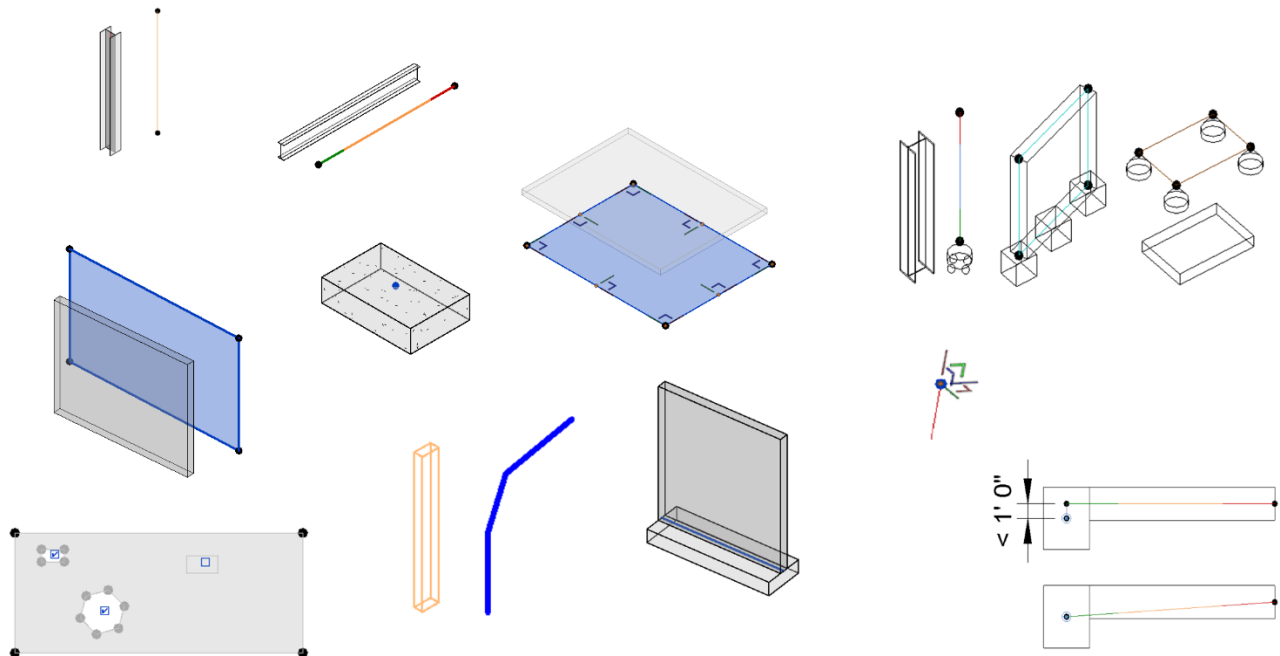
Analytical element can be enabled/disabled by checking Enable Analytical instance parameter from the Properties Palette.

Enable Analytical Model ☑

Analytical element visibility can be controlled from:
- View Control Bar - Show Analytical Model.
- Object Styles in Analytical Model Objects tab.
- Visibility/Graphics Overrides in Analytical Model Categories tab.

Check the analytical model assumptions

Identify the Counterpart

Highlight the Analytical Model

You can highlight the analytical model while working on structural elements in an analytical view. This is useful when both the physical model and analytical model are visible.

1. Select a structural element.
2. Click Modify <Element> tab > Analytical panel (Highlight Analytical). The analytical model will highlight.
3. Similarly, you can highlight the physical model when adjusting analytical models.
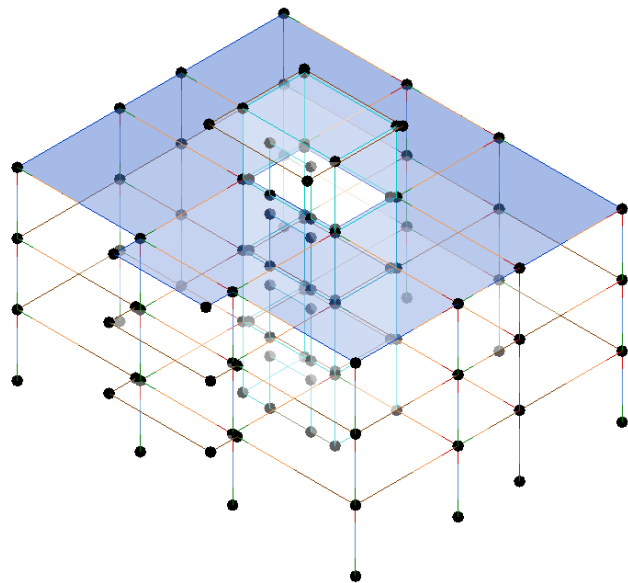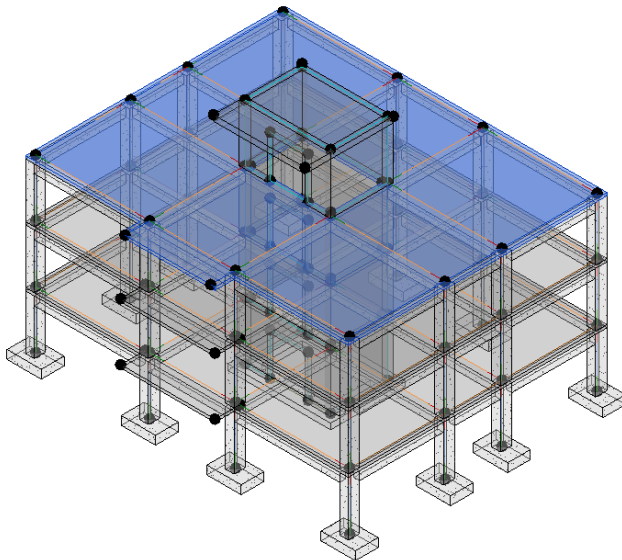
*Highlight the Physical Model*

Similarly, you can highlight the physical model when adjusting analytical models.

1. Select an analytical model element.
2. Click Modify <Element> tab > Analytical Model Tools panel   (Highlight Physical). The physical model will highlight.
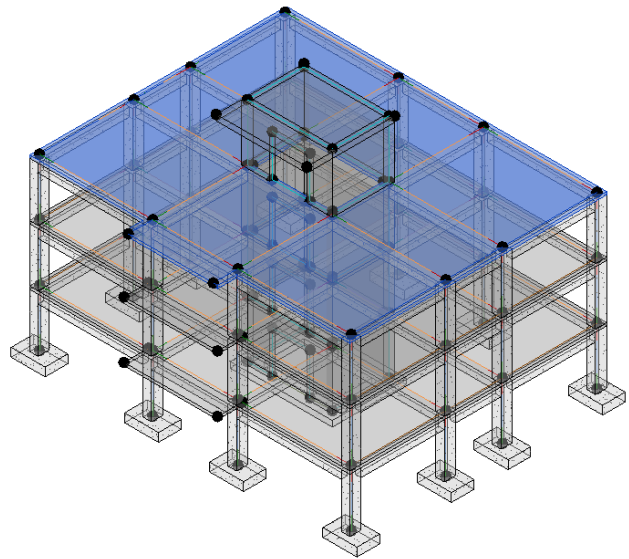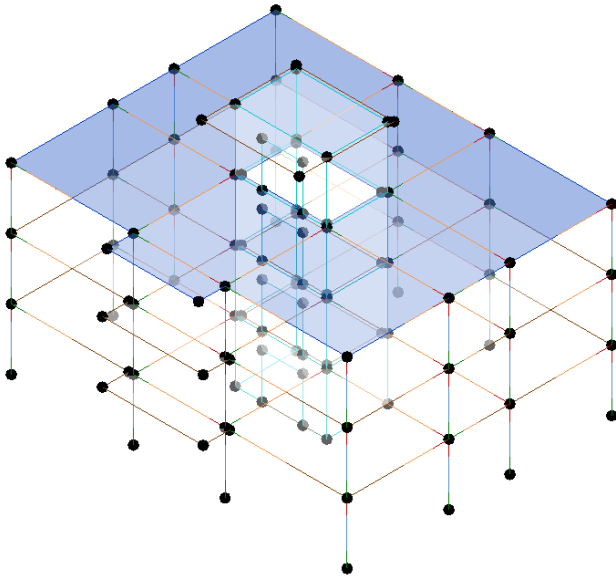
Analytical Alignment

Analytical alignment encompasses a number of different options available in placing the analytical model in relationship to itself and other analytical elements.
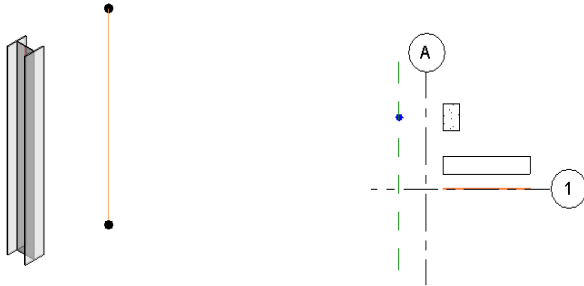
There are three methods of analytical alignment:
1. Auto-detection.
2. Projection
3. Manual Adjustment

Auto-detect Adjustment
- Automatic adjustment is performed on a structural element, in relation to a neighboring structural element.
- Revit can automatically adjust the analytical model for beams, braces, structural columns, structural walls, structural floors, and foundation slabs so that they align more accurately. This behavior is based on the instance parameters of the elements and tolerance settings.

Projection Adjustment
- Projection references for linear elements are defined as horizontal and vertical in relation to the local beam coordinate system.
- Horizontal plane (y-direction) projection references include grids, sides and center of a beam. Vertical plane (z-direction) projection references include levels, top of beam, middle of beam and bottom of beam.
- Named reference planes are included in the horizontal and vertical projections where appropriate.
- All sloped planes are included in each projection list. If both projection planes refer to a sloped reference plane the projection point is perpendicular to the sloped plane passing through the location line.

Manual Adjustment
- Some structural configurations are not suitable for direct integration with analysis and design software. Adaptive adjustment is required before a structural model is input into the analysis and design software.

Analytical alignment is determined by structural element instance properties.

The Analytical Model Element alignment can be restored to its original position.

Exercise 1 - Identify Physical-Analytical Relation

In this exercise, we'll see how we can identify the physical/analytical counterpart for model's elements.

Also, we'll do a quick overview of analytical elements alignment settings and we'll learn how to restore the analytical representation to its default position.

| Analytical Alignment	☆
Top Alignment Method	<Manually Adjusted>
Top y Projection	Location Line
Top z Projection	Location Line
Top Extension Method	<Manually Adjusted>
Top x Projection	Top Level Reference
Base Alignment Method	<Manually Adjusted>
Base y Projection	Location Line
Base z Projection	Location Line
Base Extension Method	<Manually Adjusted>
Base x Projection	
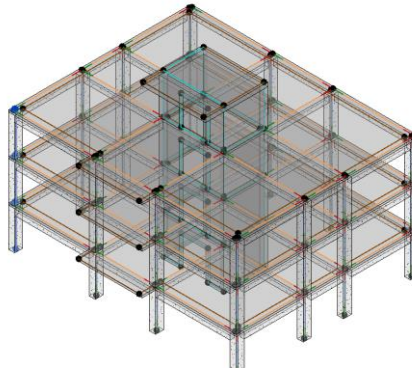
Environment

1. Open Model_001_StartPoint.rvt
2. Open Analytical Model 3D view
3. Enable Analytical Model Visibility

Highlight Analytical Counterpart

4. Select the floor on the top floor
5. From Modify Floors tab > Analytical panel > Highlight Analytical.
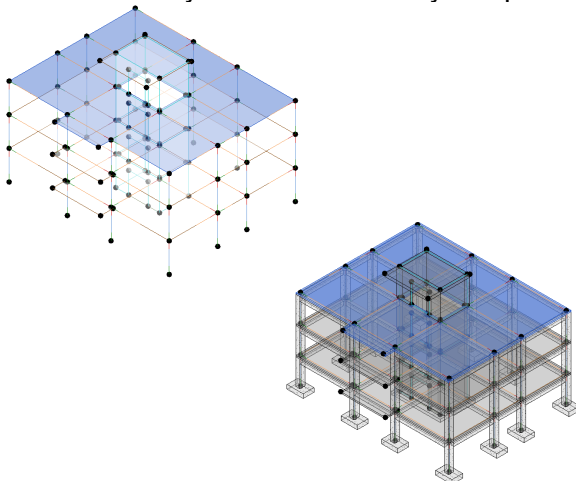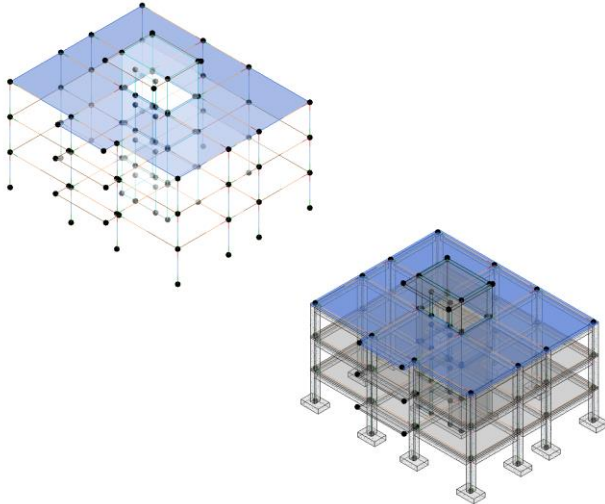

The analytical floor will highlight.

Repeat the steps for other elements.

Highlight Physical Counterpart

6. Select the analytical floor on the top floor
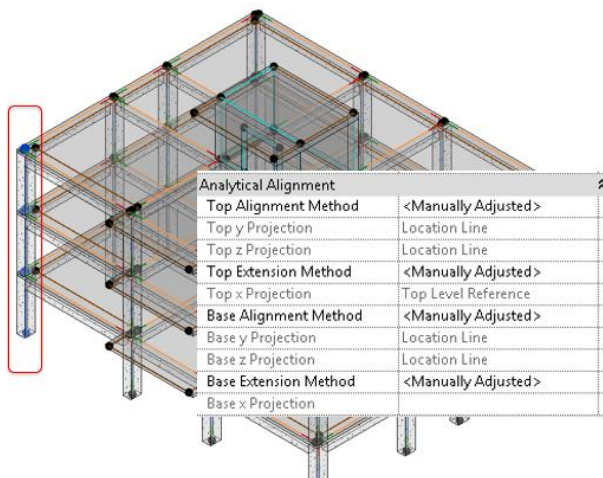7. From Modify Analytical Floors tab > Physical panel > Highlight Physical.

The physical floor will highlight.

Repeat the steps for other elements.

Identify Analytical Adjustment Settings

8. Select all the South-West corner analytical columns
9. (You can select all the South-West corner elements and use Filters to isolate the analytical columns)

In Properties palette, the Analytical Columns alignment method is set to manual.

Select other elements and identify the analytical alignement method.

Reset the Analytical Model

10. Click Analyze tab ➤ Analytical Model Tools panel ➤ 🔧 Analytical Reset.
11. Select the element to reset the selected structural element analytical model back to its original shape or location, relative to its corresponding physical model.
12. Optionally, If you are currently editing the analytical model, select the element and click Modify | <Element> tab ➤ Analytical Model Tools panel ➤ 🔧 Analytical Reset.

The selected structural element analytical model is back to its original shape or location, relative to its corresponding physical model.
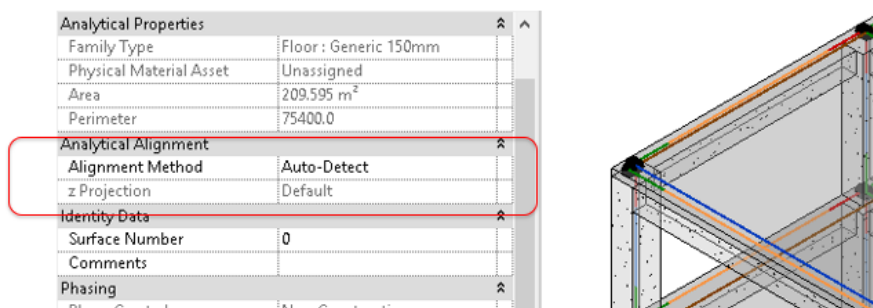

The Analytical Alignment parameter is back to Auto-Detect

Repeat the steps for other elements.

Maintain analytical model connectivity

To investigate the analytical model consistency, Revit provides tools in the early stages of design about the connectivity and stability of the structure. This gives engineers greater insight into their designs prior to submitting them for complete analysis.
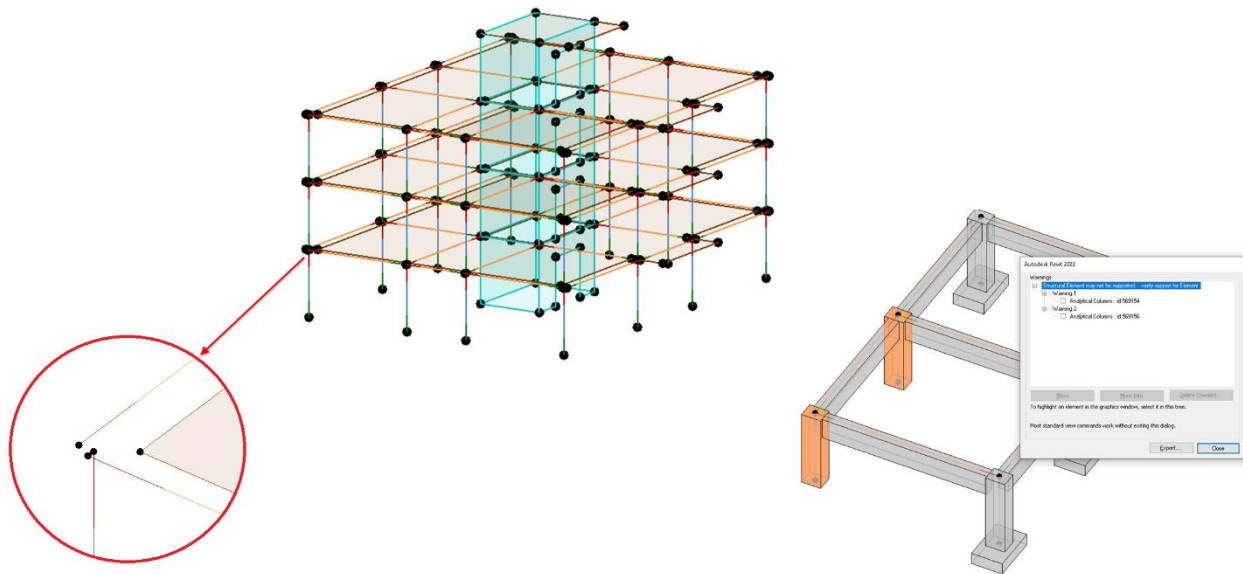

Analytical Node – Connection Status parameter

A read-only parameter that displays the connection status of an analytical node.
- o Connected - Auto-detect (when connected automatically)
- o Connected - Linear (when connected to a column or beam)
- o Connected - Surface (when connected to a slab)
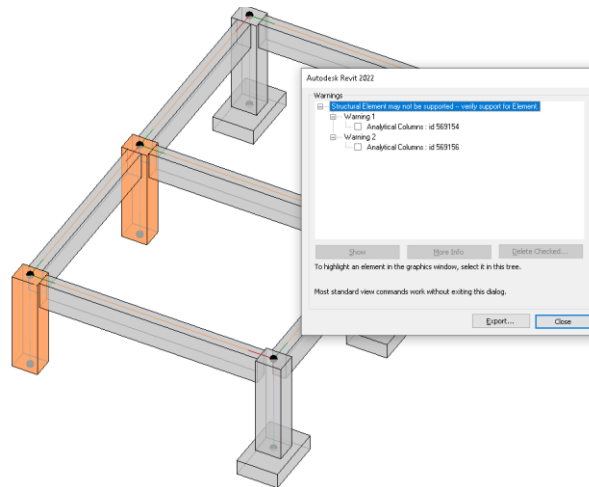- o Unconnected.

Can be used with filters and schedules to identify the unconnected nodes.
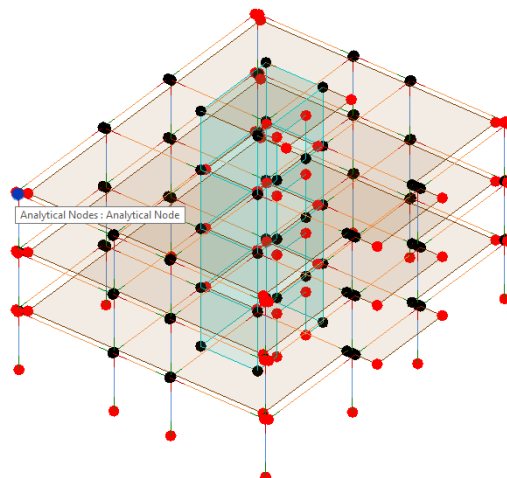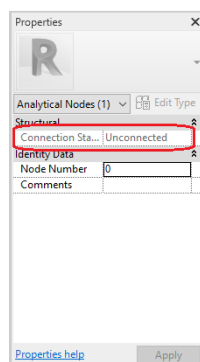
Member Supports

Is an automatic check provided by Revit.

Provides a warning when a member is not supported during model creation or modification.

It is not recommended to enable these setting in the early stages of a project. The number of elements unsupported during model creation is significant.

Analytical Model Adjustments

Auto-Detect Adjustment

Automatic adjustment is performed on a structural element, in relation to a neighboring structural element.

Revit can automatically adjust the analytical model for beams, braces, structural columns, structural walls, structural floors, and foundation slabs so that they align more accurately. This behavior is based on the instance parameters of the elements and tolerance settings.

For auto-detection to take place, the analytical Adjustment Methods instance properties must be set to Auto-Detect for an element and its individual ends. This is the default justification method for all analytical structural elements.


ANALYTICAL COLUMN INSTANCE PARAMETER FOR TOP ANALYTICAL ASSIGNMENT

Auto-detect tolerances are specified on the Analytical Model Settings tab of the Structural Settings dialog. *(see Analytical Model Settings > Tolerances chapter)*

The auto-detect feature automatically adjusts the analytical model when creating the following structural elements within a project:
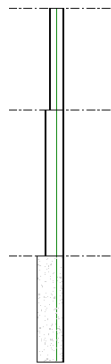
➢ *Beams*
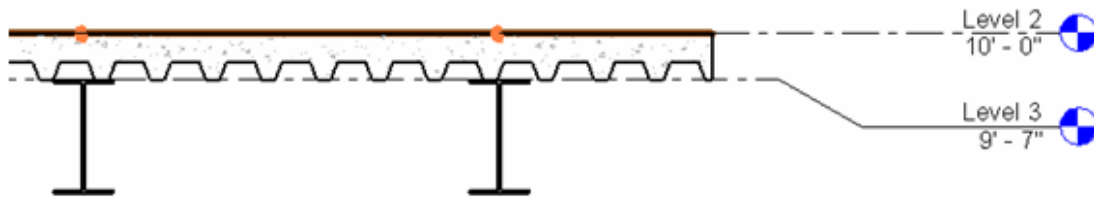
Analytical Auto-Detect – Vertical setting from the Structural Settings dialog ➤ Analytical Model Settings tab ➤ Tolerances define the distance between levels for which auto-detect adjust the analytical beam position.
The distance between elements is not considered.
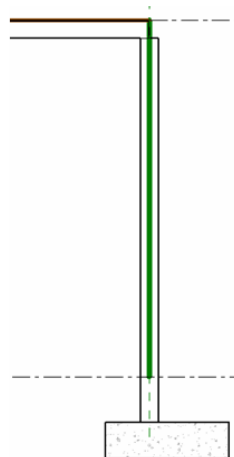
Walls

VERTICAL WALLS ALIGNMENT

The auto-detect feature aligns the vertical and horizontal analytical projection plane of walls, despite any variation in wall thicknesses or projection plane location.

💡 *Tips:*
    If walls are overlapping on the same level, the auto-detect tool will not adjust the analytical wall position.

➢ *Walls with Floors*

If a wall and floor are joined, the top or bottom plane of the wall's analytical model will coincide with the floor analytical model.

➤ *Floor-to-Floor (Wall-to-Wall)*
For elements of the same structural category (such as floor-to-floor or wall-to-wall) auto-detect is based on the order of creation, with the highest priority given to the element created first.

Projection Adjustment

Projection references for linear elements are defined as horizontal and vertical in relation to the local beam coordinate system.

Horizontal plane (y-direction) projection references include grids, sides and center of a beam.
Vertical plane (z-direction) projection references include levels, top of beam, middle of beam and bottom of beam.

Named reference planes are included in the horizontal and vertical projections where appropriate.

All sloped planes are included in each projection list. If both projection planes refer to a sloped reference plane the projection point is perpendicular to the sloped plane passing through the location line.

➤ *Horizontal Projection*
Linear analytical models can project horizontally to a specific reference plane or grid.
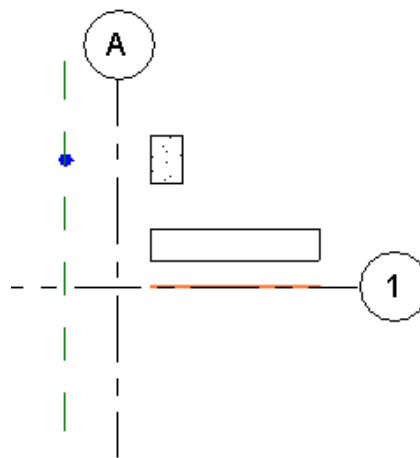
ANALYTICAL COLUMN ALIGNED TO A REFERENCE PLANE
ANALYTICAL WALL ALIGNED TO A GRID

➤ *Vertical Projection*
Top and bottom vertical projection planes for walls and columns can be adjusted to the analytical projection of a structural floor.

Manual Adjustment

Some structural configurations are not suitable for direct integration with analysis and design software. Adaptive adjustment is required before a structural model is input into the analysis and design software.
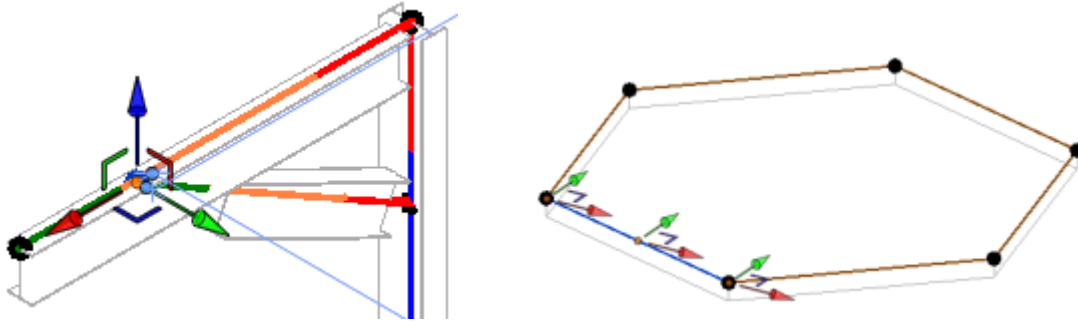

Use the Analytical Adjust tool to prepare the analytical model for various analysis applications.

1. Click Analyze tab ➤ Analytical Model Tools panel ➤ Analytical Adjust to manually adjust the analytical model.
2. In the drawing area, move and adjust analytical nodes and edges by snapping them onto analytical model geometry, nodes, grids and reference planes.
3. Click Analyze tab ➤ Edit Analytical Model panel ➤ ✔ (Finish) to exit the analytical edit mode and save changes to the analytical model or ✖ (Cancel) to exit without saving.
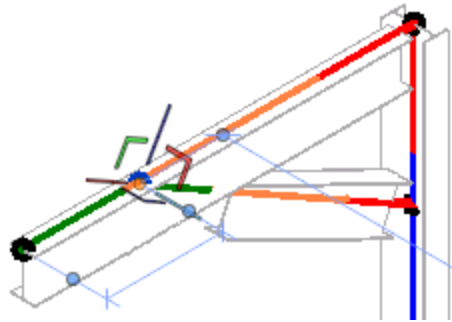
If the analytical model is modified, its Analytical Alignment parameters will specify Manually Adjusted.
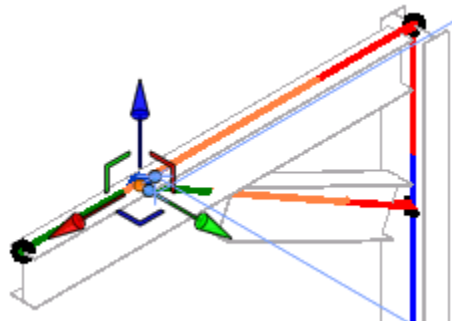
➤ *Linear Elements*

Linear analytical model elements can be manipulated by the analytical nodes at both ends.
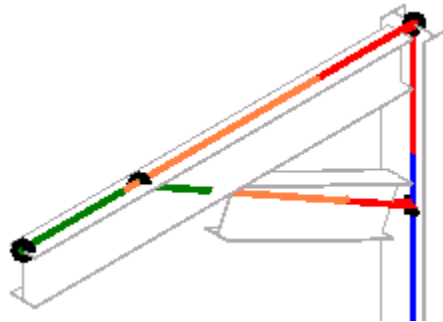
Click a node to reveal a 3D control to move the model end in the local coordinate system.

Press Spacebar to flip the control to the global coordinate system.
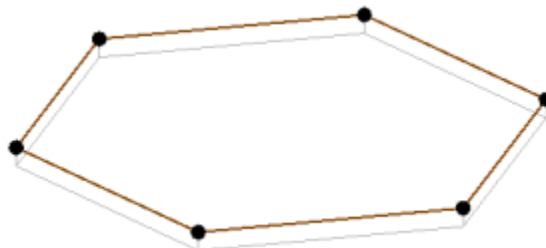

Move and adjust analytical nodes by snapping them onto analytical model geometry.

If a node is placed where it cannot be hosted, an offset will be maintained from the element's location line.
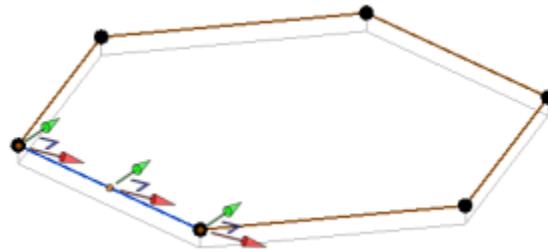
➤ *Surface Elements*
Surface analytical model elements can be directly manipulated by their nodes and edges in the analytical model plane.


Click a node to reveal its 2D controls. Drag the node as needed.
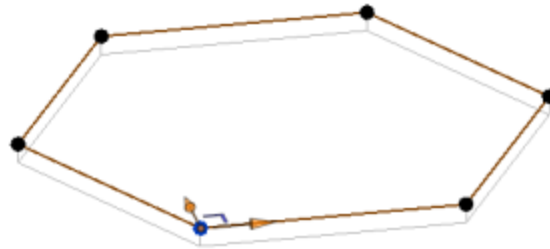
Tab select an edge to reveal its 2D controls. Drag the edge as needed.

Press Spacebar to flip the 2D controls from the local to the global coordinate system. The following 3 coordinate systems are available: local with respect to the edge adjoining the node, local with respect to the other edge adjoining the node and global.
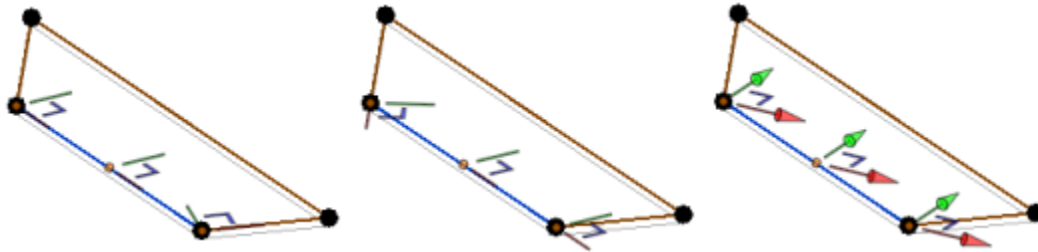
Reposition the model shape using the Move tool or click and drag an edge to move the model.
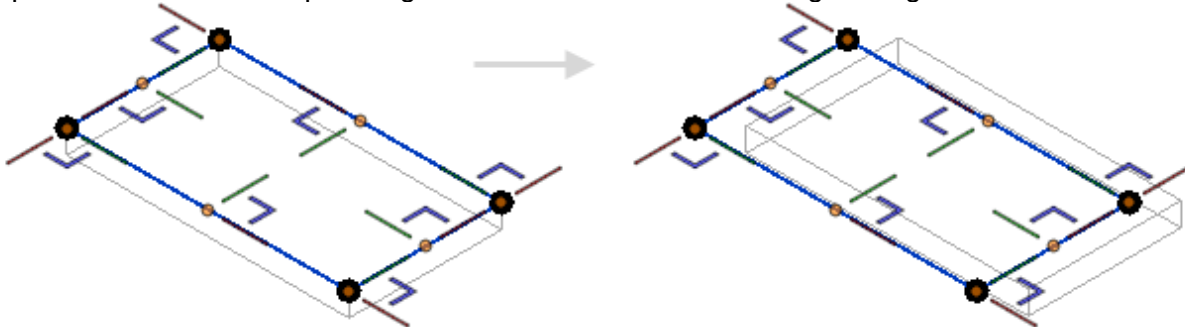
Analytical Wall Vertical Edges Adjustment

Analytical Wall Adjustment tool is used to adjust the analytical wall to:
- Another analytical wall
- Analytical column
- Analytical beam
- Analytical node of an analytical floor or an analytical foundation slab.

1. Click Analyze tab ➤ Analytical Model Tools panel ➤ 📊 Analytical Adjust.
2. Click Edit Analytical Model panel ➤ 🏢 Wall Adjustment.
Select an end edge of the analytical wall to adjust as the source analytical element. You can select only wall vertical end edges as the source analytical element.
Select the target analytical element. Elements that you can select as target analytical elements highlight when you place the cursor over them.
3. Click Select panel ➤ 🔧 Modify to accept changes and finish the Wall Adjustment tool. You are still in the Analytical Edit mode. You can continue adjusting analytical elements.
4. Click ✓ Finish Edit Mode to save changes and exit the Analytical Edit mode. To exit the Analytical Edit mode without saving changes, click ✗ Cancel.

(see also Revit Help documentation: http://help.autodesk.com/view/RVT/2020/ENU/?guid=GUID-0FB45CBB-2808-45B5-9D2C-2626BB19E31B*)*

**Exercise 2.1 - Identify Analytical Model Connectivity Issues**
In this exercise, we'll learn how to identify analytical representation connectivity issues in our projects.

Environment

1. Open Model_001_StartPoint.rvt
2. Open Analytical Model 3D view
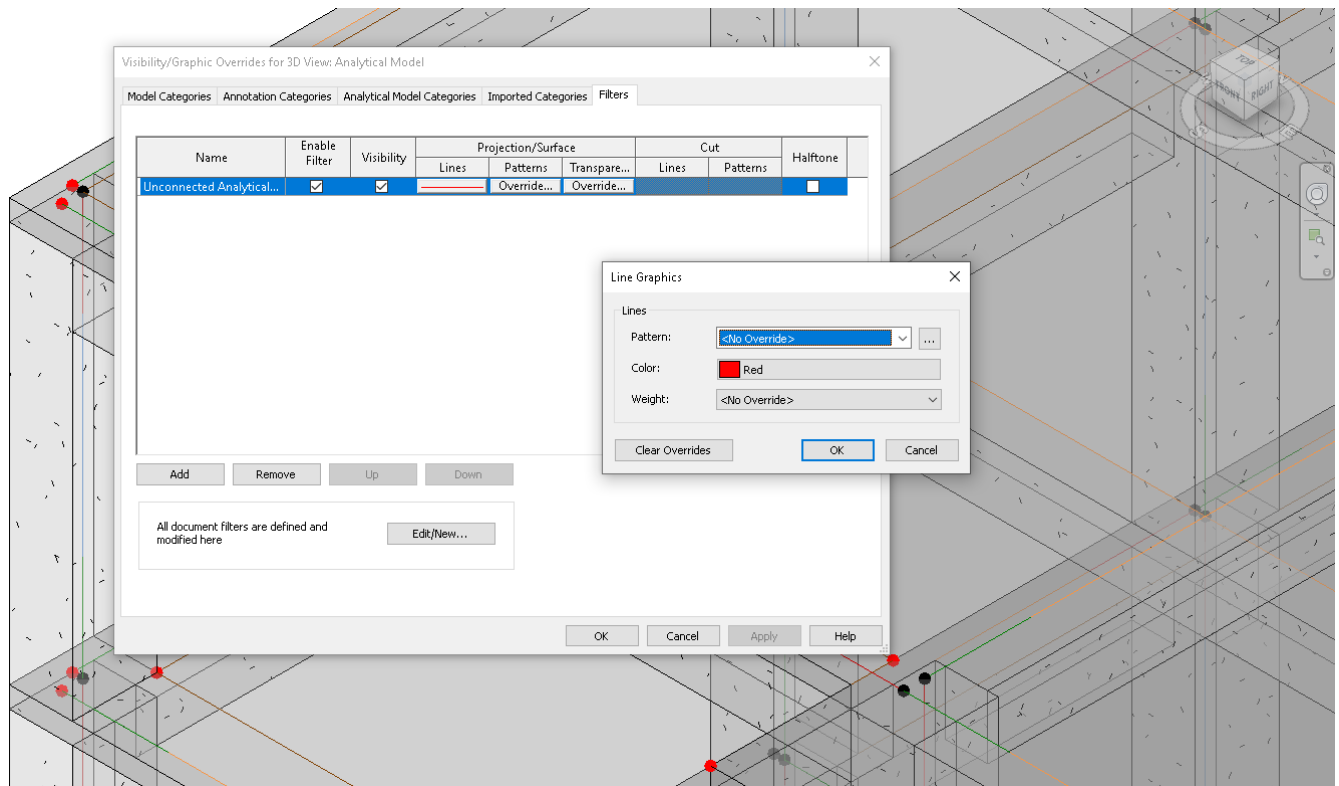3. Enable Analytical Model Visibility

Identify Unconnected Nodes

4. Open Visibility/Graphics Overrides dialog
5. Go to Filters tab
6. Click Add button
7. Select the Unconnected Analytical Nodes predefined filter
8. OK
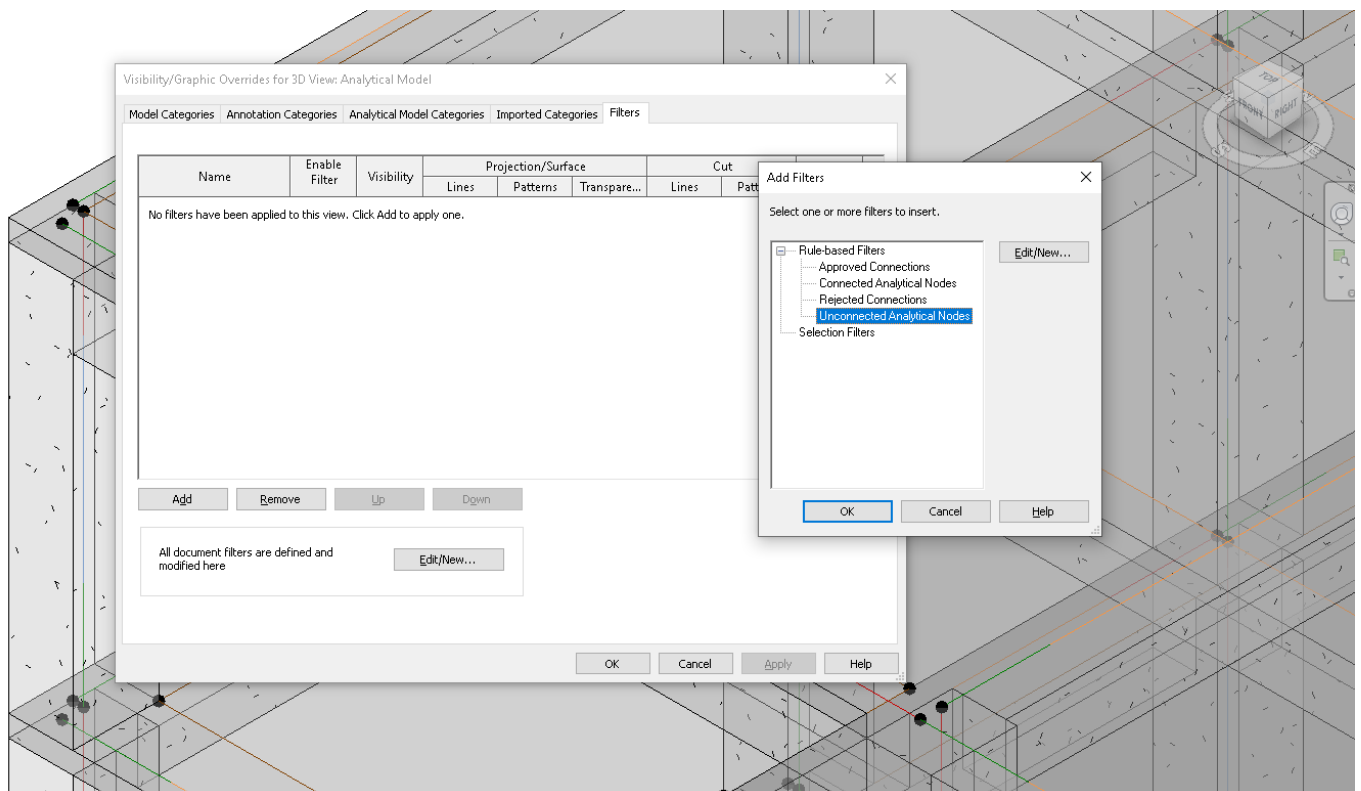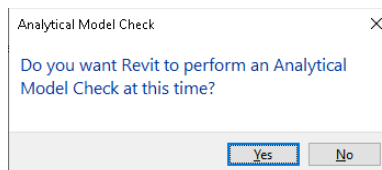

Identify Unconnected Nodes

9. Set the Lines color for the Unconnected Analytical Nodes filter to Red
10. Apply changes

All the unconnected notes are displayed in red.

Identify Unsupported Elements

11. Go to Manage tab > Settings panel > open Structural Settings dialog
12. Go to Analytical Model Settings tab > Automatic Checks area > Check Member Supports option
13. OK

A warning message will ask you to perform an analytical check for the entire model

14. Yes
15. Warnings are issued for all the walls and columns on the first level
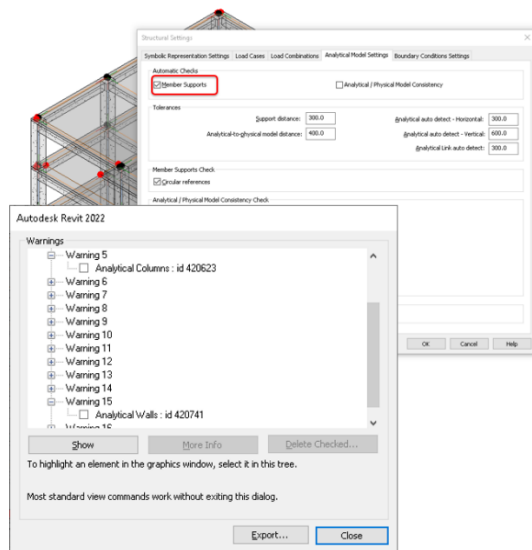
**Exercise 2.2 - Manually Analytical Model Adjustment**

In this exercise, we'll learn how to manually adjust the analytical representation when elements are unconnected.

Environment

1. Open Model_001_StartPoint.rvt
2. Open Analytical Model 3D view
3. Enable Analytical Model Visibility

Open Analytical Adjust Edit Mode

4. Click Analyze tab > Analytical Model Tools panel > Analytical Adjust to manually adjust the analytical model.
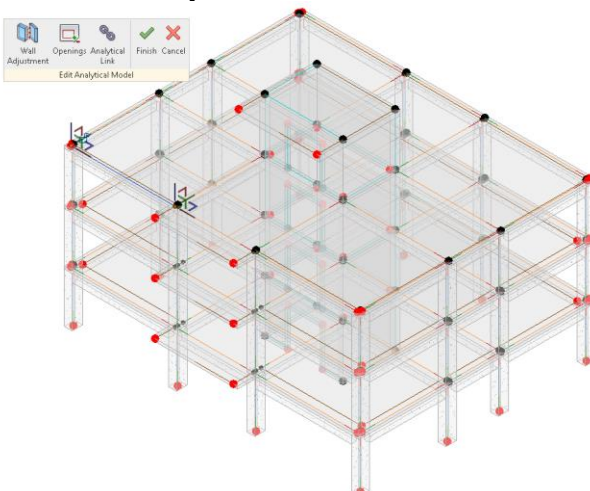
Manually Adjust the Analytical Elements

5. In the drawing area, move and adjust analytical nodes and edges by snapping them onto analytical model geometry, nodes, grids and reference planes.
6. Click Analyze tab > Edit Analytical Model panel >   Finish to exit the analytical edit mode and save changes to the analytical model or Cancel to exit without saving.
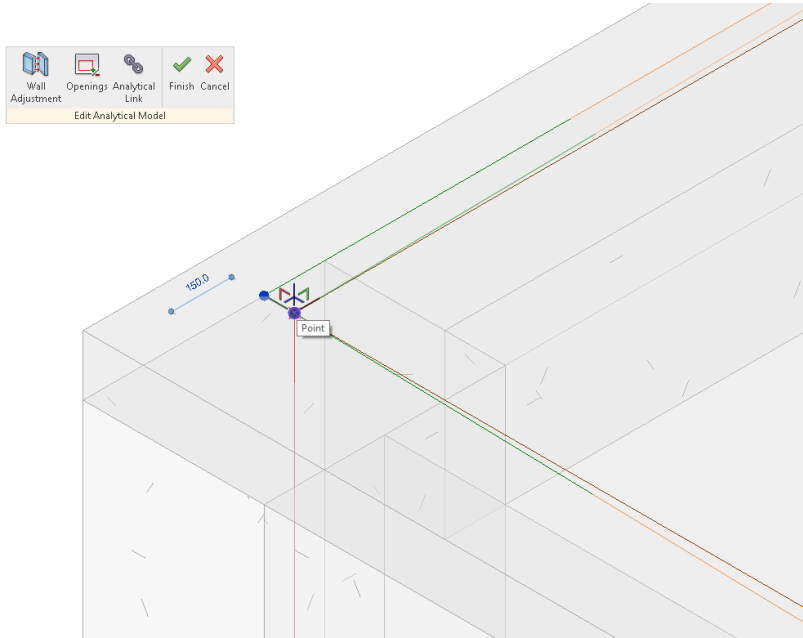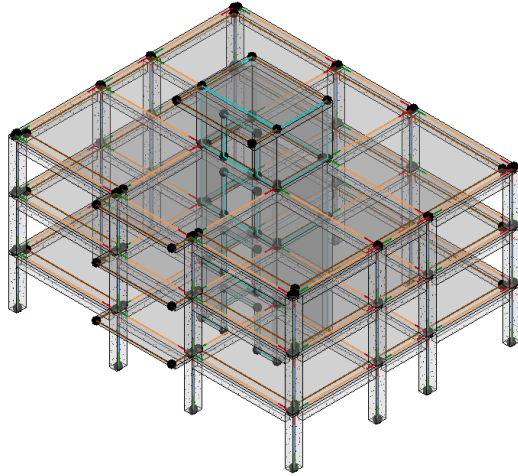
Exercise 3: Auto-detect Adjustments

In this exercise, we'll learn how to get benefit of auto-detect adjustment tool while managing the physical-analytical relationship .

Environment

1. Open Model_001_StartPoint.rvt
2. Open Analytical Model 3D view
3. Enable Analytical Model Visibility

Most of the analytical beam, columns and floors are not connected.
The goal of this exercise is to connect them using auto-detect adjustment tool.

Check the Member Supports

4. Go to Manage tab > Setting panel > Structural Settings dialog
5. Analytical Model Setting tab
6. Make sure that in Tolerances area the Analytical auto detect – Horizontal is set to 300mm

Analytical Columns Alignment Method

7. Go to Analyze tab > Analytical Model Tools panel > Adjust Revit will enter in Analytical Adjust mode
8. Select all the Analytical Columns
9. Go to Properties palette > Analytical Alignment parameters group >
   - Switch the Top/Base Alignment Method to Auto-Detect
   - Switch the Top/Base Extension Method to Auto-Detect
10. Apply the changes
11. The analytical columns position are now controlled by the auto-adjust tool

Analytical Alignment	
Top Alignment Method	Auto-Detect
Top y Projection	Location Line
Top z Projection	Location Line
Top Extension Method	Auto-Detect
Top x Projection	Top Level Reference
Base Alignment Method	Auto-Detect
Base y Projection	Location Line
Base z Projection	Location Line
Base Extension Method	Auto-Detect
Base x Projection	Base Level Reference
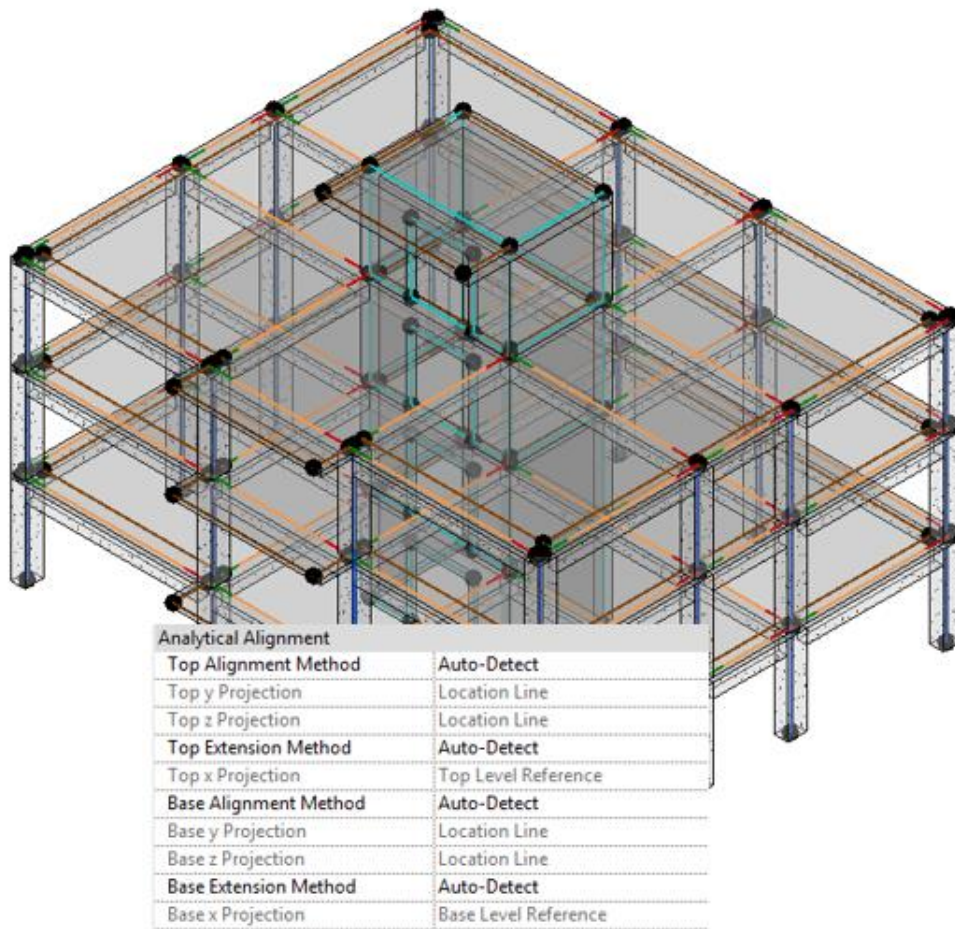
12. Select all the Analytical beams
13. Go to Properties palette > Analytical Alignment parameters group > Switch the Start/End Alignment Method to Auto-Detect
14. Apply the changes

The analytical beams position are now controlled by the auto-adjust tool. The Auto-Detect tool identifies that an analytical column is less than 300mm away from the analytical beams. It adjusts the analytical beam position, so they join the analytical columns.

Analytical Alignment	
Start Alignment Method	Auto-Detect
Start y Projection	Location Line
Start z Projection	Location Line
End Alignment Method	Auto-Detect
End y Projection	Location Line
End z Projection	Location Line
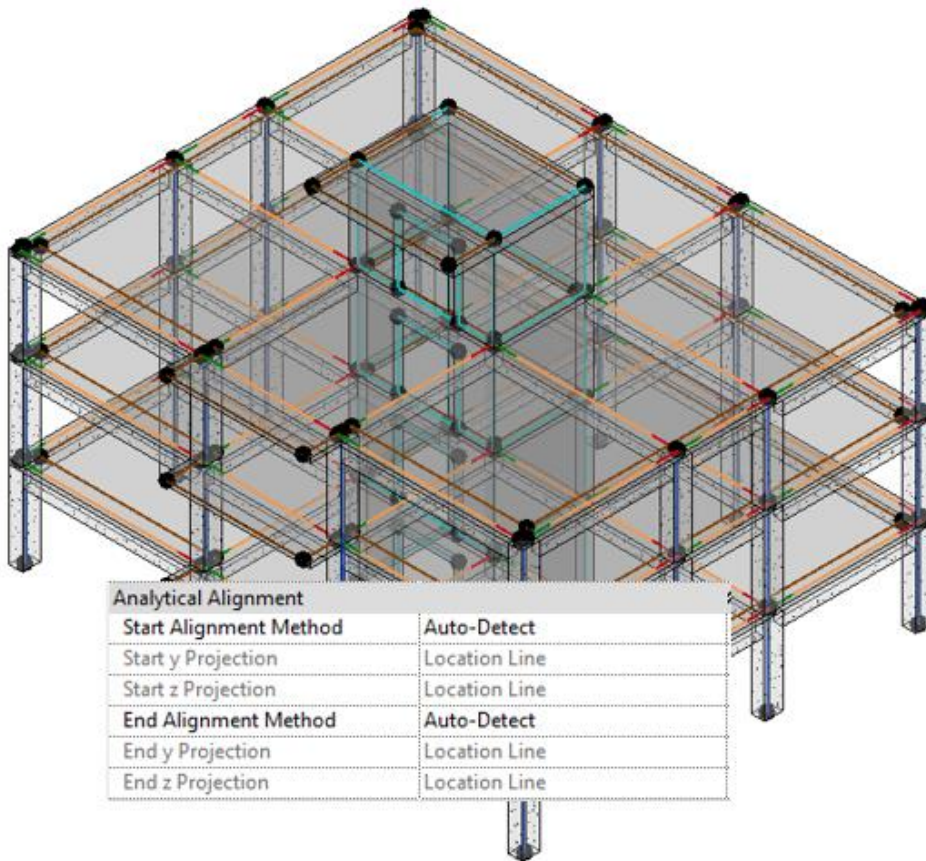
Reset Analytical Floor Position

15. Select all the Analytical floors
16. Go to to Analyze tab > Analytical Model Tools panel > Reset Analytical Model
17. Select the top analytical floor

The analytical floor position is now based on the analytical beams placed on its contour.

Repeat the operation for all the analytical floors.
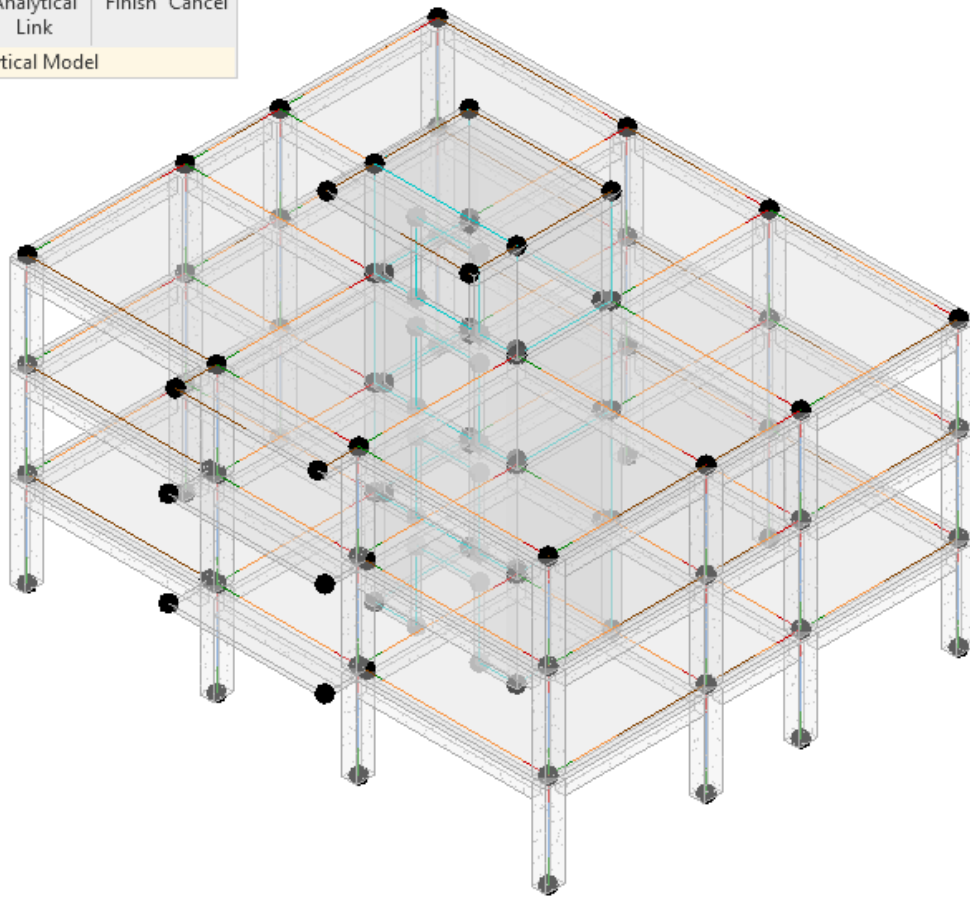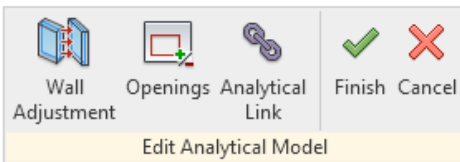
19. Finish the analytical editing.

The auto-detect tools adjusted the analytical representation position and now controls the physical-analytical relationship.

Dynamo in physical-analytical relationship

Exercise 4.1- Check the Differences Between Physical and Analytical Representation for Linear Elements

In this exercise, we'll learn how to easily identify the differences between the position of the physical elements and their analytical counterparts.

Dynamo Package used: Physical-Analytical Offset
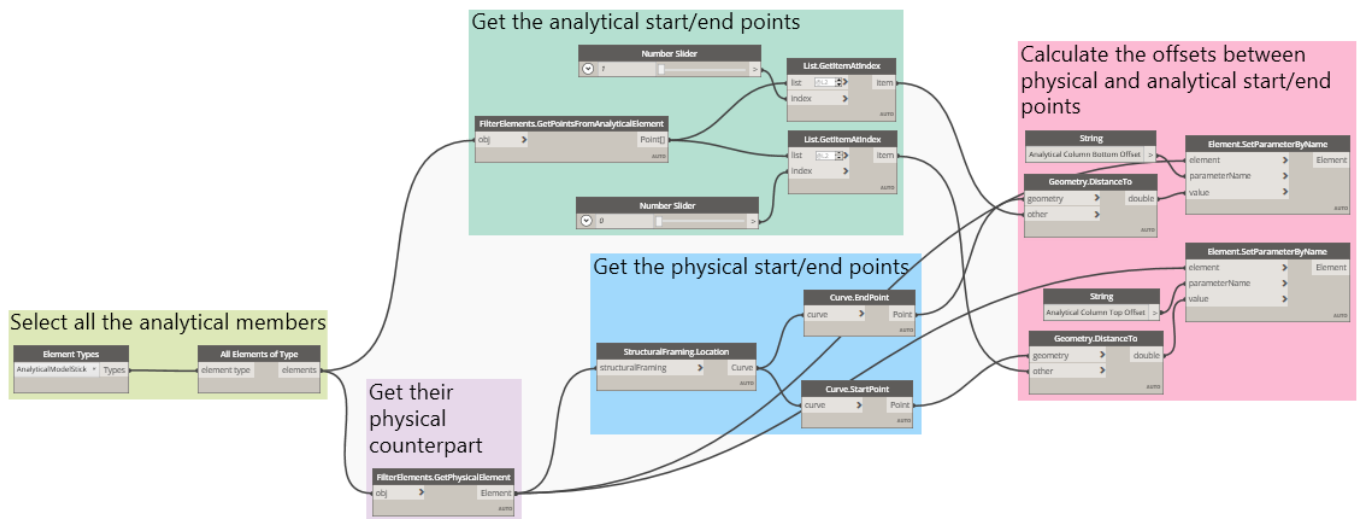

Environment

1. Open Model_001_StartPoint.rvt
2. Open Analytical Model 3D view
3. Enable Analytical Model Visibility
4. Select all columns
- From Properties palette > Constraints group of parameters > change Column Style to any Slanted option (this issue is needed for the script to run)

Most of the analytical beam, columns and floors are not connected.

The goal of this exercise is to identify the offsets between linear physical elements and their analytical counterparts.

5. For each Level create a copy 300mm bellow it
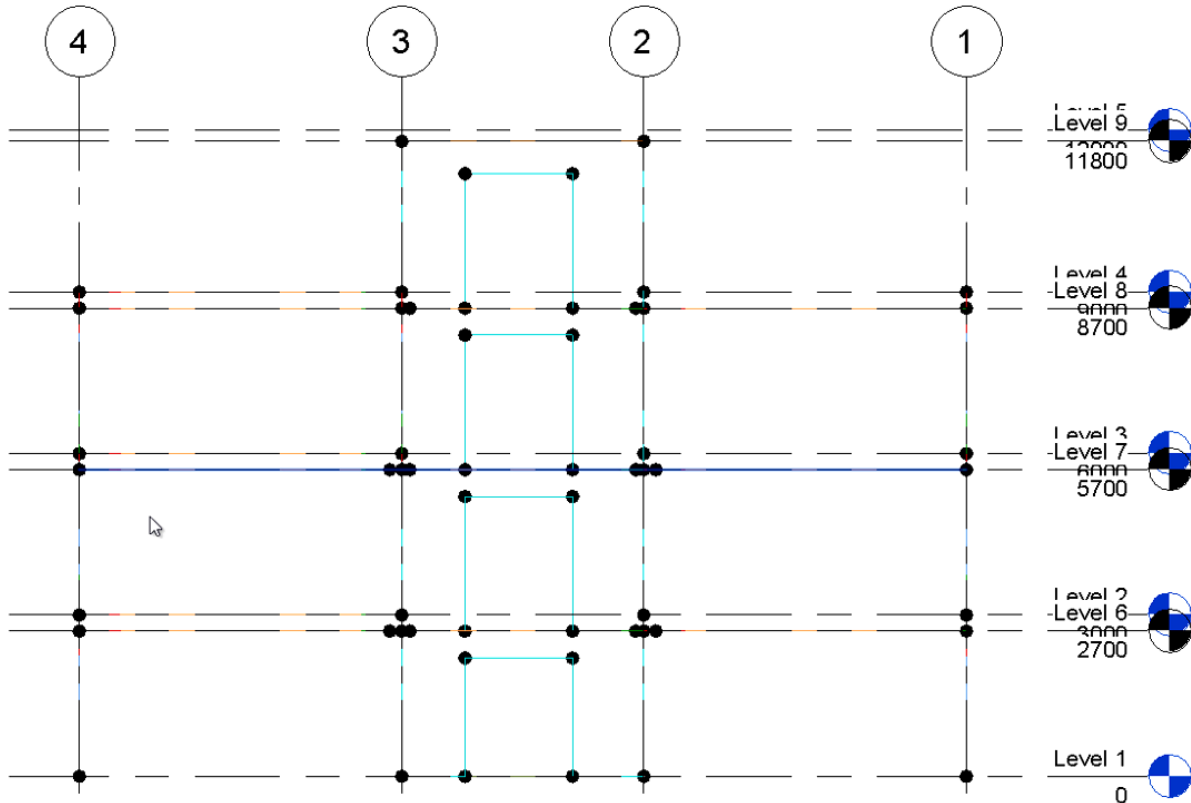
6. Adjust the Analytical Floors position using Projection settings on dedicated analytical levels
   - Select each analytical floor
   - Go to properties palette > Analytical Alignment group of parameters
   - Change Alignment method to Projection
   - Select the correspondent analytical level for each analytical floor

Define the support parameters for the offset information

7. Setup specific parameters to mark the offset between the physical elements and their analytical counterparts.
- Go To Manage tab > Settings panel > Shared Parameters
- Create two shared parameters of type length – Analytical Column Bottom Offset and Analytical Column Top Offset
- Go to Manage tab > Setting panel > Project Parameters
- Click on Add button to add a new project parameter
- Choose Shared Parameter option > Select Analytical Column Bottom Offset
- Group parameter under Analytical Alignment group of parameters
- Check Instance option (we need this parameter to be instance based one)
- Check Analytical Beam and Analytical Column categories
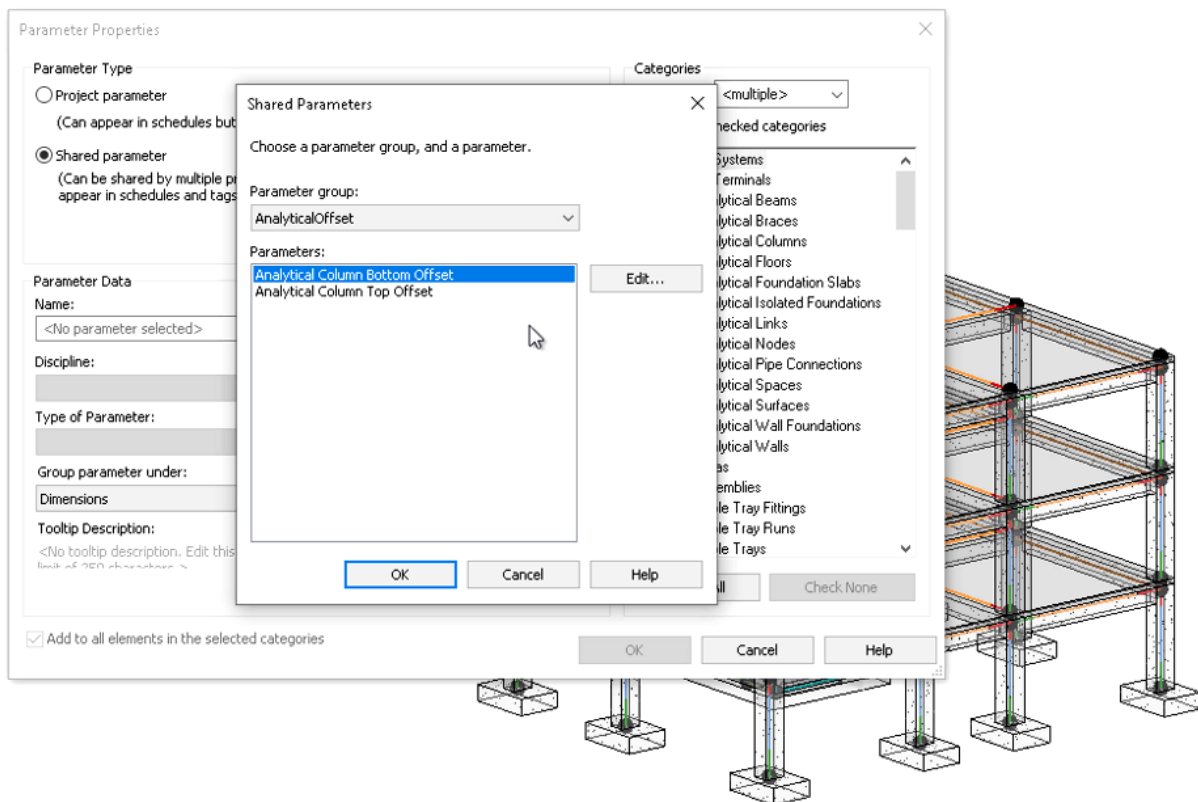
Create support for offset observation

7. Go to View tab > Create panel > create Schedule/Quantities
8. Select Analytical Beam category
9. OK
10. Add Analytical Column Bottom Offset and Analytical Column Top Offset parameters for this schedule
11. OK

Calculate physical-analytical offset

12. Run Linear Physical Analytical Offset Dynamo script
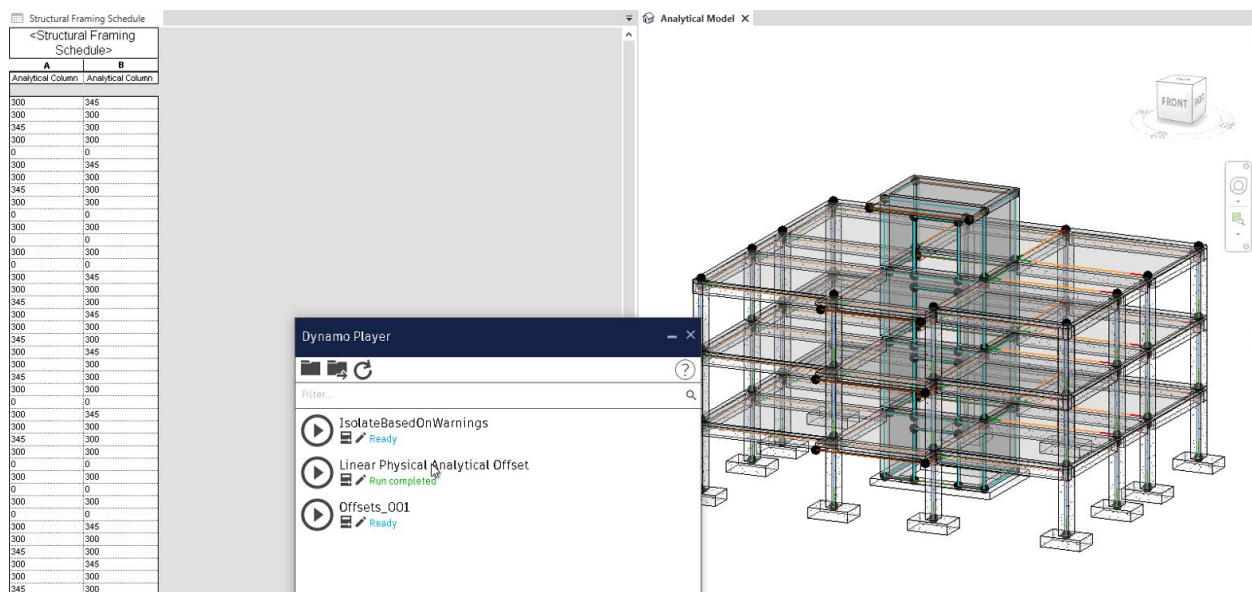
Analyze the results

The script calculates the offset between physical and analytical representation for linear elements for each end.

In this regard, a tolerance can be set in the form of a schedule filter. This will allow a quick filter of the cases that exceed an acceptable value.

The script run on-demand. The parameters are not updated automatically.

Exercise 4.2 - Maintain analytical model connectivity using Dynamo

In this exercise, we'll learn how to adjust the analytical model using Dynamo with parameterization, definition of logical assumptions, priorities and customizable scripting.

Dynamo Package used: Analytical Modeling 2021 Dynamo Package

Environment

1. Open Model_001_StartPoint.rvt
2. Open Analytical Model 3D view
3. Enable Analytical Model Visibility
4. Open Dynamo Player
5. Load Adjust Elements Between Categories Dynamo script

Most of the analytical beam, columns and floors are not connected.

The goal of this exercise is to adjust the analytical model using Dynamo.
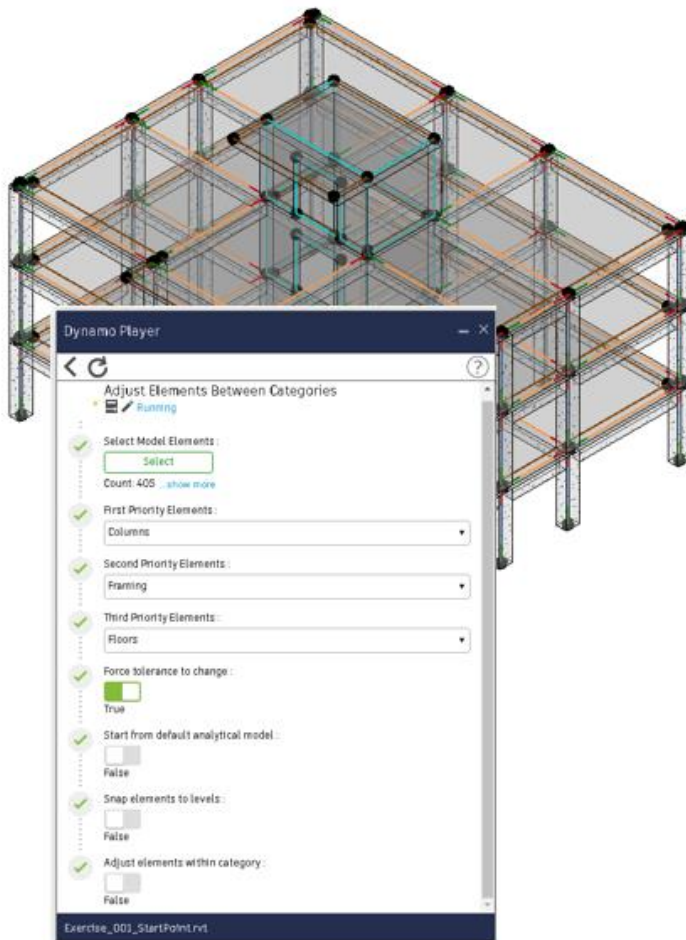
Setup script's parameters based on the project needs

6. Select the entire model
7. We'll consider Columns our First Priority elements. It is mostly a rectangular framed structure. The columns are in general position based on the grid system. From these considerents, we'll consider these elements as our "top" priority ones.
8. Select Framing as Second Priority Elements
9. Select Floors as Third Priority Elements.
10. We'll use a custom tolerance of 300mm to filter the elements based on the acceptable distance between node. So, check Force Tolerance to Change
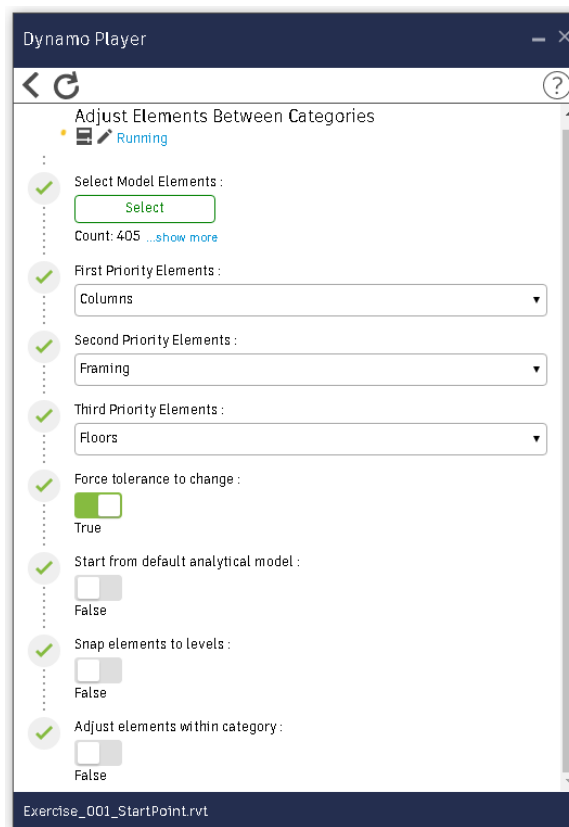
Adjust the analytical model using Dynamo with parameterization

Run the script.
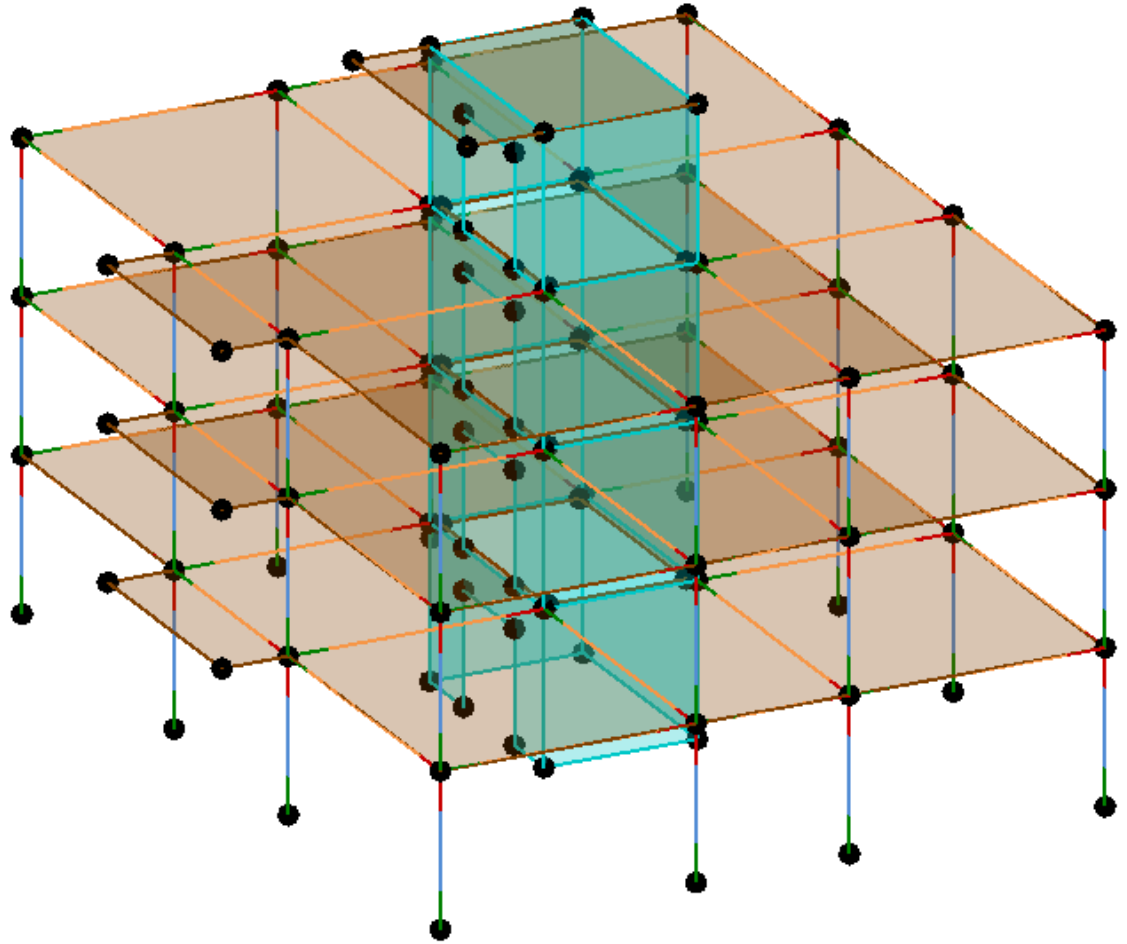
The analytical elements of type column, beam and floors were analyzed and their position was adjusted within the defined tolerance, in the order specified in the script settings – the beams are adjusted based on the column position and the floors based on the beam position.

For all the analytical elements, the analytical alignment method for each end/edge is now Manually Adjusted.

Conclusions

Managing the relationship between physical and analytical representation in a Revit BIM model can be tricky as each project has its own particularities and each collaboration in BIM environement has its specific workflows.

In these exercises we've learned some basic workflows that allow engineers to check the physical-analytical correspondence by identifying its counterpart and how the analytical representation alignement is defined.

Also, we've learned how to identify the analytical model connection errors and how to manually address each situation.

We've seen also how to let Auto-detect tool to manage this relationship. In general it does a pretty good job. Where it cannot deal with a situation, manual adjustment can easily take its place.

In the end we've learned how we can benefit of Dynamo to automate two workflows –the physical-analytical offset check and adjust the analytical model using Dynamo with parameterization.

All these will not offer a complete physical-analytical representations management solution but will help you start coordinating these two representation, using Revit built-in tools and/or Dynamo scripting.