ES17637-L

Integrating Structural Design and Analysis: The Basics of a Revit-Robot Structural Analysis Workflow

Aaron M. Vorwerk, AIA, NCARB, EIT, LEED AP BD+C
Autodesk, Inc.

Learning Objectives

- Discover the relationship between the physical and analytical models in Revit
- Learn how to use the Structural Analysis for Revit feature for quick structural checks
- Learn how to send models from Revit to Robot Structural Analysis and back for full-featured analysis
- Learn how to perform code group-based design for steel members in Robot Structural Analysis

Description

In this hands-on lab, we will explore the simple, powerful, round-trip workflow between Revit 2017 software and Robot Structural Analysis Professional 2017 software. We'll start with a simple structural model of a building in Revit software, and we'll develop an understanding of the analytical model that Revit software builds concurrently with the creation of structural geometry. We will then explore the Structural Analysis for Revit feature, which enables static and gravity analyses to be performed on the cloud directly from Revit software. Next, we'll push that model into Robot Structural Analysis Professional software to perform a basic analysis and code group-based design. Finally, we'll push the updated geometry from Robot Structural Analysis Professional software back to Revit software and observe that the model has been updated. This session features Robot Structural Analysis Professional and Revit Structure.

Note: Please refer to the accompanying exercise guide to follow along during hands-on activities.

Your AU Expert

Aaron Vorwerk is a registered architect, civil/structural engineer-in-training, LEED accredited professional, and AEC industry technology evangelist. A senior technical sales specialist with Autodesk, Inc., Aaron influences customer BIM workflow adoption and strategy as a trusted advisor and serves as a lecturer, panelist, and author on BIM-related topics. Vorwerk holds graduate degrees in architecture and engineering (MArch, MSCE, BSCE) and has acquired widespread experience in architecture, engineering, and construction over the past 20 years, including leading Revit software transition efforts in two design firms.
Structural Tools and Workflows

There are literally hundreds of product offerings in the Autodesk portfolio, dozens of which are applicable to the AEC industry to some degree. With that in mind, let’s start by sorting out the most appropriate tools for typical structural engineering workflows.

The Autodesk Structural Toolbox

A general representation of Autodesk tools that might be used in structural workflows (i.e. building and plant/industrial workflows, specifically) is shown in Fig. 1.

![Figure 1: Autodesk tools by phase for structural engineering and fabrication](image)

To be clear, the mix of tools employed on every project will vary. Not all of these tools will be used on every project; conversely, Autodesk offers products not listed here capable of providing additional design, analysis, and delivery capabilities if needed.

But for typical engineering projects, and Autodesk-centric workflow will begin with one of two products: Revit (broadly used for buildings and civil structures) or Advance Steel (commonly used for plant/industrial steel structures). Those two products offer bidirectional synchronization, so they’re not mutually exclusive either.

A third tool that might be paired with Revit or Advance Steel on the front end of the work process is Dynamo, an open source visual programming language developed by Autodesk and used to enable powerful computational design and the automation of routine tasks (without requiring coding knowledge) in Autodesk and third-party tools. Dynamo runs on top of both Revit and Advance Steel; read more at [http://dynamobim.org/](http://dynamobim.org/).

As a project moves from early design into analysis, two tools are most commonly used: Structural Analysis for Revit and Robot Structural Analysis Professional. Robot Structural Analysis Professional (aka RSA or Robot) is a powerful general-purpose finite element analysis (FEA) platform with full bidirectional interoperability with Revit; we’ll dive into that discussion in...
much more detail later. It is also possible to exchange information directly between Advance Steel and RSA. Structural Analysis for Revit (SAR), by comparison, is a cloud-based tool that uses a portion of RSA’s engine to perform rapid static and gravity analyses directly from Revit, with results viewable in a browser or in the Revit environment. Read more on Structural Analysis for Revit at http://www.autodesk.com/products/structural-analysis-revit/overview.

Moving further into the structural workflow, coordination tools begin to play a larger role. These may include the BIM 360 platform (see http://www.autodesk.com/products/bim-360/overview) and very likely Navisworks (http://www.autodesk.com/products/navisworks/overview).

Steel Design and Detailing Workflow

While model coordination typically becomes a focus fairly quickly, detailing (e.g. steel connections, concrete reinforcement) is also happening earlier in the process. Revit is a very broad platform these days, enabling users to take advantage of modules such as Steel Connections for Revit. This add-in for Autodesk subscribers yields the capability to place steel connections very quickly in Revit, including AISC code-checking. And for full-fledged steel detailing with automated, fully-annotated shop drawings, Revit models can be sent directly into (and/or synchronized with) Advance Steel. See Fig. 3.
Concrete Design and Detailing Workflow

When it comes to concrete, Revit is also capable of supporting design-to-detailing workflows. Revit is able to model complex concrete and reinforcement shapes, using a broad set of standard modeling tools, advanced tools such as adaptive component families, and
computational design via Dynamo. See Fig. 5 for a diagram of this workflow. Fig. 6 provides an example of the first precast concrete network-arch bridge in the world…modeled in Revit.

![Concrete Design and Detailing Workflow](image)

**Figure 5: Concrete design and detailing workflow**

To assist with automation of reinforcement detailing and shop drawing production, third-party add-ins such as SOFiSTiK are also available; see more details on the Autodesk App Store: [https://apps.autodesk.com/RVT/en/Detail/Index?id=354751925106132518&appLang=en&os=Win64](https://apps.autodesk.com/RVT/en/Detail/Index?id=354751925106132518&appLang=en&os=Win64).

As projects continue to move downstream in the process, information captured during structural design, analysis, and detailing phases can be utilized and supplemented during fabrication and installation using **BIM 360 Field**. This information, together with commissioning data, can be

![West 7th Street Bridge, Fort Worth, TX](image)

**Figure 6: West 7th Street Bridge, Fort Worth, TX; images courtesy Sundt Construction**
populated at the click of a button into **Building Ops** to support owner warranty, operations and maintenance activities from the date of delivery.

The focus of this session, of course, is on the front end of the workflow. In the sections to come, we will be exploring the interoperability between Revit, Structural Analysis for Revit, and Robot Structural Analysis Professional.
Autodesk Revit 2017

Revit continues to see significant development in many areas, including structural design-to-detailing workflows. In this section, we’ll cover some of the more recent additions to the product.

New Features and Enhancements

Between Revit 2016 R2, the initial release of Revit 2017, and the recent release of Revit 2017.1, a host of improvements in functionality have been added—including substantial additions to the structural toolset. See Fig. 7 for an overview list:

**Architecture/platform enhancements**
- Depth cueing
- Improved railing hosts and UI usability
- Autodesk® FormIt® 360 Converter
- Autodesk® Insight 360 integration
- Global parameter enhancements
- Improved software performance
- Autodesk® Raytracer rendering engine
- Text Editor and layout engine
- Calculate in annotation tag
- Dynamo updates and plug-in
- Tangency locks
- Schedule improvements
- LED light fixtures content
- Sketch on level
- Stairs parameters tooltips
- Import 3D shapes (Rhino®/SAT files)
- Work in a perspective view
- Corruption data loss prevention
- High-resolution monitor support
- Autodesk® Collaboration for Revit®
- Sync progress notification

<table>
<thead>
<tr>
<th>Structural engineering enhancements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforcement connectors</td>
</tr>
<tr>
<td>Variable rebar distribution</td>
</tr>
<tr>
<td>Graphical rebar constraints</td>
</tr>
<tr>
<td>Bent fabric sheets reinforcement</td>
</tr>
<tr>
<td>Structural connectivity</td>
</tr>
<tr>
<td>Autodesk® Steel Connections for Revit®</td>
</tr>
<tr>
<td>Split columns and framing elements</td>
</tr>
<tr>
<td>New Steel profiles catalogues</td>
</tr>
<tr>
<td>Improved structural foundations</td>
</tr>
<tr>
<td>AISC connection code checking for</td>
</tr>
<tr>
<td>steel connections</td>
</tr>
<tr>
<td>New steel shapes content</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical, electrical, and plumbing (MEP) design &amp; fabrication enhancements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design to Fabrication</td>
</tr>
<tr>
<td>Optimize lengths</td>
</tr>
<tr>
<td>Short segment optimization</td>
</tr>
<tr>
<td>Route and Fill</td>
</tr>
<tr>
<td>Trim and Extend</td>
</tr>
<tr>
<td>Quick Connect</td>
</tr>
<tr>
<td>Change type</td>
</tr>
<tr>
<td>Slope control</td>
</tr>
<tr>
<td>Fabrication model documentation</td>
</tr>
<tr>
<td>Hanger improvements</td>
</tr>
<tr>
<td>Electrical apparent load calculation options</td>
</tr>
<tr>
<td>Design computation improvements</td>
</tr>
<tr>
<td>Scalability improvements</td>
</tr>
<tr>
<td>Resize connected parts</td>
</tr>
<tr>
<td>Change service</td>
</tr>
<tr>
<td>Exclude FAB parts from Autodesk tools</td>
</tr>
<tr>
<td>Add or modify a damper</td>
</tr>
<tr>
<td>Split fabrication elements</td>
</tr>
<tr>
<td>Hanger support rod enhancement</td>
</tr>
<tr>
<td>AWWA valves and pumps content</td>
</tr>
<tr>
<td>Space Naming tool integration</td>
</tr>
</tbody>
</table>

**Figure 7: Overview of Revit 2017 and 2017.1 new features and enhancements**

Let’s briefly explore the structural engineering enhancements highlighted above in more detail:

- **Reinforcement connectors** have been added; these elements are family-based and fully-customizable, and they interact with the rebar they are connected to, facilitating change management

- Revit now supports **variable rebar distributions**, enabling more accurate reinforcement modeling for non-standard concrete element shapes by fitting rebar for non-standard geometry with rebar sets that vary along inclined faces; these work with multi-rebar annotations, customizable numbering settings, and schedules

- Experience an improved **graphical rebar constraints management** workflow with new in-canvas tools that replace the Rebar Constraints dialog box; these allow rebar to be placed more precisely, snapping rebar to adjacent bars or constraining them to host faces

- When placing sheet reinforcement, **bent fabric sheets reinforcement** may be sketched to accommodate different shapes of concrete hosts; these can later be edited as expected

- **Structural connectivity** has been improved with the addition of generic structural connections; these may be placed during design to supply information and support an
approval workflow—including pictures and links—about the desired connection and its relationship to structural elements

- Autodesk® Steel Connections for Revit® has been introduced to provide access to a variety of parametric steel connections in Revit software, including a built-in steel connection design engine
- The Split Element tool now works to split columns and framing elements while respecting joins, justifications, and the location of hosted objects
- New Steel profiles catalogs for Australia, New Zealand, Germany, France, Poland, US, India, and Eurocode-based are now available.
- Revit 2017 offers improved structural foundations, as structural columns may be attached to isolated foundations and footings; this means that the column length will also respond to changes to the foundation level
- To ensure that structural connections from this application adhere to current standards, the AISC code checking for steel connections was updated to the 14th edition, and each calculation includes code references to highlight the chapters to which the verifications belong
- New steel shapes content for Japanese and Chinese standards are included, e.g. I-shapes, angles, pipes and channels

These enhancements are important, as they clearly show Autodesk is continuing to invest in structural design-to-detailing workflows in Revit.

The Analytical Model in Revit

Many Revit users do not realize (or simply ignore) the fact that Revit is always ‘taking its best guess’ at creating an analytical model when a user authors a physical model. Revit builds and maintains this analytical model at all times as a user continues to edit model geometry. See Fig. 8.

Figure 8: Physical and analytical models in Revit; model courtesy the Beck Group
This behavior is important to understand if we are to experience smooth integration when performing structural analysis of Revit models.

**Physical Model**

The physical model carries information about geometry (heights, lengths, positions, etc.) and materiality (which is important for analysis, as Revit materials contain information on strength and physical characteristics in addition to graphical data).

**Analytical Model**

An analytical model is a simplified 3D representation of the structural physical model. The analytical model consists of those structural components, geometry, material properties, and loads, that together form an engineering system. The analytical model supplies information about member connectivity/fixity and structural purpose (e.g. lateral force resisting member). It can also supply member connection forces IF the engineer has chosen to supply them.

Revit allows the user to independently adjust the analytical model if the automatically-generated version is inaccurate (e.g. at cantilevers or other unique structural conditions). Additionally, Revit enables the user to manually or automatically check to ensure that all members are supported and/or the analytical model remains consistent with the physical model. Settings defining supported elements and model consistency are user-customizable via the Structural Settings dialog (Fig. 9).

![Figure 9: Revit Structural Settings dialog](image)

Structural Analysis for Revit

Structural Analysis for Revit (SAR) enables Revit users to quickly and inexpensively perform cloud-based structural analyses directly from Revit. Results can be displayed and explored on the Autodesk® 360 Structural Analysis website (Fig. 10) and directly in Revit (Fig. 11).

![Image of Structural Analysis for Revit](image)

*Figure 10: Structural Analysis for Revit, as viewed in a browser*

To prepare Revit analytical models for analysis, the Structural Analysis Toolkit add-in must be installed, and the user must login with their Autodesk ID in their Revit session. After a model has been prepared, it may be submitted from Revit or from the Autodesk® 360 Structural Analysis website.
Behind the scenes, the Structural Analysis add-in uses the Autodesk® Robot™ Structural Analysis Professional engine. However, the cloud-based SAR has a limited feature set, enabling static and gravity analyses to be performed. Full-featured structural analyses are to be conducted in Robot Structural Analysis Professional.

Robot Structural Analysis Professional

Autodesk® Robot™ Structural Analysis Professional (RSA) finite element analysis software helps engineers more quickly perform simulation, analysis, and code-based design for any type of structure. Fig. 12 highlights some of the key features of this product.

**Collaboration**
- Supports efficient BIM workflows
- Interoperability with Revit, Inventor, etc.

**Speed**
- Auto-meshing (FEA)
- Robust nonlinear and dynamic algorithms
- Over 70 design codes

**Versatility**
- Flexible, open API
- Covers a broad range of structures
- Localized for global markets

*Figure 12: Key features of Robot Structural Analysis Professional 2017*

**RSA Overview**

Robot Structural Analysis Professional is a broad platform, supporting many industry, project, and customer types. See Fig. 13 for examples of structures studied in RSA. This section will provide an introduction to the use cases and capabilities of the product.

*Figure 13: Customer examples using Autodesk Robot Structural Analysis Professional*
Typical Customers
RSA is used by customers across multiple industries, such as:
- Structural engineers
- Multidisciplinary engineering teams
- Building product manufacturers and fabricators
- Large industrial machinery providers
- Oil and gas companies
- Mining firms

Design Versatility
RSA is capable of analyzing concrete, steel, and timber designs.

Modeling Flexibility
RSA handles many different types of structures, including:
- 2D and 3D frames and trusses
- Plates
- Shells
- Grillages
- Plane stress structures
- Plane deformation structures
- Axisymmetric structures
- Volumetric structures
- Composite beams

Advanced Analytical Capabilities
RSA offers significant computational power, including:
- Advanced finite element auto-meshing capabilities.
- A wide range of analysis capabilities, including linear and true nonlinear behavior of any structure:
  - Compression / tension elements
  - Cable elements
  - Non-linear constraints
  - Material plasticity
  - Non-linear hinges
  - 2nd-order effects (non-linear)
  - 3rd-order effects (P-delta)
- State of the art dynamic solvers handle almost any size of structure efficiently, taking full advantage of multithreading. These include a full complement of dynamic analysis types:
  - Modal
  - Seismic
  - Spectral
  - Harmonic and FRF
  - Time history (linear and non-linear)
  - Elasto-plastic
  - Pushover
  - Footfall
Wind Load Simulation
Unique to RSA is the ability to simulate wind flow around a structure, generating wind loads automatically. This feature is especially useful for structures having a complex geometry, where it is difficult to define appropriate wind loads. The wind simulation feature acts as a wind tunnel and displays colored pressure maps on the model to assist with visualizing and understanding the effects of the wind, as shown in Fig. 14.

![Figure 14: Wind load simulation in Robot Structural Analysis Professional](image)

Extensibility
RSA uses Microsoft Component Object Model (COM) technology, enabling an open and flexible API. Also, Results Connect (an add-in for Microsoft Excel) is included with RSA to enable the user to seamlessly access RSA data and results in that environment with no API knowledge. Finally, Dynamo is compatible with RSA, enabling access to all aspects of the API with powerful graphical programming tools. See Fig. 15 for an example of automated foundation design using Dynamo.

New Features and Enhancements

As we saw with Revit, RSA also sees significant, ongoing development. Let’s take a brief look at the new features in RSA 2017:

- **First**, there have been some *modifications to the steel section databases* supported by RSA; American ASTM A6 Jumbo sections (rectangular and square HSS, wide flange W, equal leg angles) have been added to the AISC database, and wide flange Super Jumbo sections (produced by ArcelorMittal) have been added to the ARCLRpro database. The Australian section database has also been adjusted such that the steel section names match the AS/NZS 1100.501 Technical Drawing code.

- **Section definition improvements** include the ability to rotate a section’s coordinate system by 90 degrees (to achieve $I_y > I_z$), while disregarding the relationship between $I_y$ and $I_z$, enabling constant orientation of a member’s local axis.

- Changes to **2D Eurocode wind loads** include taking into account the presence of a dominant wall (point 7.2.9.(5), EN 1991-1-4:2005), as well as the updating of external pressure coefficients for duo-pitch roofs (table 7.4a, NF EN 1991-1-4/NA/A1:2011-07).

- In accordance with the Eurocode 8, the new **Norwegian seismic analysis provisions** (NS-EN 1998-1:2004+NA:2014) have been implemented.

- **New options for bar/slab reinforcement** are available; transversal bar reinforcement density can now be presented graphically in RSA and exported to Revit. Diagrams may be displayed for all bars for which required reinforcement has been calculated; this information may be transferred to and displayed in Revit. Additionally, reinforcement zones, directions, descriptions, and other elements displayed on the provided reinforcement maps (meshes, panels, values, etc.) may now be saved as DWG/DXF files for use in other Autodesk software.

- The free technical preview of **Autodesk React Structures** has reached its fourth release (TP4). This fast, intuitive modeler is designed to be easy-to-use and tightly integrates with Dynamo and Revit. React Structures is built on the foundation of RSA, but with a new and modern user interface that is well-aligned with the Autodesk portfolio. See Fig. 16 and try React Structures at [http://react.autodesk.com/](http://react.autodesk.com/).
This list of new features clearly indicates that Autodesk is continuing to invest in RSA for a global audience of users.
Business Value

Many of the tools mentioned in this document are useful on their own, e.g. Revit or Advance Steel for structural design, RSA for finite element analysis, etc. But in combination, especially with strong interoperability, these tools enable a broad set of capabilities supporting structural design-to-detailing workflows. From detailed modeling, to prefabrication, to model-based collaboration and coordination, to multi-disciplinary and multi-platform integration, a workflow-based approach represents a better means of doing business.

Figure 17: Interoperability between Revit and RSA; model courtesy The Beck Group