Revit Structure and BIM

Revit® Structure extends *building information modeling (BIM)* into structural design. This paper examines the value of structural engineering workflows supported by building information modeling.

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Using a Building Information Model for Structural Engineering

The Revit Structure building information model combines a physical representation of the building fully associated with an analytical representation. This common, computable building model is used for structural design, drawing production, and coordination – and drives third-party structural analysis applications.

Computable Building Model

Digital data is not necessarily computable data – a distinction that at first glance may seem insignificant but in actuality wreaks havoc for the user of the data. For example, a word processor can be used to create rows and columns of financial data, but most of the numeric calculations and modifications must be done manually. The data is digital, but not very useful.

In contrast, a spreadsheet version of the same financial data might look identical to the word processor version, but the spreadsheet model contains numerical values, relationships, and sophisticated calculations. When a number changes, the rest of the spreadsheet updates automatically. The spreadsheet model is computable whereas the word processor representation is not, even though both are digital.

The building industry, for the most part, has adopted the word processor approach to documenting building designs over the past 20 years. CAD tools are primarily used to create electronic drawings of buildings. Even some 3D models are little more than 3D drawings. Although the output of these systems may resemble the output of a BIM solution – just as the financial table in the word processor looks the same as the spreadsheet table – it is not computable information.

It's quite common to try to use this incomputable building design data for analysis and find that the data, although seemingly computable, is actually an empty shell – a collection of graphic elements with no implicit knowledge of building elements such as walls, beams or ducts. For the most part, humans look at the data, interpret it, and transfer it to new applications for additional analysis.

Architects make occasional use of analysis packages, lighting studies, or baseline energy calculations, for example, which are typically outsourced to specialized engineering firms. Whereas the structural engineer is heavily dependent on analysis, which is an integral part of the structural design process. As a result, a computable building model is a key ingredient for efficient structural design processes.

Integrated Modeling for Structural Engineering

Traditional structural processes (those that don't use a building information model) begin with the architectural document set, be it paper or CAD-based. The structural engineering team interpret the architectural design to create an overall structural design, then create specialized analytical models, using different software applications for the multiple types of structural analyses required for the project; gravity, dynamic (e.g., seismic), and wind analyses. In parallel, the structural drafters create yet another representation of the building in the construction documentation process – creating multiple drawings of the same information.

This traditional workflow results in multiple “models” (including the drawings set) that are not coordinated, requiring manual efforts to keep them in sync. Opportunity for errors abound. For instance, one of the analysis programs prompts a change to a structural column, but the structural drafter misses the change, so the analytical representation doesn't match the physical representation. The documentation falls out of sync. The other analytical models become outdated, the downstream analyses are compromised, and the validity of the design suffers.

Revit Structure allows engineers and designers to create a single building model combining a physical representation of the building which is fully associated with an analytical representation. This building model is used for the complete production of construction documents and (since it is computable) can be used for different types of analyses.

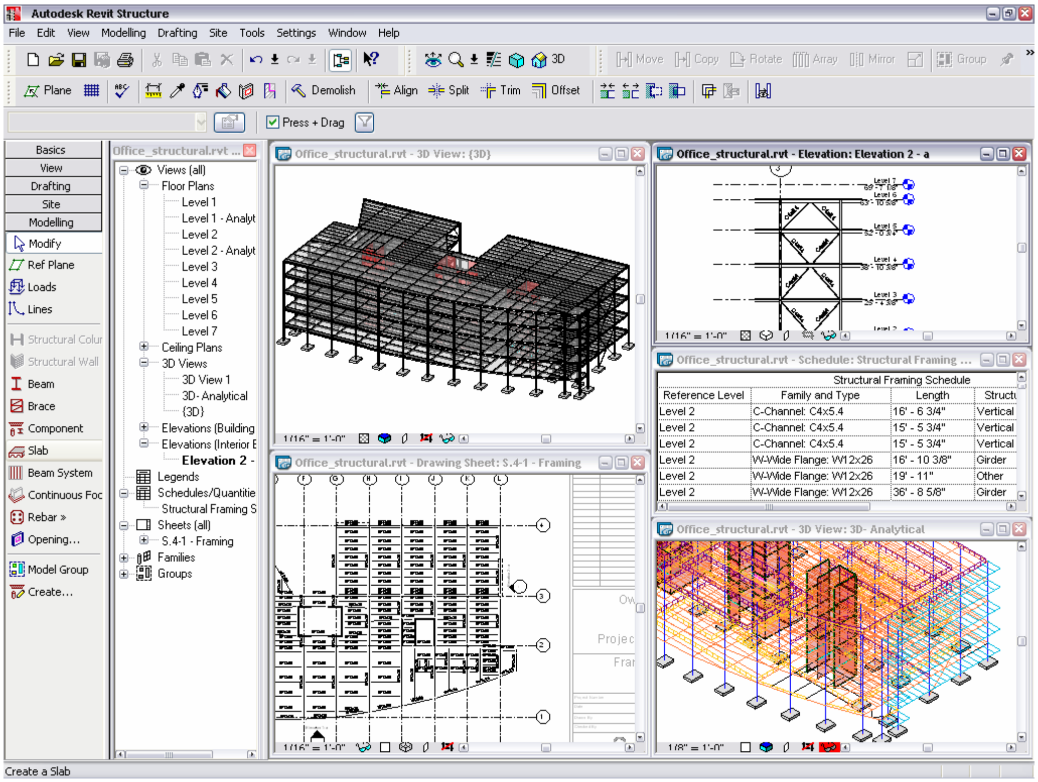

Figure 1:

Revit Structure extends building information modeling into structural design.

The physical representation denotes the physical layout of the structure in the building – beams, columns, walls, footings, etc. It also drives the construction documentation. As the physical representation develops, the analytical representation is created automatically, containing the necessary data needed for third-party analysis applications. The analytical representation is an abstract (usually simplified) 3D digital model used for structural analysis. The engineer adds specific loads, material properties, and so forth – and then runs the analysis.

Currently, Revit Structure is linked via an application programming interface (API) to several leading industry applications for building analysis: ETABS® from CSI (http://www.csiberkeley.com), RISA-3D from RISA Technologies (http://www.risatech.com) and ROBOT Millennium from RoboBAT (http://www.robot-structures.com).

If the engineers chooses to, the analysis program can then return information that dynamically updates the building model and therefore the documentation as well. This capability eliminates much of the redundant work done by structural engineers to model and analyze single- or multi-material building frames (steel, concrete, masonry, wood) using many different applications.

Design, Documentation, and Analysis Coordination

Like Revit Architecture, Revit Structure uses building information modeling – where every view, drawing sheet, and schedule is a direct representation of the same underlying database. Users can explore different structural systems and alternate design options from within the same model. As the design team makes changes to the building structure, the parametric change technology within Revit Structure automatically coordinates the changes across all other representations of the project. As a result, the design model (physical and analytical representations), design options, and documentation stay coordinated, consistent, and complete.

Structural Workflows using BIM

The value of using BIM for structural design becomes clear when comparing and contrasting the traditional structural workflow and a workflow supported by a building information model.

Traditional Structural Workflow = Multiple Models

Traditional structural workflows have two main branches, the iterative design/analysis process and the documentation process. Both begin with the architect's design, communicated through drawings.

As mentioned earlier, the structural engineers interpret the architectural design to create an overall structural design, and then create specialized analytical models in different software applications for the different types of analyses required. Time constraints usually dictate that the documentation effort parallels the design effort, so as the structural engineers begin their analyses, the structural drafters begin developing the documentation set – framing plans, bracing elevations, typical details, etc.

This use of multiple models – models that are not coordinated with each other or the documentation – requires a manual effort to keep them and the documentation package synchronized, to the detriment of a firm's efficiency, quality, and flexibility. Whereas the use of a common building information model to drive analysis, coordination, and documentation reduces these problems.

The Starting Point: Architectural Drawings

Without BIM, the architectural document set is the launch pad for the structural design process. If the drawings are paper-based, structural designers interpret the drawings and create the structural design and analytical *models* (note the plural) from scratch. If the drawings are CAD-based, some architectural files (plan drawings for example) may be imported and digitally "traced" to create structural elements.

With BIM, referencing the architectural plans is still the first step. But instead of creating several models, there's just one model – a single integrated structural model that includes both a physical representation that drives documentation and coordination, and an analytical representation used for multiple analyses.

Structural Analysis

Without BIM, individual models must be produced to front-end each type of analysis. One common complaint of structural firms is that their highly educated staffs spend too much time transcribing information from one software package to another, configuring various analytical models for input into different analysis software applications, and then manually coordinating the analysis and design results with documentation.

With BIM, the analytical and physical representations are created simultaneously, and are just different views of the computable building model, containing the necessary information needed for third-party analysis applications. Revit Structure doesn't replace the analysis applications; it provides a common modeling interface to them and a common model to document the results. Using the Revit API, data moves directly from the Revit Structure building information model to the analysis software, and the analysis results are delivered back into the model – keeping analysis, design, and documentation all synchronized.

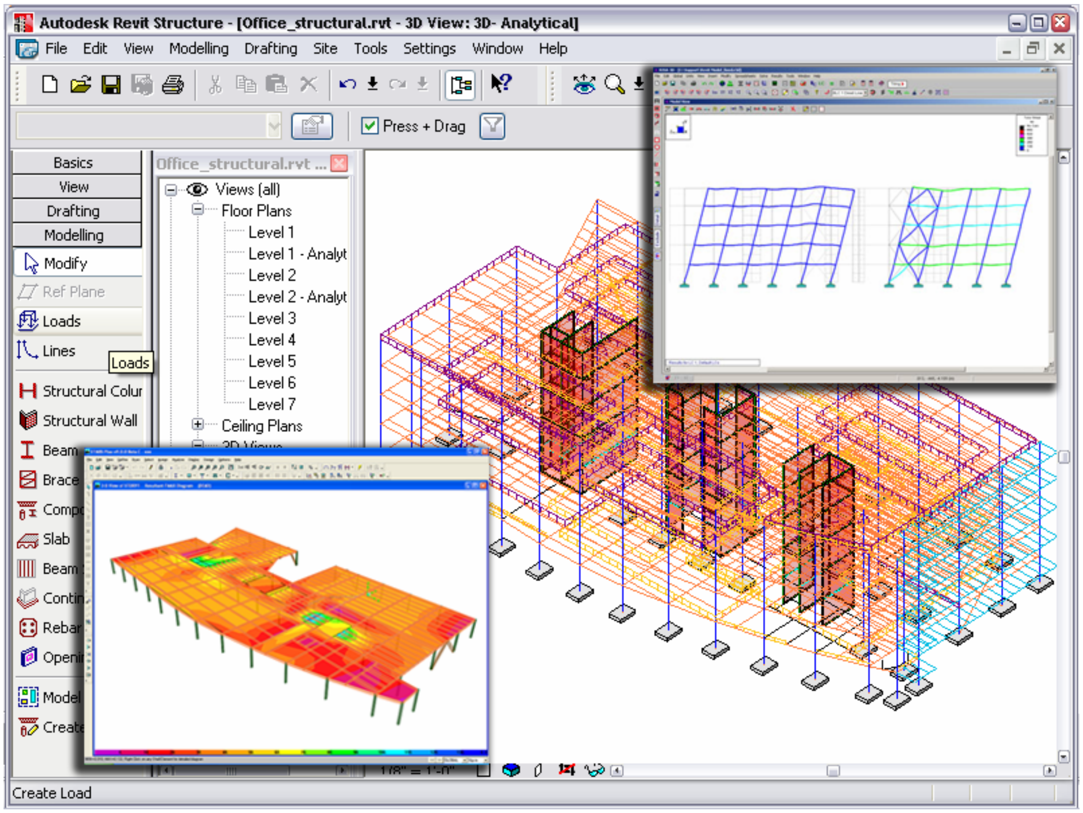

Figure 2:

Revit Structure links its analytical model to several structural analysis and design software.

Roundtrip Analysis Example

For example, an engineer needs to run a general gravity analysis. First the engineer adds analysis-specific data to the Revit Structure model – such as external loads (dead, live, snow, etc), load combinations, releases, and boundary conditions – and then selects "send model to RISA" from the Revit Structure user interface. The RISA-3D application is launched, all the necessary information needed for the analysis is extracted from the Revit Structure model – location of members, cross sections, release conditions, material properties, loads, etc. – the analysis runs, and the results are displayed within RISA-3D.

Based upon the results, the engineer can modify the structure (for instance, beef up a column size from W30x108 to W33x130) and recalculate the building as needed. When the engineer is satisfied with the analysis results, the RISA-3D application is closed and the Revit Structure model can be automatically updated to reflect the changes (in this example, the column is automatically changed to a W33x130).

Next the engineer wants to run a seismic analysis using ETABS. The Revit Structure model has been automatically updated with the results of the RISA-3D analysis, so there's no need to manually update the analytical representation required for the ETABS analysis – because it's all one model. The engineer sends the Revit Structure model to ETABS, and this new analysis iteration confirms that the redesigned W33x130 column is sized appropriately for seismic loading conditions.

Coordination and Documentation

Continuing the example above, without BIM someone would have to manually update all the documents that show that column and all the reports that include that column, and hopefully remember to change the column in the analytical model used for the ETABS analysis. Needless to say, this coordination effort can be immense. Junior staff and/or engineers in training are routinely consigned to this drudgery.

With BIM, a single model drives documentation and analysis. The column that was changed in the RISA-3D run is automatically updated in the Revit Structure model – physical and analytical representations, and all the affected documentation.

Improved Workflows with BIM

Revit Structure lets firms work more efficiently and make better use of their time with integrated modeling for structural analysis and documentation. The Revit parametric change management coordinates analysis results more reliably with design to produce higher quality, more accurate, and more consistent work.

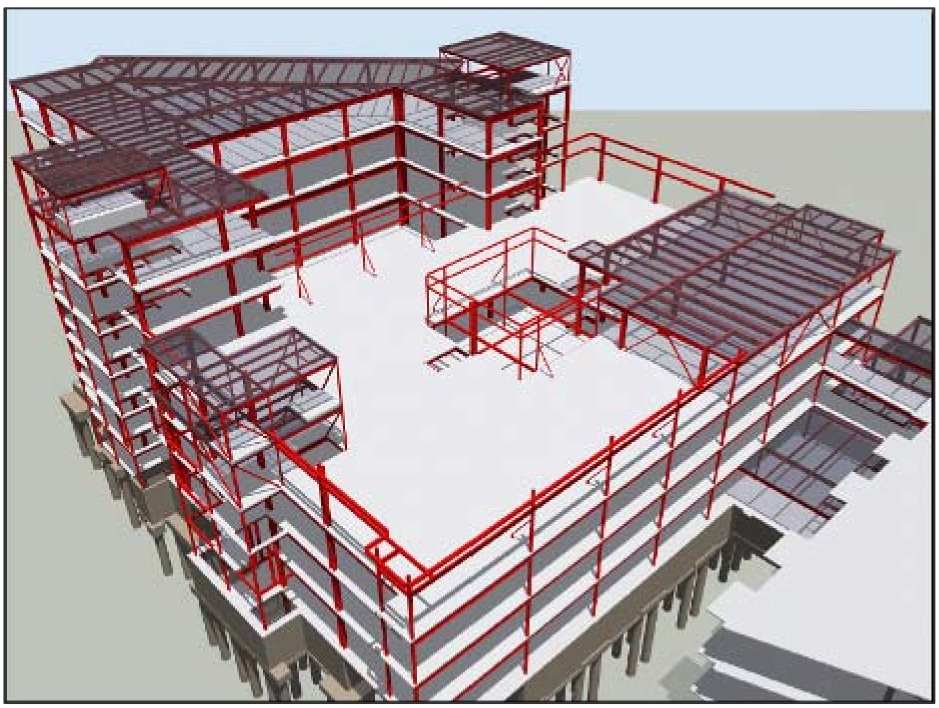

Figure 3:

Brandow & Johnston Associates use the Revit Structure building information model to increase their efficiency and overall project coordination.

Thomas Weir at Brandow & Johnston Associates – a California-based structural engineering firm that has successfully engineered over 15,000 building projects throughout California and the United States – reports that "With the advent of Revit software, and utilizing the techniques of building information modeling, we find significant advantages in our ability to navigate through the design process. Having the three-dimensional computer model enhances our understanding of the structure considerably, so our final product is done more efficiently and with better overall coordination."

Coordinating Designs

Structural engineering firms using Revit Structure can coordinate their design and documentation with the architect – leveraging digital representations from multiple design sources, particularly AutoCAD® and AutoCAD Architecture software. With the wide adoption of AutoCAD and well over 350,000 users worldwide of AutoCAD Architecture, structural engineers will find many opportunities to use Revit Structure to collaborate with architects using the DWG file format or the intelligent real-world building objects from AutoCAD Architecture.

Multiple Design Sources

One important aspect of a structural engineer's job is to share information with the rest of the design team, including the architect. To accommodate this requirement, Revit Structure offers a range of collaboration modes:

1. Importing/exporting standard CAD file formats (such as DWG, DXF, and DGN),
2. Bidirectional linking to/from AutoCAD Architecture architectural models,
3. Linking directly to an existing Revit Architecture building model.

Working with 2D CAD Files

The most common starting point for a structural firm are 2D CAD files provided by the architect. Any CAD system that supports the DWG, DXF, or DGN file format can work effectively with Revit Structure.

Revit Structure lets firms import and link DWG, DXF, or DGN files directly into Revit Structure. If the 2D CAD file is linked while being imported, it remains within Revit Structure as a backdrop and can be refreshed if the architect supplies an updated version. Imported geometry can be referenced or converted directly to create new structural components. For example, the lines representing an architectural grid on a DWG file can be used to create a new structural grid either by digitally tracing the lines (referencing endpoints, midpoints, etc.) or by selecting the appropriate lines and converting them directly to Revit Structure grid lines. 2D wall lines can be converted directly to 3D structural walls in a similar fashion (using preset floor elevations to specify height).

Equally important is the ability of Revit Structure to export to these same 2D CAD formats – not only because this is the format frequently needed to communicate back to the rest of the design team, but also because some owners require the delivery of digital-based documentation sets in these formats. Revit Structure can produce DWG deliverables just as AutoCAD software can, producing well-organized and layered DWG files using any layering standard the user wants.

Link with AutoCAD Architecture

AutoCAD Architecture and Revit Structure have an especially strong integration, bringing added benefits to architectural and structural firms using these solutions together.

Typically, the structural engineer will still start the design process using the architect's 2D CAD files, digitally tracing or converting geometry from the drawings as described above. If desired, the structural firm can also import (and link) the AutoCAD Architecture model directly into Revit Structure, using the architect's model for design reference. And for improved coordination with architects, Revit Structure exports structural components as intelligent building objects native to AutoCAD Architecture. Structural components in Revit Structure that are not of a type supported in AutoCAD Architecture (and walls with structural characteristics) are exported to AutoCAD Architecture as mass elements. So a complete structural model from Revit Structure can be shared directly with an architect using AutoCAD Architecture – enabling the architect to review the structural design inside the architectural model and check it for interferences with architectural elements, directly inside AutoCAD Architecture.

Similarly, structural engineering firms using Revit Structure can also share models with MEP engineering firms using AutoCAD® MEP, since that software is built on the same technology as AutoCAD Architecture. Revit Structure can export structural members as intelligent building objects native to AutoCAD Architecture, as described above. When exported, these can be used directly in AutoCAD MEP, enabling MEP engineers to layout their pipe/duct systems within the context of the structural model – resulting in a better-coordinated design with minimal collision issues. Revit Structure can also import ACIS® geometry and objects generated by AutoCAD MEP, allowing structural engineers to view the geometry of the building environmental systems within their structural model.

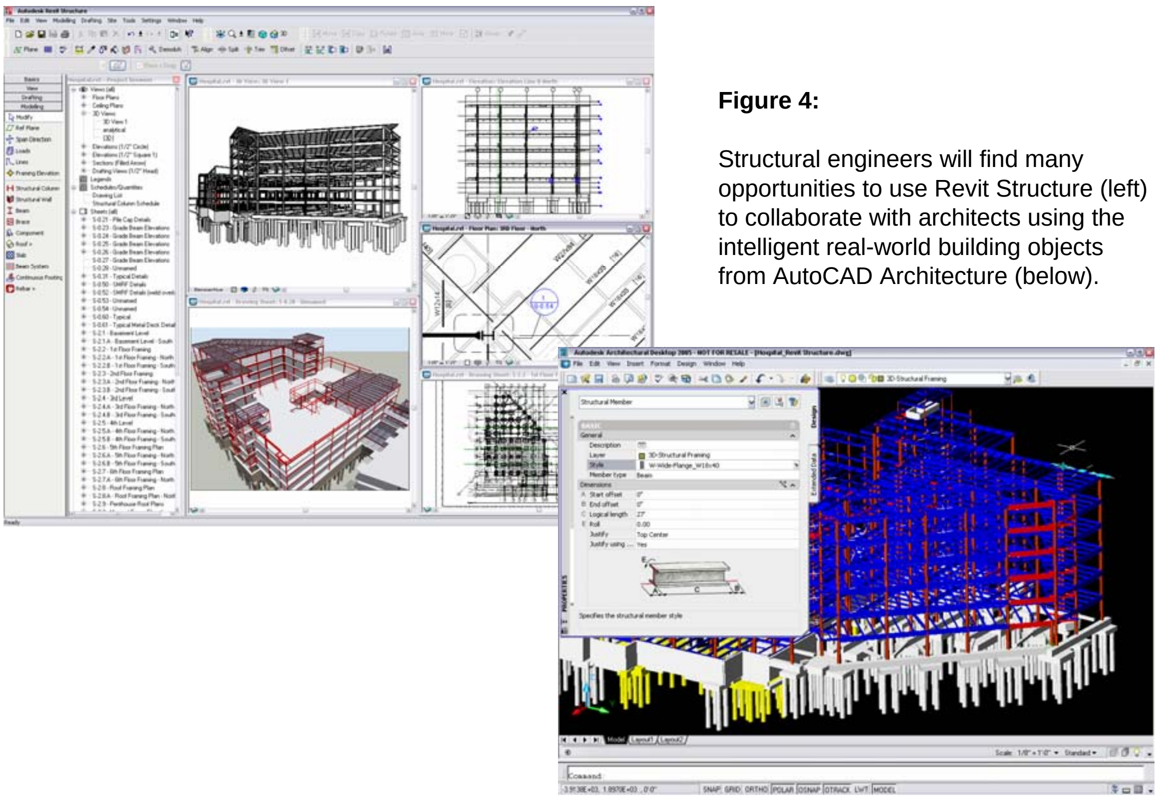

Figure 4:

Structural engineers will find many opportunities to use Revit Structure (left) to collaborate with architects using the intelligent real-world building objects from AutoCAD Architecture (below).

Using Revit Architect Architectural Models

Structural engineering firms using Revit Structure can also share models with architects using the Revit Architect software.

If the architect and the structural engineer are in the same organization (a large A/E firm for example) and both have access to the same network, they can work directly on a combined architectural and structural model. Alternatively, they can exchange and cross-link their respective models, much like an architectural DWG file might be x-referenced into a structural DWG file, but with far more intelligence. The choice depends on their team organization and preferred way of working.

Cross-linking the architectural and structural models is also the preferred means of sharing the models between architects and engineers if both are using Revit-based applications but are in separate organizations without access to a shared network.

The underlying Revit platform includes a monitoring and coordination tool that tracks all the changes that have occurred when a cross-linked model is reloaded or refreshed, and presents them to the engineer or architect in an orderly way for review. For example, the structural designer gets an updated version of the architectural model and is warned that the architect moved a column enclosure that is linked to one of the engineer's structural columns. The structural designer can then choose to respond to that design change directly in the model or to flag it for further action.

Summary

The use of a building information model gives structural firms an integrated modeling environment for analysis and documentation – so that the *structural* design and documentation are always coordinated, consistent, and complete. Leveraging existing architectural digital design information and sharing the structural building information model with architects and engineers further coordinates the *building* design and documentation – a winning combination for all parties involved in the design, construction, and operation of a building.

About Revit

The Revit platform is Autodesk's purpose-built solution for building information modeling. Applications such as Revit Architecture, Revit Structure, and Revit® MEP built on the Revit platform are complete, discipline-specific building design and documentation systems supporting all phases of design and construction documentation. From conceptual studies through the most detailed construction drawings and schedules, applications built on Revit help provide immediate competitive advantage, better coordination and quality, and can contribute to higher profitability for architects and the rest of the building team.

At the heart of the Revit platform is the Revit parametric change engine, which automatically coordinates changes made anywhere — in model views or drawing sheets, schedules, sections, plans… you name it.

For more information about building information modeling please visit us at *http://www.autodesk.com/bim*. For more information about Revit and the discipline-specific applications built on Revit please visit us at *http://www.autodesk.com/revit*.

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