Maintaining BIM Integrity in the Structural Engineering Office

A key benefit of building information modeling (BIM) is the ability to share digital model data amongst the design team. This paper examines the role of the structural engineer in the BIM process and explains how the integrity of the building model is maintained during the structural engineering process.

About BIM

Building information modeling (BIM) is a building design and documentation methodology characterized by the creation and use of coordinated, internally consistent, computable information about a building project in design and construction.

The building information model can contain data for all parts of the building -- structural information, architectural information, MEP, etc. -- at any stage of the project; prior to construction, during construction, and post construction. Even details such as finishes (flooring type, window manufacturer, etc.), pricing, and so forth -- everything about the building and it's history - can be included as digital data in a building information model.

Global Benefits

BIM brings with it many benefits to the project as a whole, such as:

- The ability to automatically track changes - between individuals within a single office and even between disciplines. For example, an engineer receives a building information model from the architect and then changes the size of a certain structural member for strength criteria. When the building information model is sent back to the architect, the changes are automatically updated in the architect's building model.
- Decreased time in the design phase of a project due to the need to produce only one model instead of several in each design discipline.
- The ease of tracking revisions and changes to the structure.
- The ability of the building owner to have full information on the building during the life of the structure (Building Lifecycle Management).

One can readily imagine that clients will soon insist on the adoption of BIM for the whole design process, but BIM also brings great benefits for the engineer within his or her own office. For example, in a structural design process, BIM:

- Means that changes made by a design engineer are picked up by the drafter.
- Brings the engineers closer to their colleagues in the design team.
- Enables engineering data to be easily transmitted to architects and fabricators.

Many structural engineers feel that BIM is not just an option for the future, rather a requirement. In addition to the very real savings that BIM brings in time and better accuracy in the structural engineering office, there is little doubt that soon clients will demand that all parties, including the engineer, take a full part in the BIM process for a project.

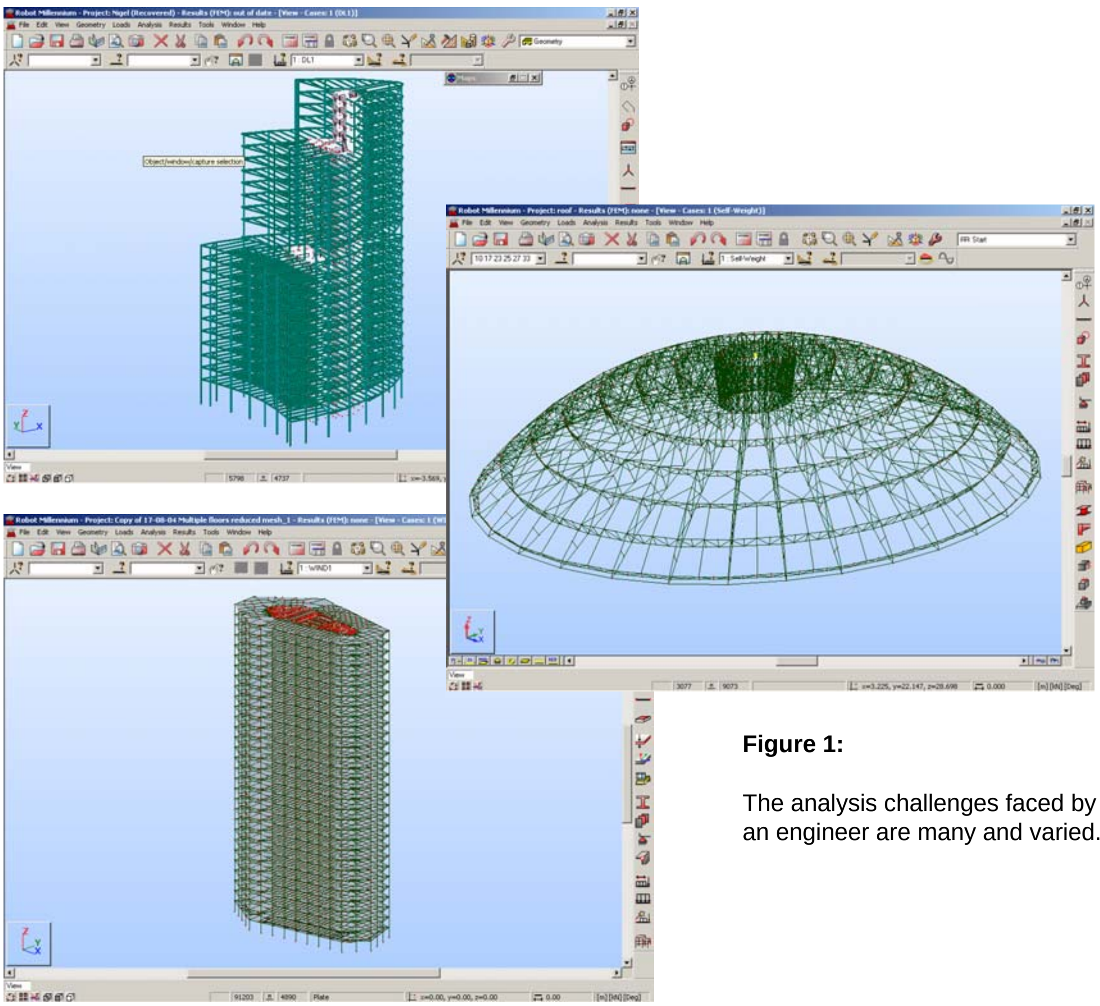

Figure 1:

The analysis challenges faced by an engineer are many and varied.

Below is a description of the traditional structural engineering workflow, followed by a synopsis of how structural engineers can leverage BIM.

How Do Structural Engineers Traditionally Work?

Structural engineers have a long history of working with digital information and are very quick to develop and adopt software solutions. This is due in large part to the numerical analysis requirements of the discipline - analysis which is often impossible to quantify without a computer. Engineering analysis often involves the calculation of huge mathematical problems – even a simple structure can produce many thousands of “unknowns” to be evaluated by a matrix approach and such calculations very often cannot be done by manual methods.

However, this calculation software is often very isolated in terms of the data that it exchanges upstream and downstream. Although analysis software is very advanced, it is typically not well integrated into the structural engineering process - let alone the complete multi-disciplinary building modeling process.

Traditional structural processes begin with an interpretation of the architectural drawings, either in digital or in paper format. The engineer takes this data and “strips it down” to produce only structurally important information. This data, if the building is anything other than the very simplest of structures, is then further interpreted into a structural calculation model, which could actually be created in several calculation programs to suit gravity analysis, stability, non linear and dynamic analysis. At the same time that these calculations are taking place, the drafters are also interpreting the very same data – producing general arrangement drawings, framing plans, etc.

After initial analysis, the design engineer will then start to verify and design structural members using a “building code,” deciding on sizes, amount of reinforcement in concrete members, etc. This data is then passed, often in the form of sketches, to drafters (who may be inside or outside the engineer’s company, depending on the local practice) to make the final detailed drawings, which are then transferred back to other members of the design team, usually in paper format.

Such a process can hardly be described as seamless or coordinated!

Engineering Data

In general, architectural drawings contain a lot of information that is superfluous to the engineer. The first stage of the engineering process is usually to rationalize this data to produce engineering data. Such data includes initial “educated guess" sizing of beams/columns and the position of beams, columns, floors and walls in 3D, plus any other features that affect the overall stiffness of the structure, such as openings in floors and walls.

A particular challenge in creating the structural model is that that the engineer is not necessarily - at this initial analysis stage at least - interested in the exact shape of a member, but rather in its stiffness and the need to represent the position of this member in the 3D model at its centroid. The center line of a member (as represented by the architect) does not necessarily correspond to the desired position in the analysis model. A similar problem occurs when considering walls and slabs of differing thickness. For example, a wall from the 1st to 2nd floor is often thicker than the corresponding wall from the 2nd to 3rd floor. In an architectural model, this would be represented as “in reality" (see Figure 2).

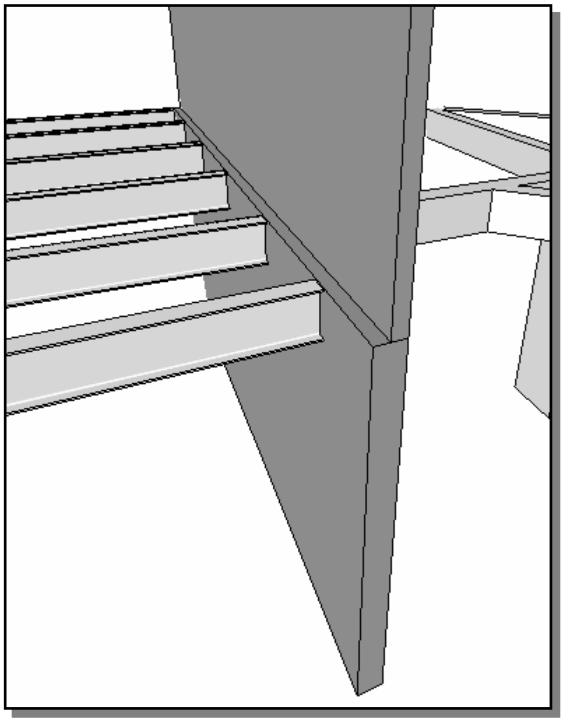

Figure 2:

The physical representation of a vertical wall in a building information model.

However, if an engineer considers the center line of each wall, it can be seen that there is no continuity between the two walls (Figure 3, left). A normal approach by manual methods is to move the wall in the analysis model to ensure continuity (Figure 3, right).

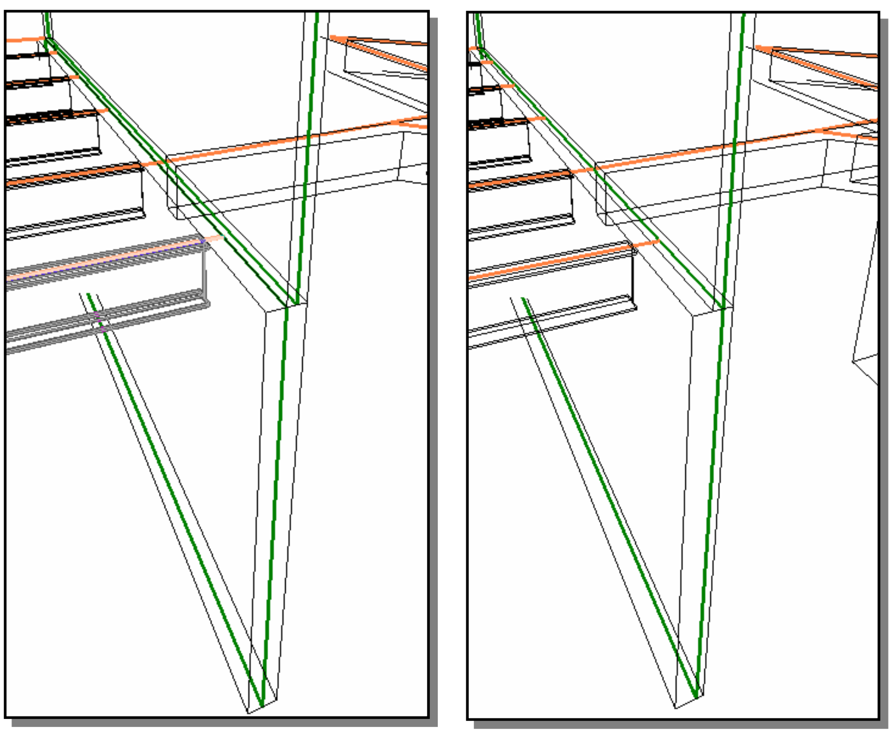

Figure 3:

The analytical representation of the same vertical wall in a building information model; disconnected (left) and joined (right).

Physical and Analytical

All of these challenges have been successfully met by Revit® Structure software with the introduction of a concept of both a "physical" and an "analytical" representation of the structure.

The physical model is a true model of the structure and the analytical model transfers this data to information needed by the structural engineer. Crucially, both the physical and analytical representations of the structure are fully associated in Revit Structure, facilitating both upstream and downstream integrity of the BIM.

In this manner, Revit Structure successfully allows the use of a single building information model, satisfying all the participants of the design process - including structural engineers. It is therefore important that any analysis solution that uses the Revit Structure BIM should fully maintain the integrity of the BIM, without needing to over-manipulate the analysis model.

Engineers typically make assumptions in order to simplify their calculation models. These assumptions may be made in order to make the model smaller and therefore faster to run, or they may also commonly be made to make the model more suitable for the particular chosen analysis solution.

It is common for the engineer, using "engineering judgment," to make assumptions about the structure to satisfy the limitations of the analysis solution and the shortcomings in many finite element "meshers" in structural analysis solutions. For instance, engineers may:

- Ignore holes in walls and floors.
- Simplify the shape of holes or surfaces (rectangular versus their true shape).
- Assume that curved walls and floors are in fact made up of many straight faces.

While the majority of these assumptions are perfectly valid when considering an analysis model in isolation, questions should be asked about the validity in terms of the overall building information model. For example, if an engineer needs to manually change the attributes of a model just to satisfy the limitations of the analysis program, then how does that affect the update of the building information model and how is that information relayed to other members of the design team?

To prevent compromising the overall building information model, the engineer must therefore ensure that the chosen analysis solution is capable of directly analyzing any shape of structure.

With this in mind, it can be seen that even the simplest architectural model will produce complex structural models, with features such as curved slabs, non-rectangular openings, etc. How many architects produce buildings only with rectangular walls and no openings? These are challenges that the engineer must face armed with a capable analysis and design software.

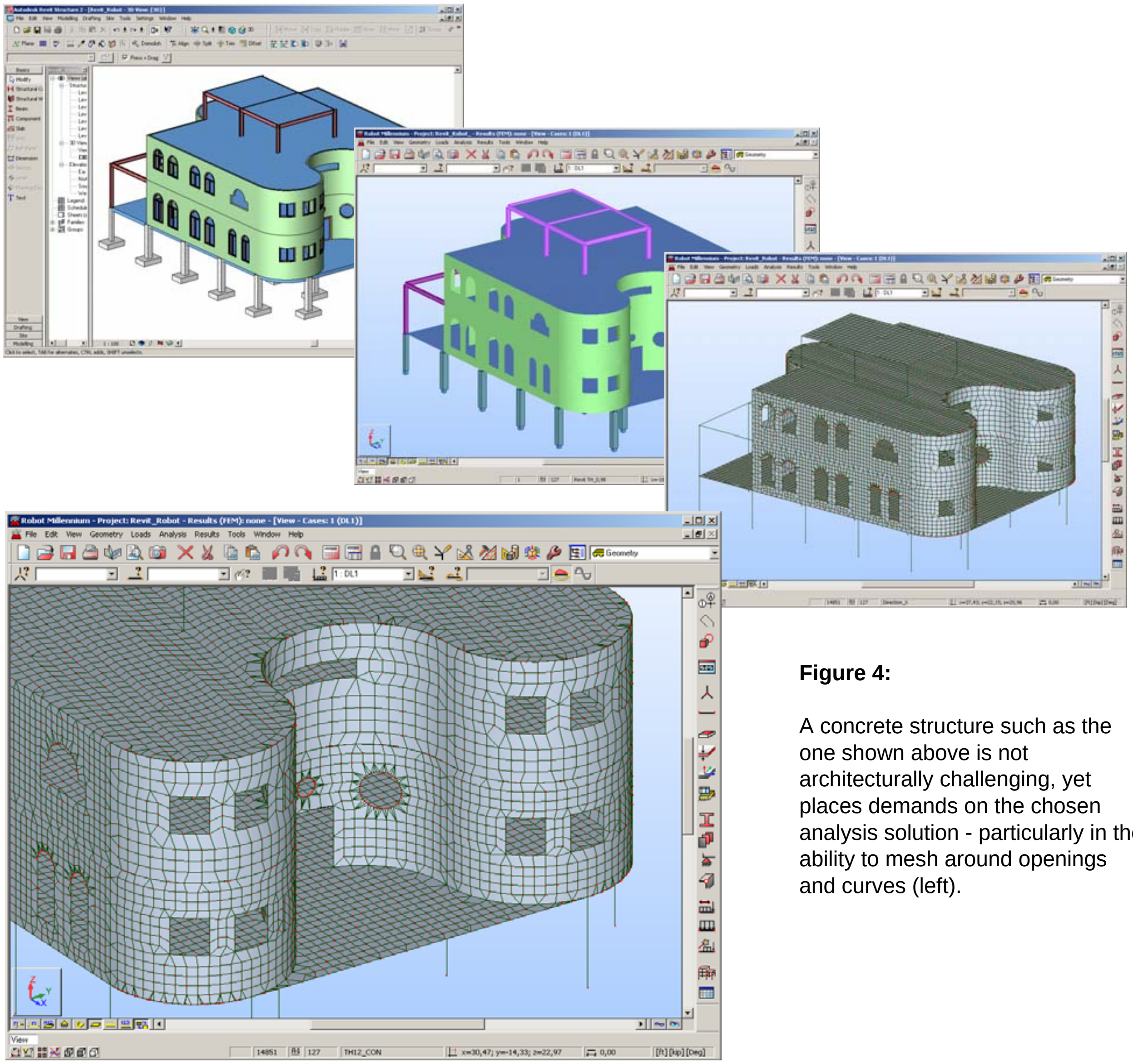

Figure 4:

A concrete structure such as the one shown above is not architecturally challenging, yet places demands on the chosen analysis solution - particularly in the ability to mesh around openings and curves (left).

Non Cosmetic Structural Data

We have discussed the importance of ensuring that the generated structural analysis model accurately mirrors the “virgin” data in Revit Structure. This is certainly true for obvious displayed information (such as geometry, section sizes etc) but it is also important for “non cosmetic” data too. We must remember that exchange of data in the BIM process is rarely a “one pass” and that it is common to iterate between documentation models and analysis models several times during the design process. In this scenario it is important to retain data that is crucial to the analysis program, but irrelevant to drawing production. Such parameters include:

(i) Member and node numbers

(ii) Steel design parameters, such as code buckling lengths

(iii) Concrete design parameters, such as deflection limits

(iv) FE meshing density

(v) Analysis parameters, such as non linearity, dynamic settings

The adoption of such parameters by structural analysis software vendors, implemented using the Revit Structure API, will ensure that this data is preserved and need not be assumed for subsequent data transfer.

Selection of Analysis Software for use with Revit Structure

Engineers are often familiar with a few different analysis programs and the initial selection of a program to be used with Revit Structure is often based on the software currently used in the Engineer’s Office.

Another consideration in the choice of structural analysis software for BIM must also include the range of analysis types and design codes that are available. During the course of a project, the engineer may be required to make several analytical studies, such as:

- Linear static analysis.
- Steel design to local codes.
- Concrete design for members and surfaces to local codes.
- Dynamic and seismic analysis.
- Non linear analysis (cables, PDelta, plastic hinge evaluation, etc.).

Revit Structure conveniently allows the engineer to use a variety of analysis programs for these tasks within the same project, yet the selection of a broad and detailed single application will permit the full range of analysis challenges to be tackled directly without the need to keep updating the building information model between separate programs. There is indeed a trend in the market for analysis suppliers to move towards a “one stop” solution that is capable of providing the full range of analysis options.

Summary

Very soon, BIM will become a project requirement. Those engineers ready to embrace BIM will not only save time and improve accuracy - they will also have a significant business advantage over their competitors.

Engineers can benefit greatly from BIM, as can the whole design process. But it must be remembered that even a very basic architectural building information model can produce complex analytical solutions that the engineer must be prepared to analyze directly in their chosen analysis solution. Revit Structure allows the engineer to rationalize the analytical representation before transfer to the selected analysis application, yet the selection of an analysis program that is capable of dealing in complex geometry will minimize the need to make such actions. By adopting such analysis solutions, the engineer can become a key part of the BIM process.

About the Author

Gary Wyatt, CEng MIStructE, is International Sales and Marketing Director of RoboBAT. Gary has over 10 years of experience in the structural design of buildings and bridges. RoboBAT have developed a close bi-directional integration between their analysis and design software ROBOT Millennium and Revit Structure. See *www.revit.robobat.com* or email *gary@robobat.com*

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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