BIM and Algorithmic Form Finding

This white paper explores how the parametric change engine at the heart of the Revit® platform for building information modeling (BIM) provides advanced modeling techniques for exploring innovative real-world building designs.

The skylines of the 21st century are changing. The boxy towers that dominate our cities are getting some interesting new neighbors: buildings that owe their architectural form to an algorithmic design approach. How does BIM support the exploration of design possibilities for these new structures?

Building information modeling (BIM) is the creation and use of coordinated, consistent, computable information about a building project in design - information used for design decision-making, production of high-quality construction documents, predicting performance, cost-estimating and construction planning, and, eventually, for managing and operating the facility. A purpose-built BIM solution based on parametric modeling technology such as Revit Architecture can also be used very early in the design process for conceptual form finding and algorithmic design studies, based on mathematical parameters for controlling building forms.

This white paper outlines a few typical techniques for using Revit® Architecture software to create complex, intricate architectural forms – design ideas which can be the starting point for expressive building structures of the 21st century.

Designing the Rules

Revit Parametric Components (also referred to as Families) offer an open, graphical system for design thinking and form making. Revit Families are extremely powerful because they are driven by the Revit parametric change engine. The parametric change engine means that a change made to a family will propagate throughout the entire project. Once created, a family's parameters remain exposed and can be edited directly within the Revit project. Ultimately, it is the parameters that drive a family's geometry. Mathematical formulas can be used in Families to drive parameters - for example, using a formula in a window family that always makes the width of the window twice its height.

Formula-based parameters can also be used to create very complex, imaginative forms for exploratory massing studies. These are design ideas used during the iterative design process – not the traditional conceptual designs that dominate the architectural schematic design phase. Rather they're ideas that can be quickly generated and visualized, shared with the client, perhaps even exported to Google Earth™ mapping functionality, or the like, to view in the context of the built city.

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Figure 1:

Revit Architecture is used to create early form finding and algorithmic design studies, such as this tower for a project in Dubai, currently in design by Aedas Hong Kong.

Below are step-by-step procedures for creating: a parametric massing study, a matching structural form, and a pleated curtain wall – all based on algorithmic form finding techniques.

Parametric Massing Study

A simple blend, driven by formula-based instance parameters associated to single “Level” parameter, is used to create this massing study. Later, the ability to control rotation and orientation will lend a spiral effect to the overall mass.

- The simple blend shown in Figure 2 is the basis for this conceptual model.
- An integer coefficient drives algebraic formulas that determine the amount of rotation between the top and bottom of each mass as well as its orientation relative to the overall masses height (see formulas listed in the Family Types dialog box shown in Figure 2).

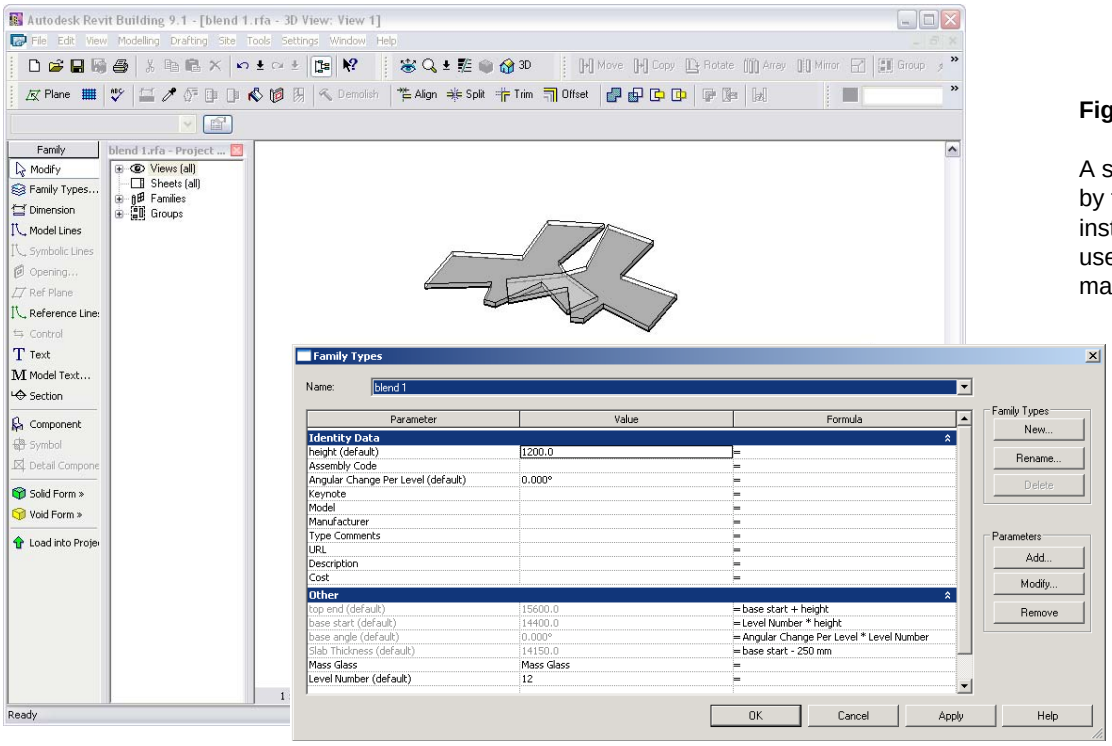

Figure 2:

A simple blend, driven by formula-based instance parameters, is used to create this massing study.

- In the conceptual model, multiple instances are created and stacked on top of one another, and the height of each instance is set to a corresponding floor to floor height.
- To create the tower form (shown in Figure 3), each instance's integer coefficient is set to a corresponding level number, thus determining its proper orientation and rotation.

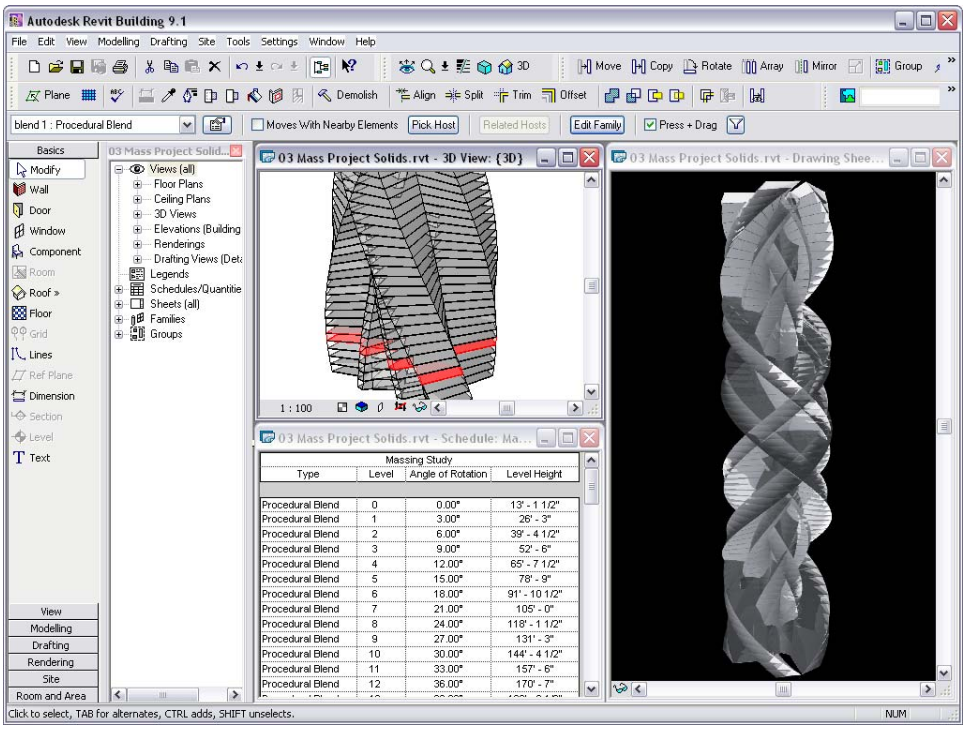

Figure 3:

Formulas control the orientation and rotation of the stacked instances of a single blend.

Structural Forms to Match

Continuing with this same general design idea, the designer may want to investigate the structural expression of the form as well. To that end, the same initial mass element is used, but as a void versus a solid (so it cannot be seen but is still the controlling shape). Swept forms associated to the vertices of the void create the structural system.

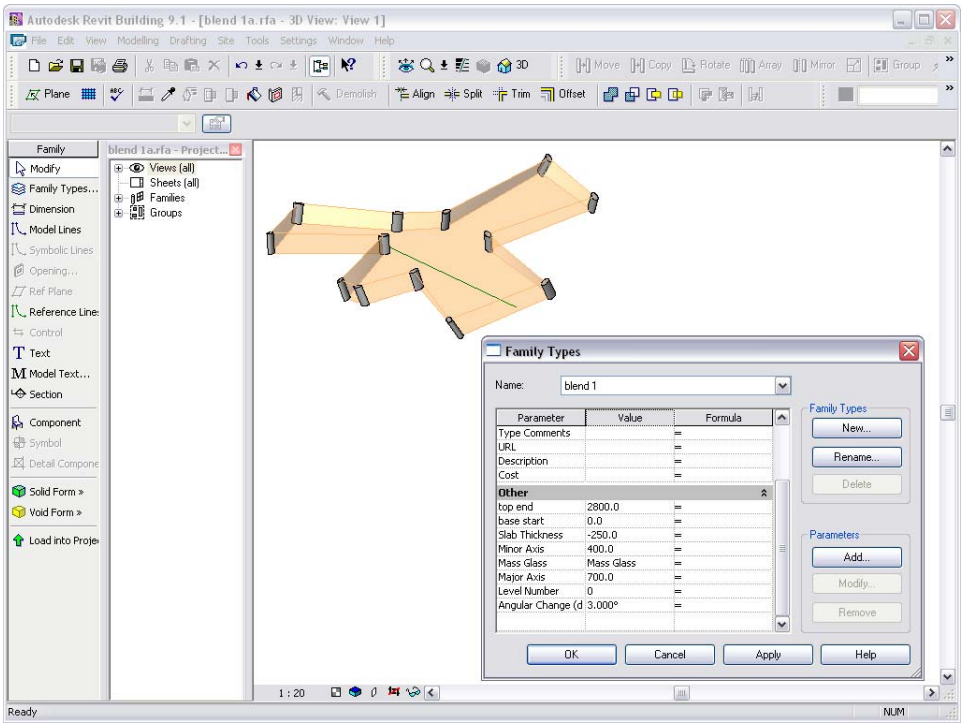

Figure 4:

The volume shown here, although not visible in the conceptual model, provides control over the structural elements.

- Conceptual massing tools are used to create and parameterize a volume (shown in Figure 4) that, although not visible, provides control over the swept forms (i.e., the structural elements) once they are snapped to its vertices.
- As in the previous example, similar formulas and parameters allow the user to control properties such as angle of rotation and floor to floor height that will later help define the structure for each level.
- Multiple instances of the family are arrayed vertically and each instance is assigned a level. Based on the Level parameter, the height and angle of rotation will adjust to the proper location.
- Once set, each instance aligns with its two adjacent instances to form a continuous structure (shown in Figure 5).

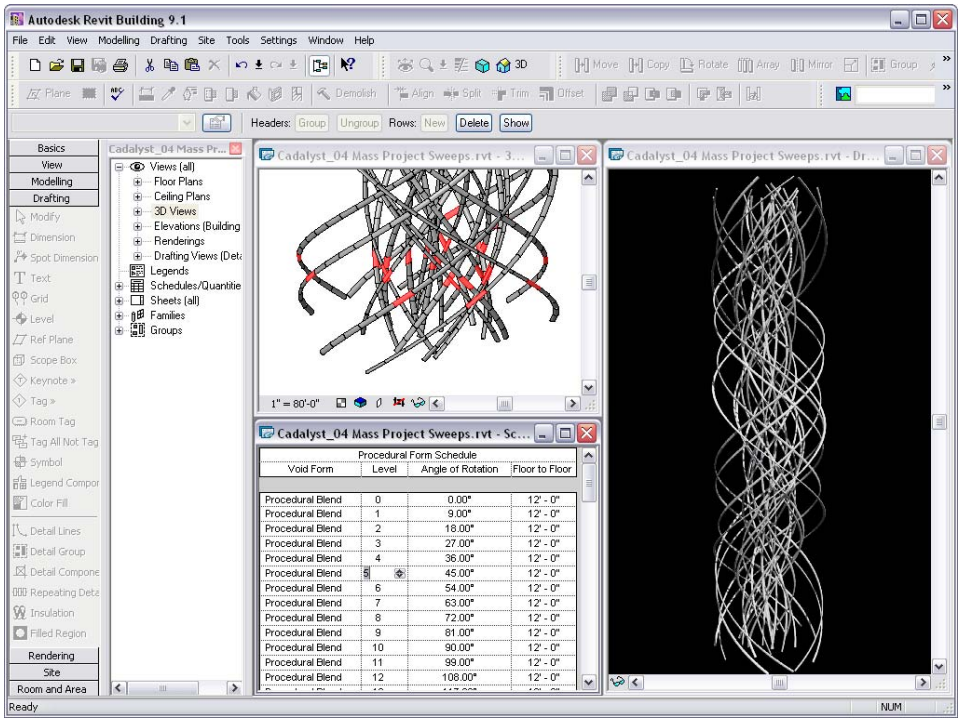

Figure 5:

Swept forms associated to the vertices of the void create the structural system.

Skin in the Game

The technique highlighted in this last procedure also uses a mass element as a void – this time to drive the form of each individual panel of a pleated curtain wall (shown in Figure 6). Cylindrical sweeps are created by snapping to the vertices of the void. By varying the parameters of the void the user can change the height, width and amount of "pleat" in the curtain system.

Unlike the previous examples, this design element *would* typically be used in the ongoing building information model. It's created as a Revit Curtain Panel Family and can be used with an overall curtain wall system.

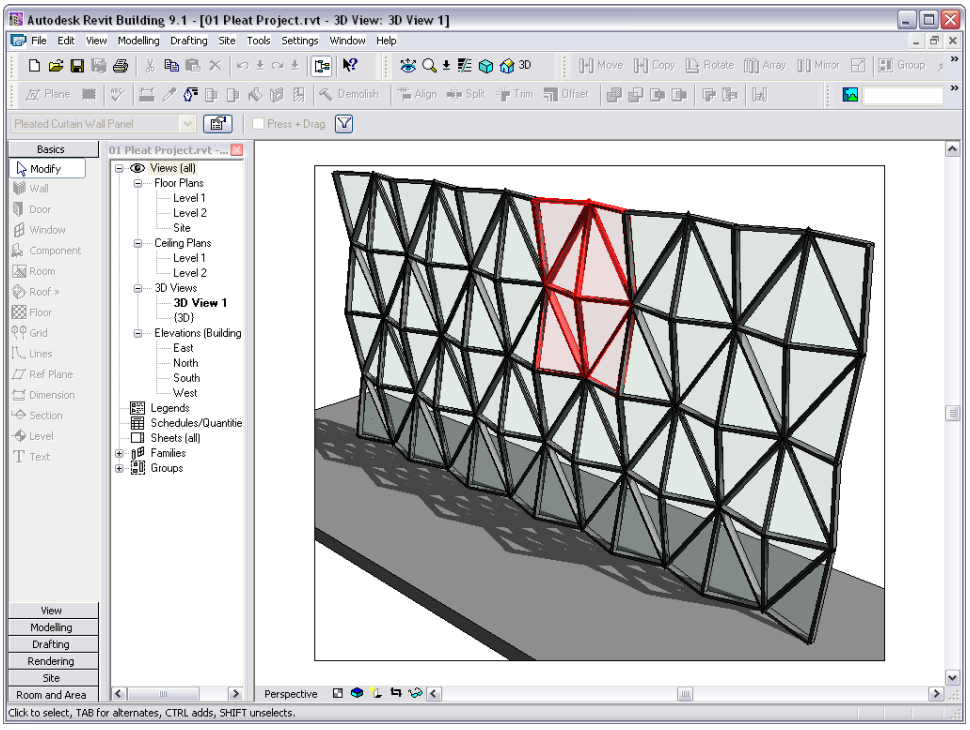

Figure 6:

By varying the parameters of the panel element (highlighted here in red), the user can change the height, width and amount of "pleat" in the whole curtain system.

- Like other Revit Curtain Systems, the Pleated Curtain System is an array of unique Curtain Panels (shown in Figure 6).
- A void blend is modeled to define the contour of the curtain panel. Because of a void's visibility properties, the blend is not visible in the curtain panel, although, it does provide a base for all model geometry in the Curtain Panel. It is parameterized to manage changes in variables such as height, width, and depth (see Figure 7).

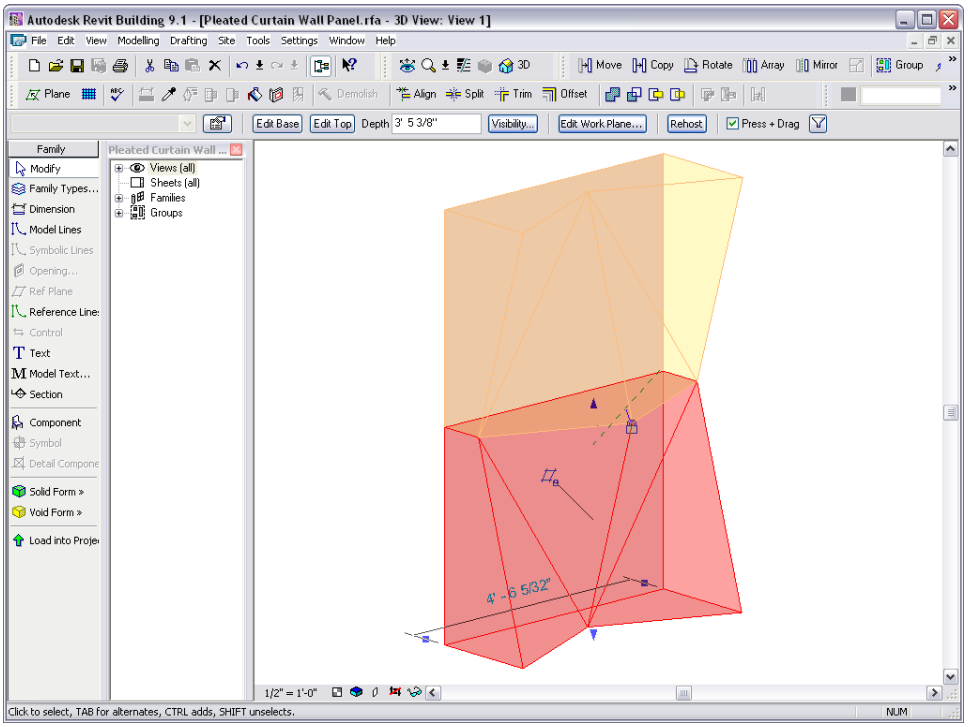

Figure 7:

Parameters of the blend used to control the shape of the base curtain panel element.

- A thin layer of glass is modeled on top of the void form (shown in Figure 8).

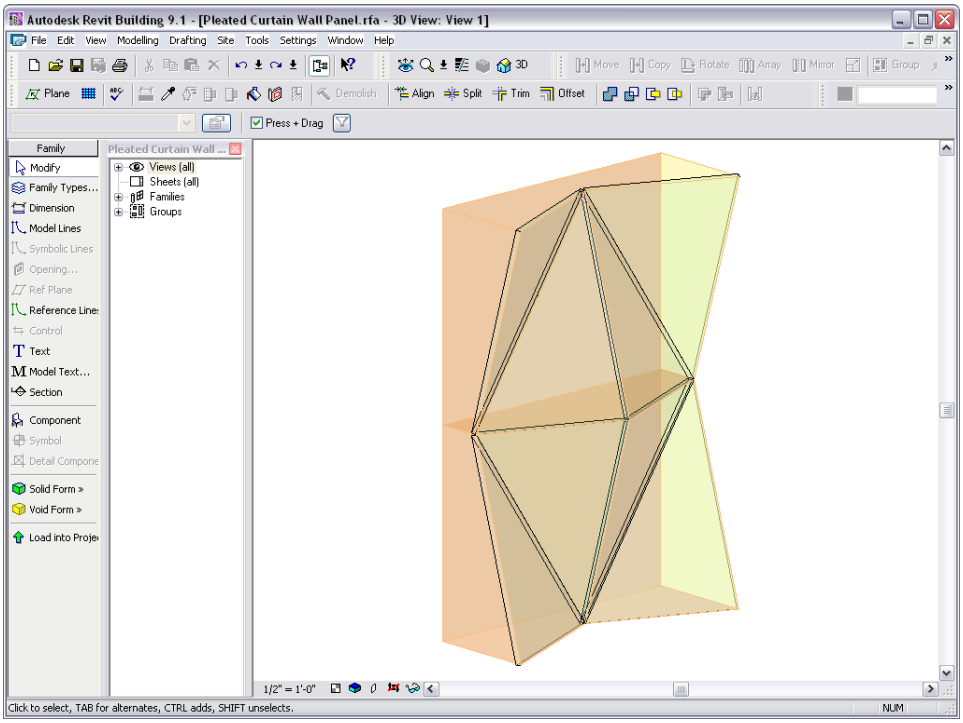

Figure 8:

A thin layer of glass is added to the void form.

- Finally, the vertexes of the void are used to create mullions (shown in Figure 9).

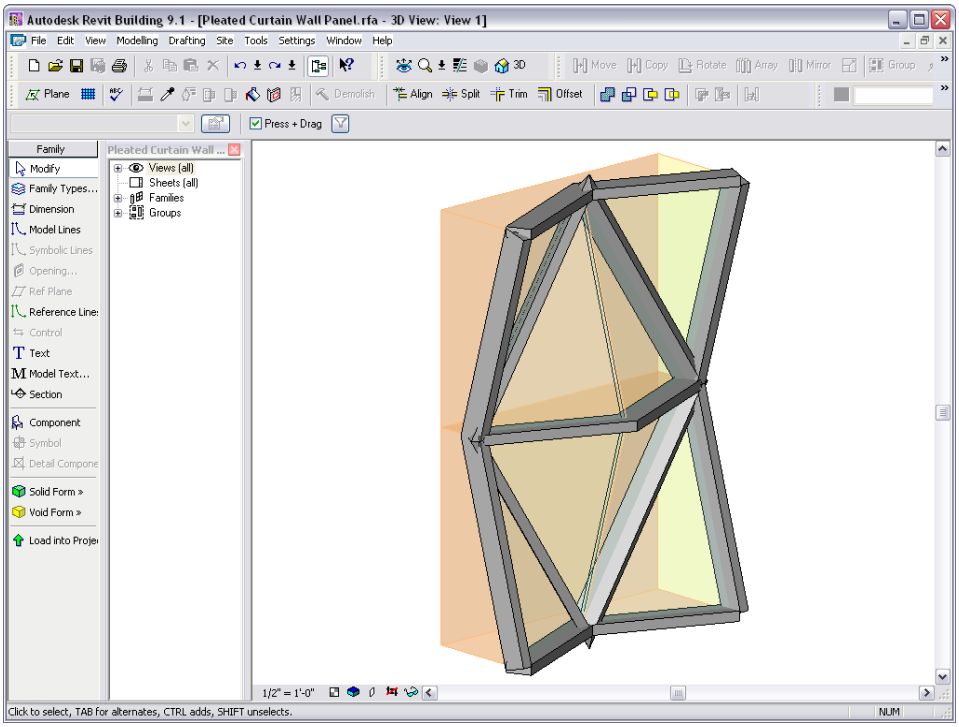

Figure 9:

The vertexes of the void are used to create mullions.

Conclusion

BIM solutions are often associated with the most time-consuming portion of the building design process – the detailed design and construction documentation stages.

That said, a BIM solution based on parametric modeling technology such as Revit Architecture can also be used for early algorithmic form finding – supporting broad explorations of design possibilities and architectural form.

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 software products 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 Autodesk Revit and the discipline-specific applications built on Revit please visit us at *http://www.autodesk.com/revit*.

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