AUTOMATION OF STANDARD CURTAINWALL CALCULATIONS

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By automating the structural engineering calculations of standard curtainwall units as part of the pre-sale and pricing phase of a building project, resources are optimized, building material quantities are reduced, and a standardized set of deliverables is developed for the bid proposal presentation. As a bi-product, automated calculations eliminate mistakes caused by human error in standard calculations. The automation of these calculations enables structural engineers to focus on job specific challenges that distinguish Enclos from the competition.

TIME

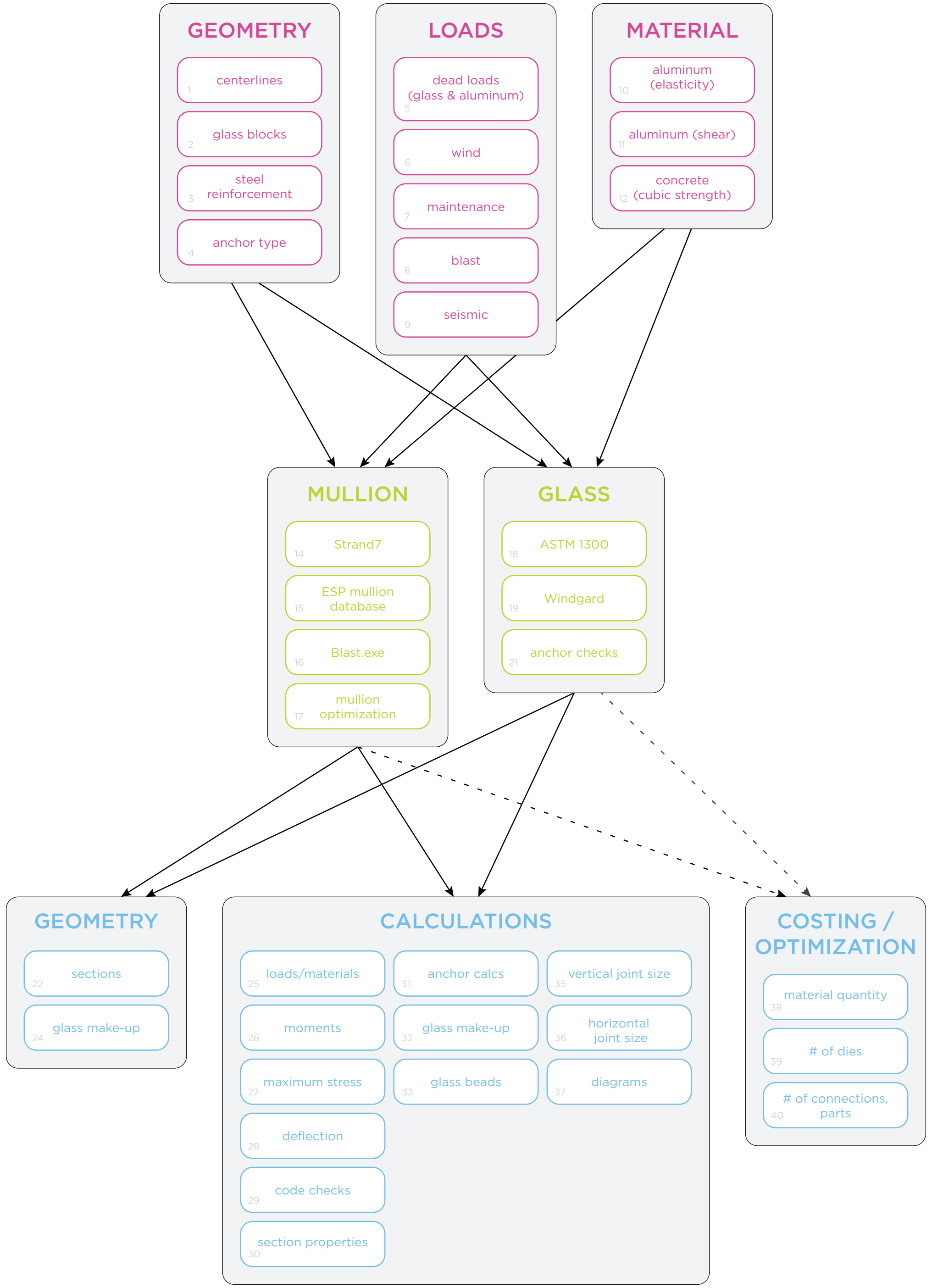
Throughout the bid process, structural engineers spend a significant amount of time on the design analysis of standard curtainwall elements. The structural engineer's sizing of facade elements and the designer's mullion section is a somewhat iterative process that is critical to the pre-sale process. If the Studios can reduce the turnaround time of proposals, we are able to bid for more work with the same resources.

STANDARDIZATION

The engineering calculations included in proposals produced by the Studio include unique content for each project. This is not desirable, at least for the standard curtainwall units. Although the added value of the Studio is embedded in the capability to solve nonstandard complex problems, there is no added value in varying the calculation report of standard curtainwall units.

OPTIMIZATION

Market conditions in facade manufacturing are moving into a direction that favor optimized use of material. Labor costs and logistical know-how may sway an owner in awarding a project, but everything else being equal, material quantities and associated costs are increasingly becoming a deciding factor. The structural engineer sets the limit of minimum amount of material that can safely support specified loads. The responsibility to optimize material quantities and increase the likelihood of project award rests in the Studios' hands.



GOALS

The goals of the automation effort are:

- Reduce the time to size members and produce the report for structural calculations of standard curtainwall units by a factor of 10. This reduction in turnaround time enables Enclos to bid an increased volume of work on an annual basis with the current structural engineering staff.
- Standardize the structural calculation output report for standard curtainwall units in Studio proposals.
- Optimize material use (glass and aluminum) to enhance the Studios' competitiveness in the marketplace (cost proposition).

SCOPE

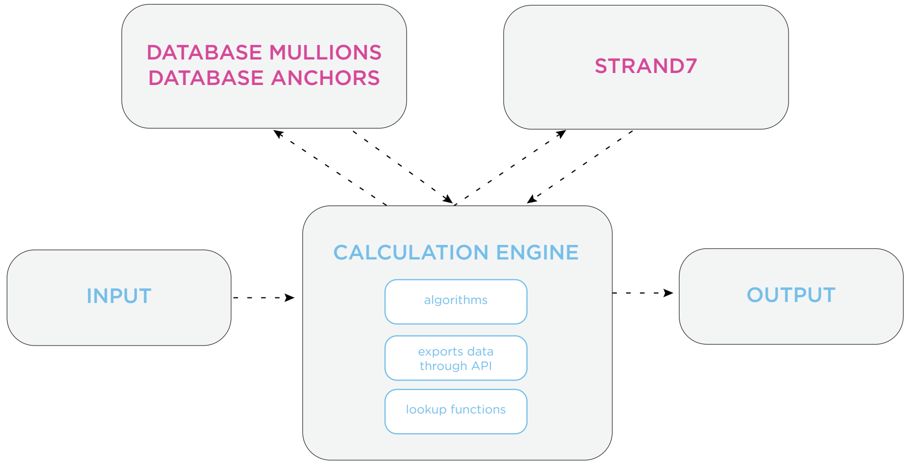
Standard curtainwall units (see Figures 3 & 4):

- Calculation package for pre-sale purposes to include in the bid proposal package.
- Elements span up to five building stories with varying floor-to-floor heights.
- Standard anchor types (top of slab and face of slab).
- Wind loads and dead loads.
- Minimum of three vertical mullions.
- Minimum of two horizontal mullions.
- Panel material transfers wind loads based on tributary area.
- Self-weight of the panels is concentrated at the setting block locations on the horizontal mullions.

COMPUTER PROGRAM

INPUTS AND OUTPUTS

Computer executable programs generally consist of inputs, a computing engine or process and outputs (see Figure 1).



COMPUTING ENGINE

Enclos uses the Strand7 calculation engine through the Application Programming Interface (API). Strand7 is used to analyze internal forces (i.e., bending moments and shear forces) and deflections of the structure of the curtainwall due to the imposed loads (see Figure 2).

STRAND7

Through the API it is possible to build and analyze a Strand7 model that is parametric without actually opening Strand7 by using a 'dummy' Strand7 model with the following elements:

- Nodes
- Beams
- Beam releases
- Plates
- Load patches with normal distributed wind load
- Concentrated loads
- Supports
- Material properties
- Section properties library
- Rigid links

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FIGURE 1
Automated workflow production for a standard engineered calculation package for curtainwall units.

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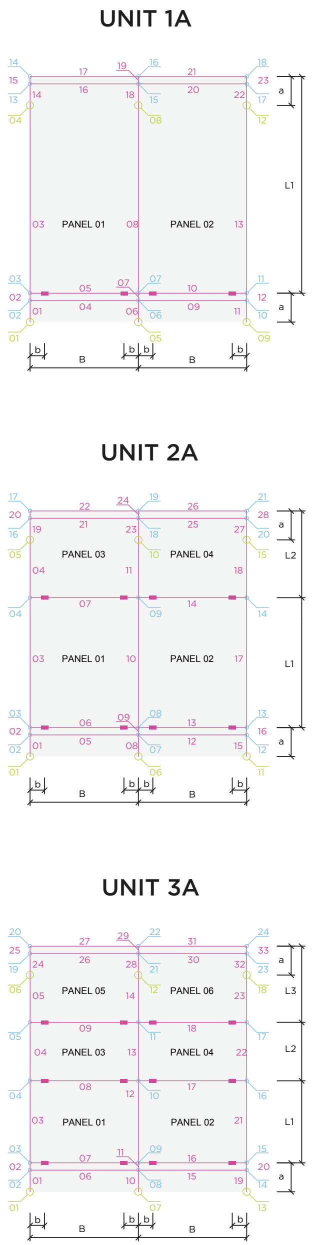
FIGURE 2
Diagram showing Strand7 API process in the program.



KEY

- mullions
- nodes
- anchors
- glass

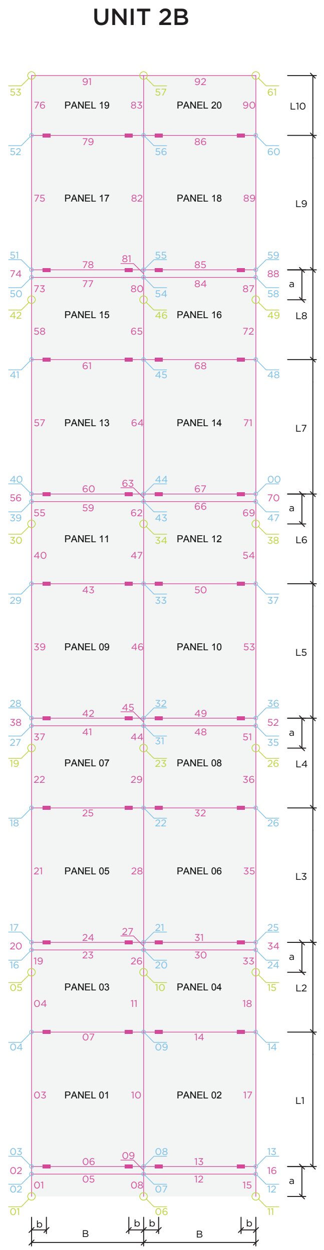


FIGURE 3
Three variations of a single-span unit.

FIGURE 4
A multi-span unit.

The elements in the 'dummy' model don't have the correct values since the model can be populated with the correct values by 'copy-pasting' the correct values into the model through the Strand7 API. After the correct values are thus imported the model is built and analyzed.

GEOMETRY INPUT

The geometry of standard curtainwall units falls into two categories.

SINGLE-SPAN UNITS

For single-span units, the three types displayed in Figure 3 are considered. The input consists of the length (L), the width (B) of the panels and the location of the setting blocks. In the future, more types can be developed, but for the first stage of the automation process the three types depicted above are developed. This is represented by 'Input Option 2'. Input of the node coordinates by the user is deemed to be cumbersome and error prone. The node coordinates, beams, etc. are generated in the calculation engine before the Strand7 model is built by the aforementioned process.

A 'toggle function' in the program enables the choice between single-span Types 1A, 2A and 3A, or the multi-span Types 1B, 2B and 3B.

MULTI-SPAN UNITS

For the multi-span unit (Type 2B) in Figure 4, the input consist of the lengths (L1 through L10), the width (B) of the panels, the location of the stack joint (a), and the location of the setting blocks (b). Type 1B and 3B have similar input. The difference between the types is the number of panels. Type 1B has inputs for L1 through L5 and type 3B has inputs for L1 through L15.

In the future more types will be developed, but the first stage of the automation process consists of these three types.

RESULTS

CURRENT STATUS

Enclos chose to produce an executable file scripted in C# with several user input screens. Results include:

- Creating a Strand7 model with the correct geometry for Type 2B walls that is both quick and effective.
- A database/library of previously designed mullion sections that can be referenced and continually added to.
- Pre-processing of wind loads in accordance with ASCE7-2010.
- Post-processing of mullion sections as part of standard report output.
- Saving the Strand7 model and results file in a location accessible to the user. Any data in the Strand7 model and results file is therefore retrievable and auditable.
- Standard report with graphics are available within a much accelerated timeframe.

FUTURE WORK

Eventual iterations to include:

- The creation of additional wall types.
- The creation of double span wall types.
- Incorporating anchor calculations into the program, including seismic loads.
- Incorporating glass make-up calculations into the program.