VIRTUAL DESIGN AND CONSTRUCTION:

An Owner's Perspective

By Robert Malczyk

In the 1990s, 3D modelling was introduced as a design tool that enabled architects to better visualize their projects and perhaps more importantly, to convey their ideas to clients and the public. The software has become so sophisticated that it is sometimes difficult to decide whether an image is a photograph of a completed building, or simply a rendering of one that is proposed. It is not difficult to understand why this photo-realistic capability of modelling software has been so seductive for architects, but it is time to explore the real value it can provide.

1

It is only recently that 3D modelling has advanced to the point where we can explore the process of construction. The software not only enables design teams to identify and resolve potential conflicts or 'clashes' between elements of the building designed by different disciplines but, by adding the fourth dimension of time, enables us to visualize the sequence of construction. This ability to analyze and optimize alternative approaches, has the potential to further improve the efficiency and economy of construction.

While engaging key members of the project team (including the general contractor and major subtrades) early in the design stage comes at added cost, the conventional wisdom is that these costs are more than offset by reduced construction time and fewer changes on site. As a theory, this seems reasonable but, despite the claims of software manufacturers and specialist 3D modellers, it does not typically result in 'real world' savings for the client. My recent experience as a developer has given me insight into why this is so.

LESSONS FROM THE ON5 PROJECT

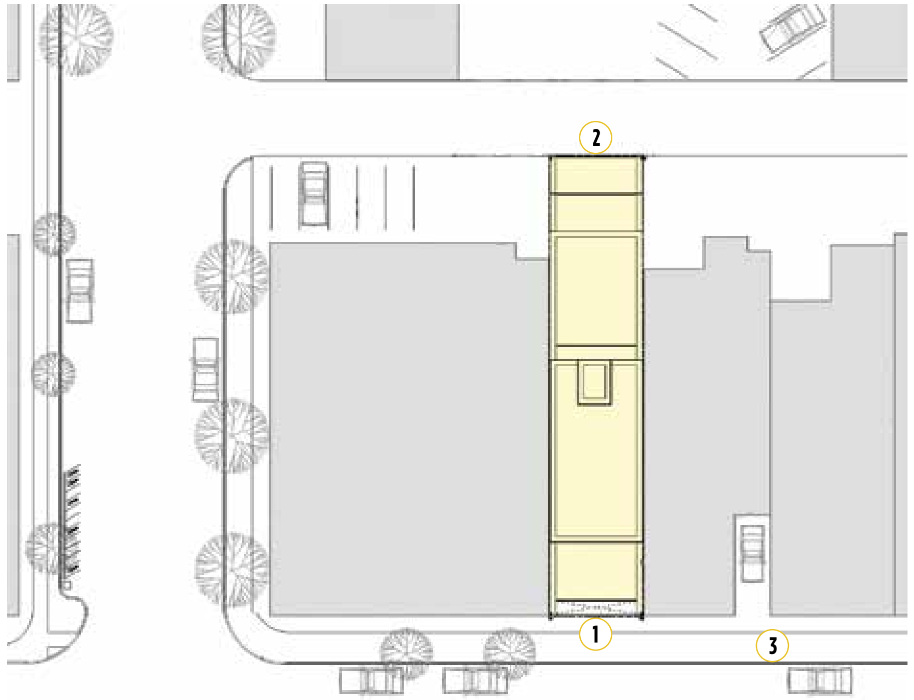
ON5 is an 840m2, 4-storey commercial/industrial infill project located on a 7.6m wide infill lot in Vancouver's Mount Pleasant neighbourhood. The zero-lot line condition and prescriptive zoning requirements already made this a challenging site to develop; to which was added our objective to achieve Passive House performance.

The team we assembled, including Hemsworth Architecture, Naikoon Contracting and myself as structural engineer, had been working together on 1 Lonsdale Avenue, a small commercial infill building in North Vancouver (see SABMag 72, Fall 2021) so we were able to benefit from the lessons learned on that project.

3D SOFTWARE AND THE DESIGN PROCESS

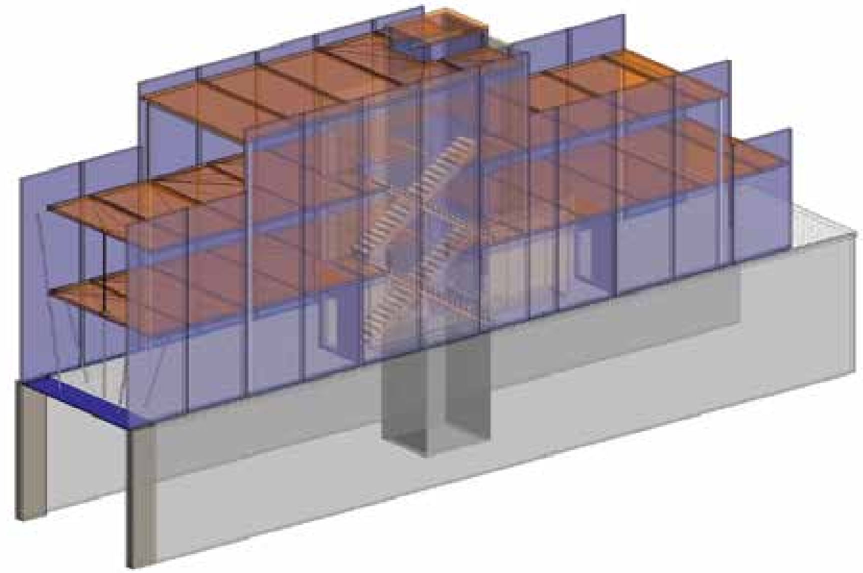
Over my career as a structural engineer, I have used numerous 3D software packages, including ArchiCAD, cadwork, Revit and Rhino. Most timber engineers have settled on cadwork, which is now powerful enough to produce 3D models to shop drawing quality. Yet the question among designers remains, 'At what stage should we start creating models at this level of detail, and who should take responsibility for their accuracy?' Standard industry practice is to have the contractor prepare the shop drawings and take on that responsibility.

With ON5, we began to create these models even before we initiated an integrated design process. Working with the architect, we figured out some of the more complicated details, such as the scissor stairs that were required to make the program work. Then, for pricing purposes, Naikoon Contracting created the first Revit model to determine material quantities. In what has become common practice, we continued to use cadwork until we completed the IFC (issued for construction) drawing set, after which everything was discarded.



Site plan
1. Front entrance 2. Class A loading 3. Existing sidewalk

1. A rendering of ON5, an 840m^2, four-storey commercial/industrial infill project located on a 7.6m wide infill lot in Vancouver's Mount Pleasant neighbourhood.
2. The zero-lot line condition of ON5. Credit: #1 Hemsworth Architecture.



Revit Construction Model

3. Virtual construction analysis showed that the optimal staging area to be the floor slab of level 2.

At that point, we started another cadwork model to 100% shop drawing quality, the only real difference between this model and the previous one being the attention to detail. In the first iteration, we might have marked a particular dimension as 7.62m; when it was actually 7.625m. When you have all the consultants going through this same process, there is a duplication of time and effort that is both wasteful and costly to the client. It may not be appropriate to work at this level of detail at the conceptual design stage, but an integrated, shop drawing quality model could and should be created much earlier in the process.

When an integrated design process is used, then the responsibility for creating a durable, high-performance building becomes a team effort and a shared responsibility, the success of which should result in a shared reward. This is not something that is easily achievable under current contractual arrangements.

SETTING REALISTIC EXPECTATIONS

The sales pitch from the software companies, modellers and even some consultants, may claim that an accurate 3D model can eliminate all conflicts between the work of different disciplines, but in practice it can't. The model is something that helps construction but it cannot make construction perfect. It is not a question of all or nothing, but rather what is a reasonable target to achieve.

Just as the 15kWh/m2/year energy prescribed for Passive House certification cannot be achieved economically on many projects, but 30kWh can, so we must be reasonable about our expectations with models. Rather than 100% 'clash detection' perhaps a target of 60-70% would be reasonable.

As an owner, you need to look at where the use of 3D and 4D modelling actually saves you money by speeding up construction. Using an outside consultant can result in exhaustive clash detection lists, with several hundred items presented without any hierarchy of importance. The additional time taken by consultants to review their lists, results in added costs to the owner. We need to differentiate between the clashes that are 'must do' the 'would be nice' and the 'too minor to bother about'. This approach would allow the consultants to create an action plan that could actually be implemented.

THE VALUE OF VIRTUAL CONSTRUCTION

Most important on tight sites such as ON5, is to build your building virtually, with all parties in the room. When you involve the crane crew; the erection crew and someone who knows the rules and cost of closing off the street, you can determine whether having to close a street for an additional week, or bringing in a higher capacity (and so more expensive) crane that can speed up construction is the better choice.

For ON5, we had ten or more meetings to review, evaluate and optimize the construction process, with ideas being put forward by all of the players. Like design, this is not a linear process, but in the end, you build a team with a shared understanding of the problems and the process required to address them. For those consultants who still think they know best, it is salutary to find out that some of the best ideas come from the tradespeople who really know their job.

STAGING & SEQUENCING

The necessity of a staging area where materials can be laid down prior to assembly is an important consideration for planning construction on any site, but it is critical on a zero-lot line site like ON5. Virtual construction enabled us to explore alternative sequencing, on a site where the only staging area was the floor slab of level 2. As a result of this analysis, we closed off the stair opening to the ground floor to create a continuous flat surface for maneuvering; chose a crane that could reach from the street to the rear of the lot; reduced the size and weight of some CLT panels to ensure they could be lifted, even when the crane was fully extended; and established the installation sequence for the CLT panels, ensuring that those already in place did not impede the installation of those that followed.

4. Virtual construction analysis also decided the selection of a crane that could reach from the street to the rear of the lot.

CONSTRUCTION SAFETY

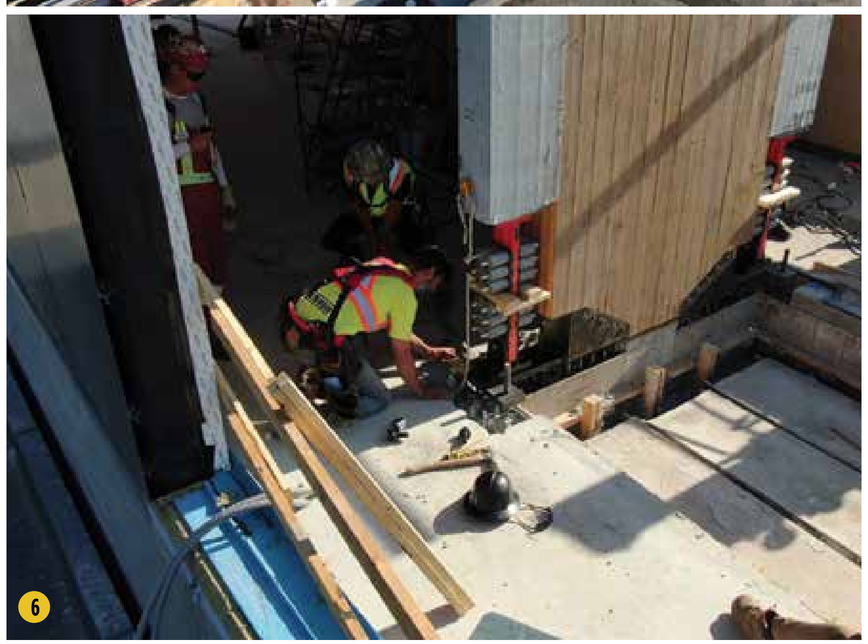
All the while, we had to ensure that, at the end of each work day, we had a structure that was strong and stable enough to resist whatever wind force it might experience over night; and also, that the panels were adequately protected from damage by rain.

This information also informed us which components had to be prefabricated and which did not. Again, rather than an all or nothing approach, we were able to make the decisions based on the value prefabrication would provide. Given the need for a stable structure at the end of each day, we prefabricated interior walls, stairs and landings – as all these elements were required for stability as construction progressed.

The other strategy that came out of this was to build the structure from back to front, rather than from bottom to top. We also 'balloon framed' the building, using full-height CLT panels – an alternative solution not yet codified because of ductility concerns.

TRUCKING AND HANDLING

We also looked into the logistics of trucking and handling, concluding that stacking panels horizontally would avoid the potential crushing of panel edges and enable us to lift them from picking points on the top of the panel. The installation could then be done without causing excessive stress. This limited us to one fully enclosed prefabricated panel (used for the fire resistance rated zero lot line side walls) per truck. This also contributed to our decision to construct the building from back to front.



5 and 6. 'Threading the needle' - lowering and securing one of the full height CLT panels.

Even then we had to consider what could be achieved within a standard eight-hour day, and whether each shift would enable us to reach a point where the structure was stable enough to be left overnight.

Another concern was how to install the hold-down anchors for seismic restraint, as they were too heavy to be lifted by hand and too large to be stored easily in the limited staging space. In the end we changed the details for anchoring into the concrete slab and accommodating the anchor itself within the CLT wall.

TRAINING THE TEAM

As we resolved these issues, we began to record the construction sequencing in a movie file on Revit. Not only did the entire workforce know how work was going to progress and what their role in it would be, but we divided the sequencing into 15-minute intervals showing each worker where they needed to be on site, and what tasks they were expected to perform. We began this process about four months ahead of construction, and with hindsight one can compare it to an athlete training program ahead of a big event. Athletes visualize how they want things to unfold on the day; in our case, we used virtual construction to train an entire team, so they could visualize the process from start to finish.

Nonetheless, work went slower than planned on the first day; but then speeded up a little on the second day and continued to improve throughout the first week. We had planned from the outset for a construction to take place in July and August, taking advantage of Vancouver's drier summers. We were lucky with the wind and, when the rains came early in mid-September, the building was already enclosed.

FINAL THOUGHTS

As architects and engineers, our use of 3D modelling technology has been largely focused on the beautiful, rather than the meaningful. Glamorous renderings may be powerful tools for marketing design, but 3D software can deliver far more value when we focus on construction. Only then, through a process of experimentation, collaboration and optimization, can we achieve the real goals of efficiency and economy.

Even these goals are constrained by current contractual arrangements and implicit assumptions about responsibility and liability. Virtual Design and Construction is primarily a tool that facilitates meaningful collaboration, and only by re-examining the contractual instruments of project delivery can we maximize the benefits it can offer to all members of the project team – including the client.

ROBERT MALCZYK IS A STRUCTURAL ENGINEER AND PRINCIPAL AT TIMBER ENGINEERING INC. IN VANCOUVER BC

7. The project refined the virtual construction process in a series of meetings held over four months.
8 and 9. The virtual construction process also informed the choice to build the structure from front to back of the lot.