210 King Street: BIM Case Study

Introduction

The development of a BIM model for 210 King required a different approach than what could be expected from the BIM process for new construction. Critical elements needed to be discovered and identified rather than drawn and detailed, structural ambiguities had to be resolved empirically rather than inferred from construction drawings, hidden wall sections had to be assumed rather than be assembled. In the case of 210 King which involves the interaction of 4 buildings built at different times, the interaction between the buildings themselves had to be understood beyond simple connecting blocks. But above and beyond this, the nature of the approach to understanding this heritage building in terms of BIM was very unique.

The process was hampered by unknown wall compositions, surveying inconsistencies, various sets of blueprints and plans that did not match, and ambiguous interactions between elements which could not be discovered without actually ripping holes in the walls. The use of BIM 'families' had to transcend their usual purpose as re-usable building elements; instead, 'families' were often used to connect the standard elements to the ad-hoc maintenance and repairs which occurred over the life of the building. Whether or not this extended use of families will cause an issue in the future simulations is unknown at this time.

The main difference between BIM for existing construction and BIM for new construction is that existing architecture has a life story – it has experience and exists in time. All of this is etched in its architecture, its maintenance, and its inhabitation. By going through this process, some discoveries were made that helped the building communicate its story. For 210 King, the process of creating the BIM dataset had the added effect of revealing the story embedded in the architecture.

In this preliminary case study, a few of the storylines embedded in 210 King Street, discovered by virtue of their interactions with our approach to the BIM process, will be described.

The Approach

The following is a brief overview, in chronological order, of our approach to creating the preliminary BIM model for 210 King.

- Site documentation (1^{st} round of measurements, photography, research)
- Grid design in Revit Arch.
- Exterior wall construction (ongoing) (2^{nd} round of photography, measurements)
- Development of structural systems
- Floors
- Circulation (3^{rd} round of photography and measurements)
- Roof and roof elements
- Room definitions in Revit Arch.
- Space definitions in Revit MEP
- Centralizing the file for collaborative workflow

This approach developed organically, based on necessity and on-site problem solving. The ability to immediately check assumptions against the actual architecture was a great benefit to the process of creating a BIM dataset, especially since the architectural drawings we had were not very accurate. The approach began with general photography of the whole building. The inaccurate but aesthetically acceptable CAD drawings were imported into Revit Architecture as an initial building block to help get a 'feel' for the building. The process of discovering and correcting the errors in the CAD files was the first glimpse into the story of 210 King. The discovery of windows that were bricked over, doorways that didn't exist anymore and unnaturally deep foundation walls hinted at a rich architectural history. What is sometimes revealed in architectural details as a singular 'process of making' seemed a chaos of changes, repairs and renovations in the details of 210 King.

Confronted with these details, the only plausible approach seemed to be to simply follow the leads the building was giving us. Although the process is outlined in chronological order above, it simply represents the general path the building led us through. In reality, although we started with the grid design in Revit, we had to revisit it multiple times for fine-tuning. The exterior walls were started early, but they were the last elements to be completed, and still warrant further study and analysis. Similarly, the exact dimensions and positions of the circulation spaces, the offices, and the floors needed to be fine tuned throughout the project, as newly discovered information changed proportions or measurements back and forth.

The Structural Grid

As with most new construction, the structural grid is the first BIM element that was defined. In the case of 210 King, 4 different structural grids were interacting in plan, while 2 sets of floor elevations were interacting in section.

As can be seen from *Figure 1*, the structural grids for BLDG3 and BLDG4 are off by about 2 degrees. This slight offset was discovered by examining the plans from the architecture firm which organized and executed the 1997 renovations of 210 King. As it later turned out, the firm only focused on certain very specific areas of the building and as such, their overall plans and elevation drawings were not an accurate description of the building measurements. At the time of this writing, it is not easily possible to confirm this offset exactly. How or why these offsets exist is not entirely known to me, although we might speculate that the natural movement and settling of the building over time may be responsible for some of the deviation.

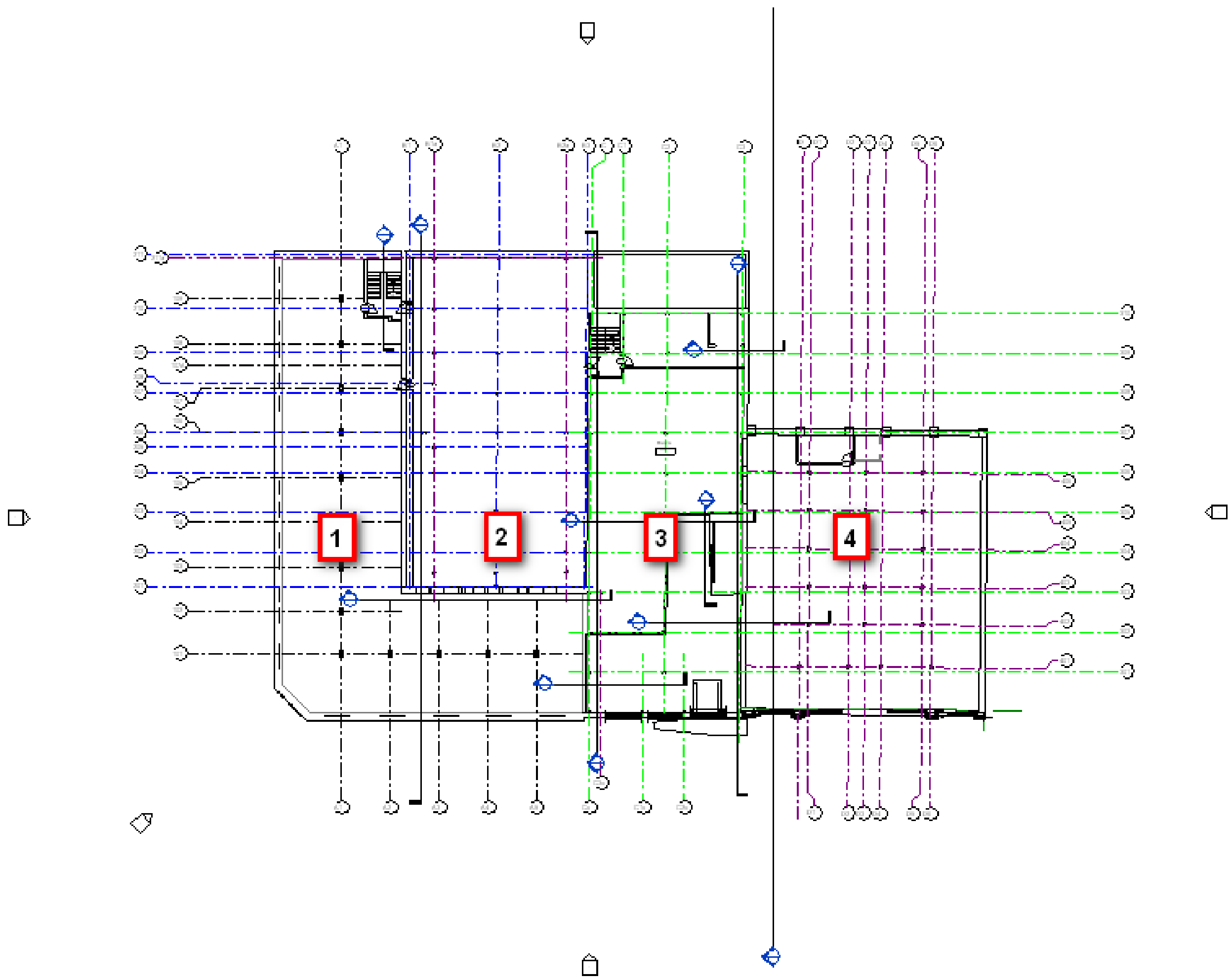

Figure 1: *210 King – Buildings 1 to 4 – grid lines. BLDG3 and BLDG4 girds are slightly askew*

In elevation (*Figure 2*), the floor heights of BLDG 4 were slightly lower than those for the other 3 buildings. This was not a difficult problem to deal with, but indicated that the connections between BLDG4 and the rest of the buildings had to be carefully examined.

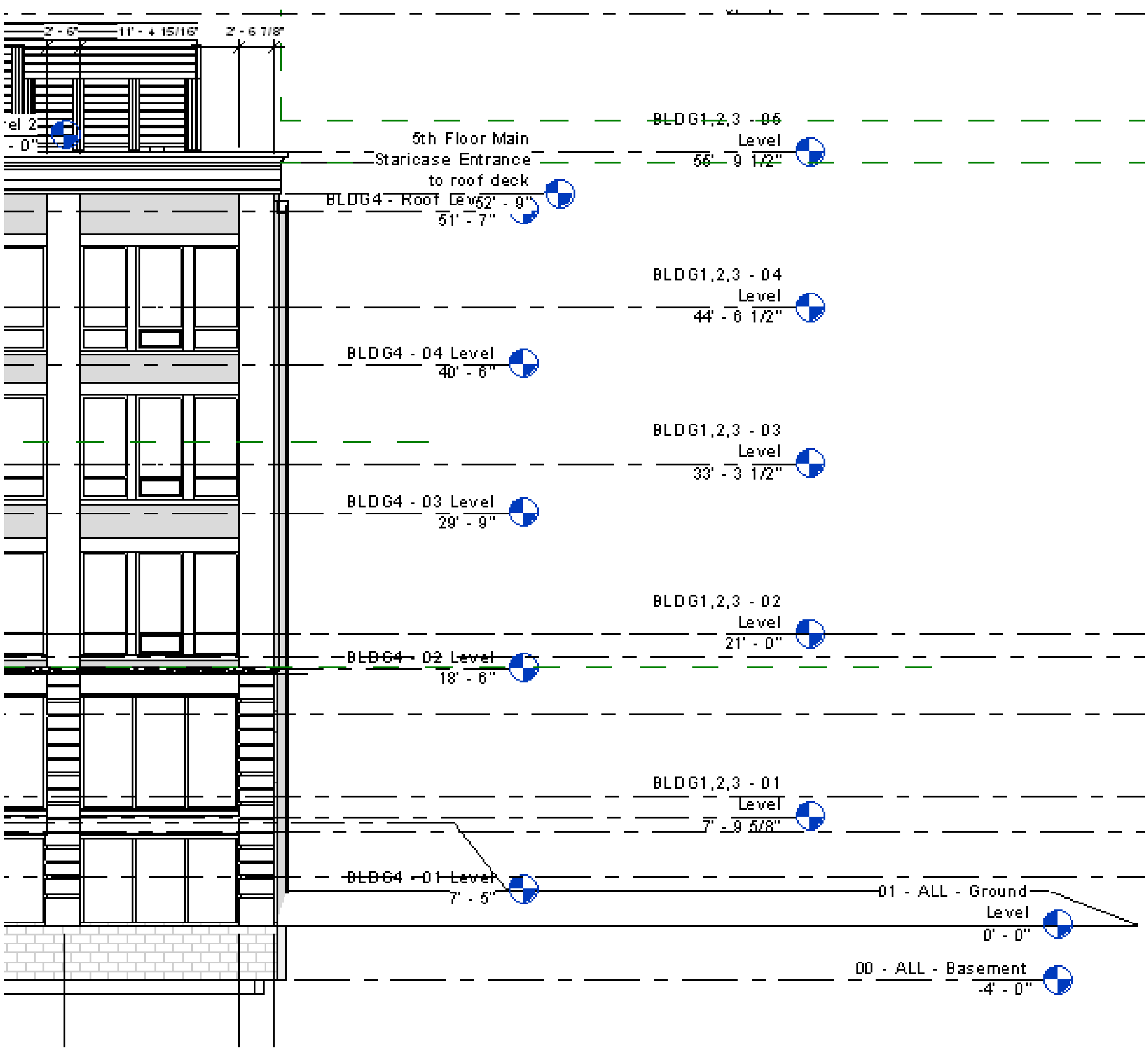

Figure 2: *South elevation view showing the level heights for BLDGs 1 to 3 and BLDG4. BLDG4 levels are slightly lower than the rest.*

In addition, some of the structural elements did not lie directly on the simplest structural grid, so additional sub-grids needed to be created to accommodate these renegade elements.

Exterior Walls

Beginning an analysis of the exterior walls of 210 King was not an easy endeavor. First off, the wall sections were not clearly visible from any angle – short of taking a core sample through the wall, it would not be possible to determine exactly how the wall built. Clues found throughout the building, however, allowed some inferences to be made.

The exterior walls of all 4 buildings were joined together in several places. Determining the nature of this joint required examining the interior and exterior conditions around the joints. Even with such examinations, it was difficult to determine exactly how the walls were joined together. To clarify, this is not an issue of whether or not one can design an appropriate joint for that condition – the issue is whether or not we can determine exactly what was done to join them together, and keep the amount of guess work and inference to a minimum. This way, the information is not only accurate, but useful and reliable. Unfortunately, not all the joints were accessible in a manner that would allow empirical knowledge of their construction, and some inferences were necessary to continue the model. Once the model is being used for simulations, we can then revisit these areas and determine whether or not our inferences are plausible based on the data from the simulations.

Foundation Walls

An interesting part of the 210 King story is the order of erection of the 4 buildings and how their foundations interact with each other. For example, *Figure 3* shows how the foundation walls of BLDG1 and BLDG2 are positioned right next to each other. At first, it was not immediately evident exactly how the walls changed as they rose vertically through the building. We knew that the foundation walls were thicker than the upper walls from simple observation; however we couldn't tell exactly where the changes were taking place. Some of the brickwork was covered, sometimes by drywall, sometimes by plaster, and details were being lost. It was around this time that we discovered the stairwells.

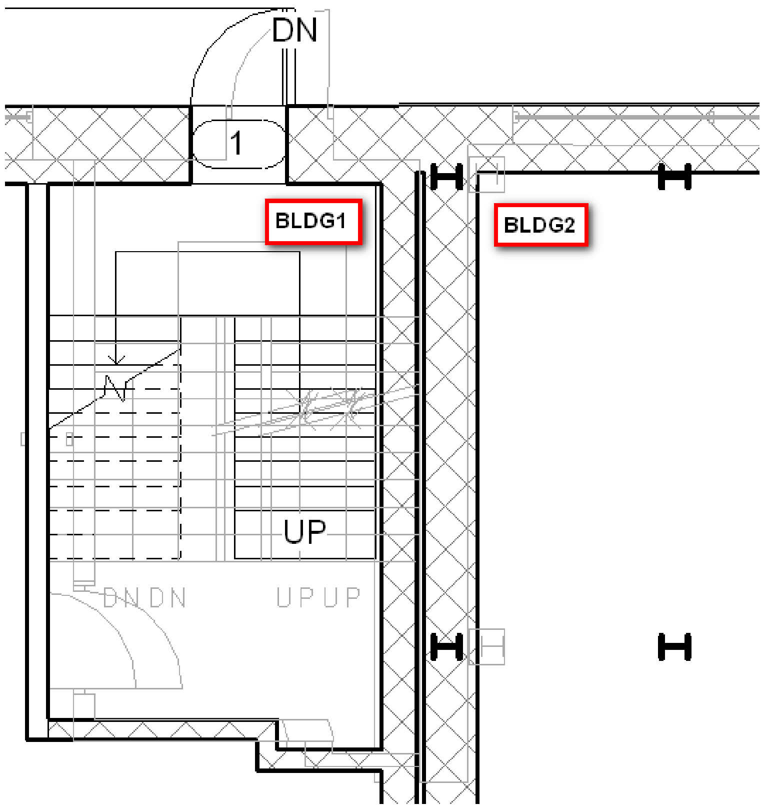

Figure 3: *BLDG1 and BLDG2 Adjacent foundation walls and exterior walls.*

Stairwells: An Architectural Core Sample

The most interesting part of 210 King was the stairwells – most of the main and emergency staircases were located at the junction between 2 buildings. We had found a data goldmine. Not only was the brickwork left exposed, but we were able to see exactly how the wall thicknesses changed from the basement right up to the roof. The stairwells became the most precious data-well in the entire building, and like a geological core sample can tell us of the history of a place, so did the stairwells tell us exactly how and why the wall thicknesses changed. In some areas, the wall thickness seemed to be much thinner than would have been required if the buildings were not leaning against each other for support. In fact, from our observations, we might guess that the east wall of BLDG1 is actually offering some of the support for the west wall of BLDG2, which would indicate that BLDG1 was built before BLDG2. This hypothesis would have to be tested with structural simulations to be confirmed.

Figure 4: *Stairwell between BLDG1 and BLDG2*

Red lines indicate changes in materiality or thickness in the east wall of BLDG1 / west wall of BLDG2

Revit Families

Families were a particularly useful way of dealing with many of the custom details of 210 King. Some of these details included the ornamentation on the exterior walls, the brick arches over many of the windows, the various types of entryways, surface columns, etc.

One of the problems when dealing with families such as windows or doors in a model such as 210 King is the recurring situation where the family is positioned will cut through 2 different wall types, such as a brick wall sitting on top of a foundation wall, with the vertical center of the doorway lying on the joint between the 2 wall types. Often, the family will only be recognized as hosted within a particular wall and only cut that wall instead of cutting both. There are 2 possible solutions to this problem – One would be to change the “construction phase” of all the items to a matching phase. The other would be to use the ‘curtain wall’ object to allow a cut through both walls, since the curtain wall is defined as another wall type rather than a doorway or a window. A door can then be added to the curtain wall.

Again, it is unclear how these types of substitutions and solutions will affect simulation results.

Revit Rooms

As the floor-plans of 210 King are open-concept, unbounded spaces, defining rooms in 210 King requires an understanding of the layout of the mechanical and electrical systems and their effects on various parts of the building. Since the MEP systems are still to be modeled, the room definitions are not permanent – they will require updating and fine-tuning in order to be useful for analysis. For example, every floor has an open kitchen nested in one of the hallways. The heat generated from the refrigerator, microwave, coffeemaker and so on are localized to a particular part of the hallway – which means that this part will need to be considered an individual room, even though it is a part of the hallway. Although the room has been defined in the current BIM dataset, this may need to be altered depending on the location of a vent or extra outlet that may fall outside the currently defined boundaries. If this occurs, the room boundaries will be adjusted to include all these interrelated systems. The ability to go back and forth between Revit MEP and Revit Architecture allows for this flexibility throughout the BIM process.

Revit MEP: Spaces

In Revit MEP, the 'spaces' were defined in much the same way as rooms. Further work in MEP will involve the calculation and modeling of circulation densities, electrical loads, and mechanical systems in each defined 'space'. Once these parameters are input, the simulations can then be programmed to test the sustainability of the electrical and mechanical systems used at 210 King.

Overall Progress

At this point in time, the BIM dataset for 210 King includes the following:

- Exterior walls, foundation walls, roof, and roof deck
- Interior walls and floors
- Circulation including elevators and emergency stairs
- Entrances and exits
- Windows, doors, and other openings

- Structural system (beams and columns)
- ‘Room’ boundaries and ‘space’ boundaries for sustainability simulations

Still to be added or enhanced:

- Some textures need to be altered
- Some wall sections need to be confirmed
- Furniture and cubicles need to be added
- Mechanical and electrical systems need to be added and spatially defined

Concluding Remarks

A question that often occurs is “when do we know when we have a complete dataset?” As this is a preliminary case study, the story of 210 King is still disjointed. There are still many variables present in the dataset which will need to be addressed in the next phase. This is exactly why the BIM process is so useful: learning how exactly 210 King is put together, piece by piece, reveals the story. Once the story makes sense, the BIM model is complete. For existing architecture, BIM is as much a process of understanding and experiencing as it is one of documentation.