BIM for Existing Buildings: Best Practices

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SE1510 Capitalizing on Building Information Modeling (BIM) for new buildings is easy—you get to start with a fresh, clean file, and you can lay out everything you need precisely where it is supposed to be. However, what if you are doing an addition, a renovation, or historic preservation? Most of what is important to a structural engineer is probably hidden behind an existing facade or finish. And yet the model must go on. This class offers tips and suggestions for modeling existing structures, including extrapolating information from incomplete data, identifying known and unknown elements, and managing ownership of scope areas.

Learning Objectives

At the end of this class, you will be able to:

- Identify potential pitfalls when modeling existing buildings
- Get relevant information at a BIM kickoff meeting
- Use phasing and view filters to identify existing and new elements
- Asses the pros and cons of laser scanning

About the Speaker

Robert Silman Associates is a structural engineering firm with offices in New York, Boston, and DC. As the Digital Design Manager for the firm, Kate is responsible for coordinating procedures and standards for software used in the design process, including CAD, BIM, and design/analysis programs. Before rejoining RSA (where she also worked from 2003 to 2008), Kate was a Technical Marketing Manager for Autodesk, working on the AutoCAD family of products, specifically AutoCAD LT. She has over 10 years' experience with Autodesk products, and has been a highly-rated AU Speaker since her first AU in 2004.

Introduction

Any BIM project will have its own sets of challenges. That's especially true for work on existing structures. This handout will go over some of the concerns particular to renovation, restoration, and remodeling.

- Successful BIM kickoff meetings and project setup
- Acquiring information about the existing building
- Strategic modeling for existing structures
- Using phases to mange a project lifecycle

Starting at the beginning of the design process, making sure you start your project poised for success. Then we'll move on to acquiring information about the existing building, whether that's through paper drawings, CAD files, or laser scans. Next up, modeling strategically. What can you model? What should you model? And how do you know how real it is? Finally, we'll spend some time talking about phases, and how you can use them to make sense of your project's lifecycle.

Starting Off Right

Every project, new or existing, should start with a clear vision of the model. And it's important that everyone on the team have the same vision. Your chances of getting that unified vision go up exponentially if you have a BIM kickoff meeting.

Every project, no matter how small, needs a BIM kickoff meeting. At a minimum it should involve two people from each firm—one designer & the project's BIM lead. This way you have people who speak both "languages" at the table, and can cover each issue from many sides.

At a BIM kickoff meeting, you'll want to go over the project's BIM Execution Plan (BEP). If you're a subconsultant, you're probably lucky—the architect will often take the lead on this document. But if they don't, you can, and should. There are many resources available for creating BEPs, and an excellent place to start is Penn State's BIM Planning website (http://bim.psu.edu/). They have all kinds of articles and downloads to help you develop your own BEP.

A typical BEP will cover as many aspects of the BIM process as the team can come up with. It may include (but is not limited to):

- Who's on the team
- The goals and uses for the project
- Deliverable and information exchange requirements
- What version of Revit will be used
- File naming conventions
- Workset conventions
- Shared coordinates
- Authorized uses and expectations
- Inter-team dependencies
- Level of Development criteria
- Model element ownership

For that last item, you may want to fill out a Model Element Table (MET), also known as a Model Element Worksheet (MEW) or Model Element Matrix (MEM). This is a document that spells out who is going to model what, and to what Level of Development, at each stage of the project. The AIA provides a table that can be used as a template, in Section 3.2 of E203 (http://www.aia.org/groups/aia/documents/pdf/aiab095712.pdf). It may or may not be sufficient for your needs. You may find it more helpful in an Excel format, and Google can help you find some samples.

There are other things to add to the standard kickoff list if you're dealing with an existing building. Things like:

- **Availability of existing documentation.** What do you have? Is it complete? What format is it in?
- **Reliability of existing documentation.** If you have documentation, how good is it? Does it reflect any alterations made previously in the life of the building? What is it based on—the original design, as-built drawings, a recent field survey?
- **Scope of work.** Is this a complete gut & renovation? Seismic retrofit? Isolated work on some stairwells? Your BIM team needs to understand the scope just as well as your engineers & designers, so they can concentrate their efforts in the best place.
- **Scope of model.** How much of the building is the team going to model? What are we going to do about areas that outside the scope of work?
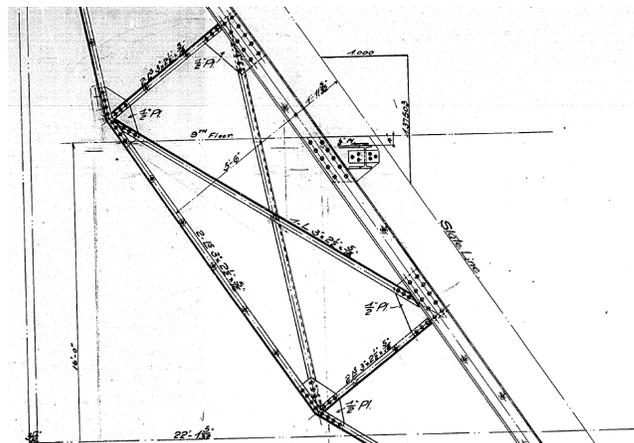
What's Out There?

Once you've got the essentials of the modeling process down, how do you find out exactly what to model? It's one thing for a new building, where you don't have anything old to worry about. For an existing structure, you probably don't have an as-built, well-maintained 3D intelligent model. (Won't it be nice when all buildings have those?) Instead, you work with what you've got. And when it comes to existing buildings, sometimes that's not a lot.

As important as the structure and infrastructure of a building is, it often gets covered up by architectural elements. And all right, it usually looks better that way. But the result is that essential elements for structural and MEP models aren't available for easy evaluation and measuring. This isn't just a BIM problem. Even in 2D, it's important to know the details of a building's construction. So, how do you get it?
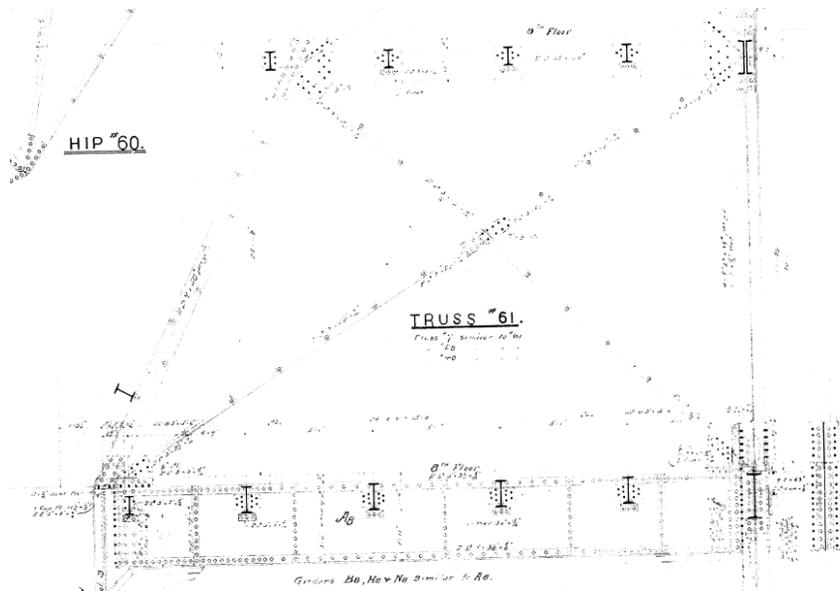
Existing Documentation
If you're lucky, you have the original building drawings.

If you're *really* lucky, they look like this:

If you're not, they look like this:

In that case, all the documentation in the world isn't much help.

Even with the best documentation, you have to "trust but verify". There's a reason post-construction documents are called "as builts", not "as designeds". So you go out to the field...and you still can't see what you need. (Because the architects covered it up.) Sometimes it's exposed structure...sometimes you're allowed to do a few probes. Most of the time, you have to interpolate and extrapolate based on the little you can see. There will be more on how to deal with the reliability of this information a little later.

Building Scans
What about X-rays, or ground-penetrating radar (GPR)? They can be extremely useful in certain situations, but not always. Structural engineers most often use GPR to locate rebar in concrete. This can be essential information for evaluating the capacity of an existing structure, but not as helpful for creating construction documents. So it is another form of BIM, but certainly not a panacea.

What about laser scans? They're a great tool, but not always as helpful as you would hope, at least from a structural perspective. First, they have the same problem as visual surveys—if you can't see it, you can't scan it! There are other logistical concerns as well, like tying together surveys done in different rooms, or getting access to extremely tight spaces. That said, if you have exposed structure, and a talented modeling team, you can get some really good results.

Tips for Laser Scanning
In order to get those good results, there are some things you need to consider before even starting the project.

First, what *exactly* do you need from your model? Are you intending to use it for analysis, or simply for documentation? If it's for analysis, what kind of elements will be best suited to the structure? Many analysis programs support shells, solids, and plates. Depending on your material and construction, one may be better than the others, and it's important that your scanning team know the goal ahead of time.

Second, can you get access to what you need? If you can't see the structure, how confident are you that you can interpolate from the architectural elements that you *can* see? How much space do you have to work in? Confined spaces present a challenge to laser scans, both in terms of physical space and in terms of connecting discrete scans to make one overall model. Is there anything else in your way, like scaffolding or temporary structure? If so, how are you going to work around it? The laser scan will pick up scaffolding just like it picks up real building elements.

Third, will you be able to use the data you get? How will you handle the "smoothing" out of points to get a workable structural element? (See above on scaffolding.) Who will do your shape extraction? Do you have the expertise to handle it in-house or should you work with your laser consultant? Assuming you leave it to the laser pros, what kind of elements do you want from them? (See above on analytical elements.) If you need your 3D model to contain plates, whose corners are interpolated between the interior and exterior points of the wall, floor, or roof, make that known in advance. Otherwise you may get solid elements, with no "centerlines"...which may or may not be what you need.

There are probably fourth, fifth, and sixth points to consider, but they'll vary depending on your specific project. And there aren't any easy answers to the first three topics—again, they'll vary with the project. But if you can figure out what you need as early as possible, and identify as many challenges in advance as you can, you'll really improve your chances of getting a good scan and model.

Strategic Modeling

Once you've got as much information as you can get (whether it's from existing drawings, laser scans, or regular field surveys), it's time to get modeling.

STOP **Before you so much as place a beam, think about what you need to model.**

Maybe you've got a contract to model the entire existing building—great. Maybe you've got such good existing documentation that it just makes sense to model the whole thing—great. Maybe the work is so extensive that you need to model the whole thing for coordination purposes...great?

On the other hand, maybe the scope of your part of renovation is fairly limited. Maybe your work is confined to specific areas, and you're leaving the rest of the building alone. In that case, why would you model the whole thing? Especially as a subconsultant, when you can take advantage of the architect's work to use as backgrounds to provide context for your elements. (Sorry architects, there aren't usually any shortcuts for you.)

For architects and MEP engineers, the entire building is often in your scope of work, since you're dealing with details as small as paint colors and light fixtures. But since structural engineers don't care about paint colors and light fixtures (at least professionally), it's a very relevant question for you.

If your contract specifies a full-building model, then "what to model" is an easy question. But if the structural scope doesn't require it, and If the fee's not high enough to do more, then you have to make decisions. One approach is that if an existing element is being modified, or if it directly connects to a new structural element, it gets modeled. For areas that are not structurally modified, the architectural floor plan can be used as a background (mostly just the walls). Detail lines should *not* be used in plans...at least, not to represent existing structure. If it's that important that a beam show up on a plan, model it. It works out better when you're cutting sections later.

Building Systems

Once you've settled your scope, you need to think about the level of detail you're willing to go to with your existing building model. The word "detail" is there on purpose: the elements you're modeling exist in the real world, so a level of "development" doesn't really apply. Each element is fully developed by definition (it exists), but you probably don't have the information required to really make it an "LOD 500" element.

So what's the ROI (return on investment) on modeling your existing elements?

Steel

A steel-framed building is possibly the easiest to model. When you can pull shapes out of the Bethlehem catalogs (or maybe an actual AISC manual), you're in pretty good shape. One exception to "easy" steel is trusses. They're a little more complicated to model...and to demolish. (More on demolishing elements later.)

Concrete/Masonry

Concrete is maybe the next-easiest construction system to model. Especially if you're dealing with a fairly regular system with rectangular beams and columns, all you need are the exterior dimensions and you're good to go. Even if your building has some tapered beams and sloping columns, they probably haven't changed shape much since the original pour. It's likely not worth it to model the rebar in an existing beam, but having the outer shapes of the elements will be a good representation of the existing condition.

Archaic Systems

When you start to get into obsolete construction methods, that's where things can get interesting. What if your exterior walls or foundations are made with cut stone instead of a more modern material? How much detail do you need on the individual blocks? Is it enough to just model the general shape?

Similar considerations apply to archaic floors. Terra cotta arch floors would be a real challenge to model accurately in 3D, and possibly not worth it if all you're worried about is clearances. Instead, you can model the steel support beams and the flat topping slab, and sketch the arches in your 2D details. In the image below, the concrete slab and steel beam are "real" (i.e. 3D), although the concrete has been masked to approximate the infill area, and the brick arch is a 2D filled region.
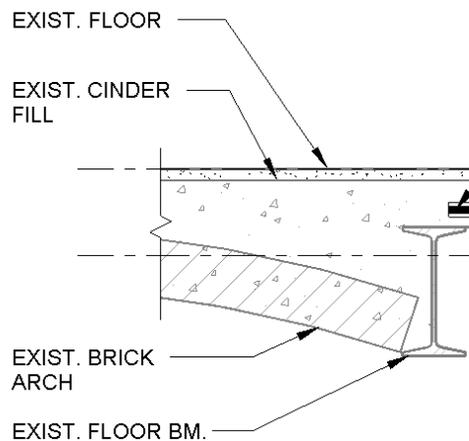
Wood

Wood is also a little tricky. Will it be worth it to model every single floor joist and wall stud where it was built? Or can you substitute wall elements and floor elements, with metadata describing their composition? A hybrid approach might be appropriate: use mostly walls and floors, and add in individual elements where they're relevant to the modifications. If your wood building is historic, that will add extra wrinkles. It's practically guaranteed that a house built in 18-whatever doesn't have very many straight lines in it anymore. If you're going to model its walls, are you going to use straight lines or try to map the deformations?

Out-of-plumb Elements

Speaking of deformations, how will you handle them? At what point is a wall sufficiently out of plumb that it can no longer be modeled orthogonally? How much sag can you tolerate in a floor before it becomes relevant to the project?

If you decide the irregularities are important, you may turn back to your laser scans to get the true mapping. A new potential solution for aligning the existing shape with the intended configuration is Autodesk Point Layout software. It's brand new to the Autodesk portfolio, acquired only this summer, and is really intended for contractors and suppliers to use for construction layout. But it also has deviation analysis for surfaces, and could be a really interesting tool for modeling historic or damaged buildings. See more here: http://www.autodesk.com/products/point-layout/overview

Reliability of Information

Let's talk a little about the reliability of the information contained in your existing building model. By definition, all existing elements have some level of uncertainty. Because you weren't there when it was put up, and you can't see inside it now, there's probably going to be *something* you don't know about each element. This has interesting implications for your model. In 2D CAD files, you can draw a line, label it "EXISTING BEAM (V.I.F)", and no one can read more information into it than you intended. But as soon as you put that beam in Revit, it LOOKS real. It has a size in all 3 dimensions. It has an elevation. If what you modeled was simply your best guess as to the existing condition, how do you convey to other people using the model that you don't really know what's going on there?

Placeholder elements

One way is merely to use a deliberately generic family. You might approximate a steel beam as a rectangular section, or model all your concrete beams as 24"x24". Whether or not they exist as separate families, the type names and/or type marks should indicate the placeholder status. Type names will help you grab the right element as you model (and covey information to others who use the model), and generic type marks can be used in tags so that no more data appears on the drawings than you intend.

Another alternative is to use your best estimate of size & shape, and eliminate overly specific information from the tag. For example, existing steel framing is often identified simply as "W12" instead of "W12x16".

If you're really concerned about misinterpretation, you can also take the generalization one step further, and use floor and wall elements instead of modeling individual objects in the framing system. No one can misunderstand data that doesn't exist.

Communication

Even with the best intentions & execution, technology cannot can't compensate for a lack of communication. Too much in Revit looks more "real" than it is—whether it's unconfirmed existing construction or partially-designed new construction—to rely solely on the model for the communication of design intent. (It's part of why we still have 2D construction documents, right?) Engineers and architects are often concerned about turning models over to a contractor too early in the design phase, for fear that they'll make assumptions about the (unfinished!) design that weren't intended. This issue comes up a lot with fast-tracked projects, which might involve a foundation package submitted for construction before the superstructure is fully coordinated. Often one solution is a narrative—a written description accompanying the model that explicitly spells out which elements may be used for permit/bid/pricing/whatever and which elements are provided for information only.

A similar narrative can be used for existing buildings. It doesn't have to be long. Sometimes a few sentences will do. Here's one sample:

> Dimensions and elevations of existing construction given in structural drawings are based on information contained in various original design and constructions documents (provided by the owner) and limited field observations and measurements. Contractor shall verify all information pertaining to existing conditions by actual measurement and observation at the site. All discrepancies between actual conditions and those shown in the contract documents shall be reported to Engineer of Record for evaluation before affected construction is put in place.

The above is an *example only*. You will want to clear any language like this with your project manager and the design team, and possibly your legal advisor.

Mastering Phases

So far this has covered the mechanics of modeling existing elements of a building, but the reason for doing this is almost always that you're going to model some new elements too. That means you have to be able to distinguish between what was already there and what's being added. Thoughtful use of phasing will be an absolute lifesaver as you create your construction documents.

Revit Phases

Every Revit project includes two phases by default—Existing and New Construction. Sometimes, this might be all you need. But there are many scenarios that might call for separating the project into more than the default phases. Maybe your renovation requires some temporary structure to be installed prior to demolition, and you want to show it as new construction on some drawings and as existing or demolished on others. Maybe you actually have "Phase 1" and "Phase 2" in your new construction. Or maybe your existing building was modified after it was originally built, and you want to keep track of how it's evolved.

To add a phase to your project, go to the Manage tab, Phasing panel, and click on Phases. This dialog lists the oldest phases at the top, and the newest ones at the bottom. To add something before "New Construction", select the number next to the phase row, and click "Before".
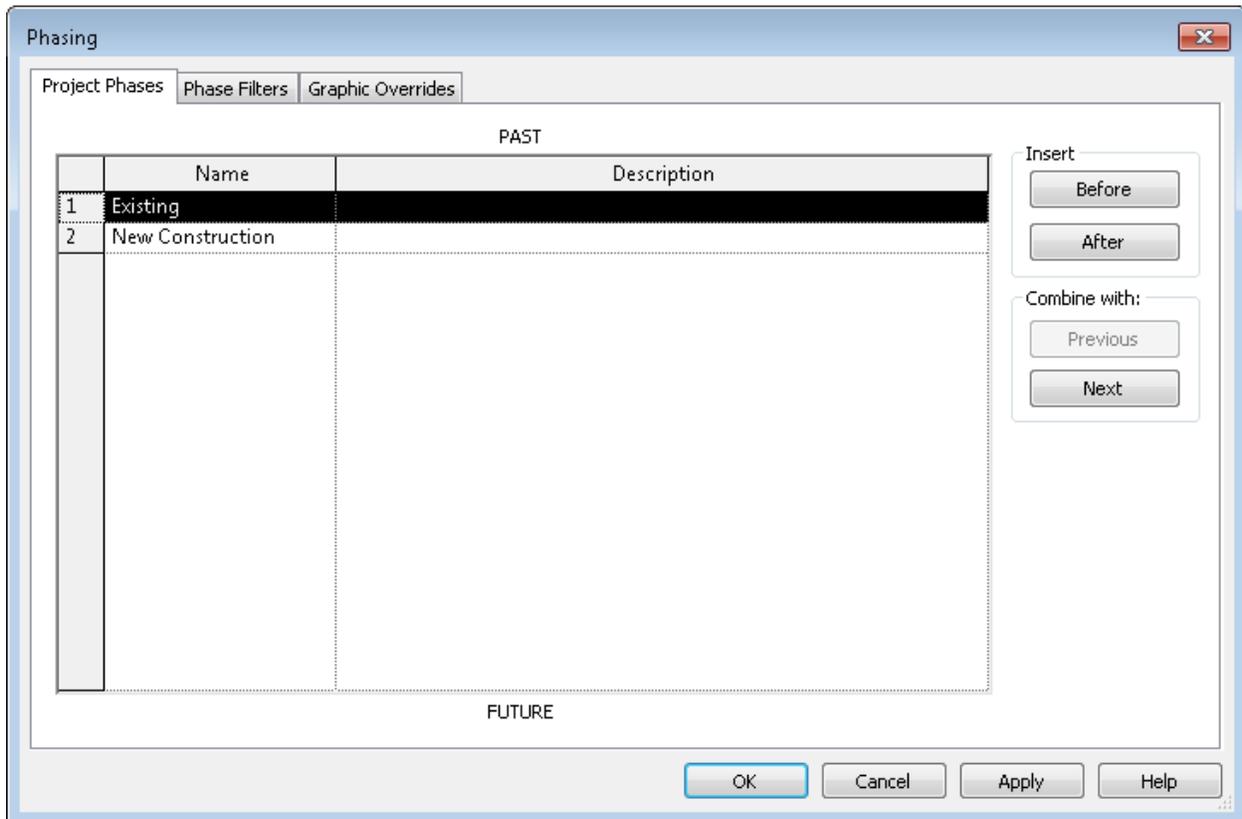
Note that there are no "move up" and "move down" buttons. You can't change a phase's position in the sequence after it's been created. If you make a mistake or change your mind, though, there are ways to fix it. Simply add your new phase where it belongs, and use "combine with" to merge the old phase with the one before or after it. (If you already have elements assigned to the old phase, you may need to re-assign them before you merge. See below for how to apply phase filters to views, to help you select only the elements belonging to a particular phase.)

Once you have the phases you need, you can assign them to elements and views. Let's start with views.

Phases for Views
Views have two phase-related parameters: "Phase" and "Phase Filter". "Phase" simply sets the current phase, while "Phase Filter" defines what elements are displayed in the view—and how.
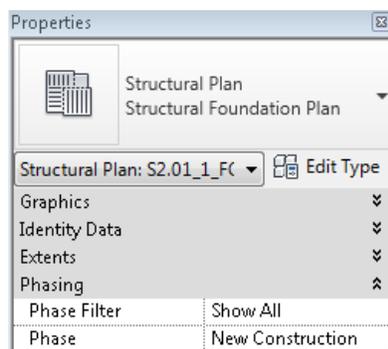
The Phase property is fairly straightforward. Phase Filters are where things start to get complicated. The first thing to remember is that "New", in a phase filter, means *current*. As an example, an existing steel beam is considered "new" in the *existing* phase.

(Sidebar: Plans & sections aren't the only view types with Phasing properties. Schedules have them too.)

Here are Revit's default Phase Filters:

	Filter Name	New	Existing	Demolished	Temporary
1	Show All	By Category	Overridden	Overridden	Overridden
2	Show Complete	By Category	By Category	Not Displayed	Not Displayed
3	Show Demo + New	By Category	Not Displayed	Overridden	Overridden
4	Show New	By Category	Not Displayed	Not Displayed	Not Displayed
5	Show Previous + Dem	Not Displayed	Overridden	Overridden	Not Displayed
6	Show Previous + New	By Category	Overridden	Not Displayed	Not Displayed
7	Show Previous Phase	Not Displayed	Overridden	Not Displayed	Not Displayed

And here are their descriptions:

- **None.** Does not apply a phase filter to the view. The view displays all elements from all phases.
- **Show All.** Shows new elements (using the graphics settings defined for that category of elements) and existing, demolished, and temporary elements (using the Graphic Overrides settings for each phase defined using Manage tab Phasing panel Phases Graphic Overrides tab).
- **Show Complete.** Shows the completed project, after demolition and new work have been performed in the current phase.
- **Show Demo + New.** Shows demolished elements and all new elements added to the building model.
- **Show New.** Shows all new elements added to the building model.
- **Show Previous + Demo.** Shows existing elements and demolished elements.
- **Show Previous + New.** Shows all original elements that were not demolished (Show Previous) and all new elements added to the building model (+ New).
- **Show Previous Phase.** Shows all elements from the previous phase. In the first phase of a project, existing elements are new to that phase, so applying the Show Previous Phase filter causes no elements to be displayed.

The properties for each filter are set in four columns: New, Existing, Demolished, and Temporary. For each column, you can select one of three display methods:

- **By Category.** Displays elements as defined in the Object Styles dialog.
- **Overridden.** Displays elements as specified in the Graphic Overrides tab of the Phasing dialog.
- **Not Displayed.** Does not display the elements.

Refer to the image above to see how the columns are combined to create each of the default phase filters. For example, for "Show Previous + New", New is set to *By Category*, Existing is *Overridden*, and Demolished and Temporary are *Not Displayed*.

Again, remember that the column headings are relevant to the *current phase*. So if your view phase is set to Existing, the phase filter "Show Demo + New" will display different elements than if the current phase is set to New.

The out-of-the-box filter set is fairly comprehensive, but if you need more filters you can always make them yourself.

Phases for Elements

How do you control which elements are displayed in each phase filter? With more parameters, of course.
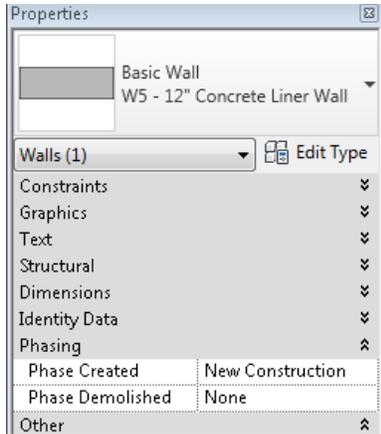
Each element has parameters for "Phase Created" and a "Phase Demolished". The default value for "created" is the *current phase for the view*. Remember that--it's important. The default value for "demolished" is None. Revit assumes that when you put something in, you intend to keep it.

Remember the four columns in Phase Filters? (New, Existing, Demolished, and Temporary.) The values of "Phase Created" and "Phase Demolished", combined with the view Phase, define which column an object is controlled by. The chart below shows some some sample creation/demolition combinations and the resulting filter category.

Current view phase = New Construction

Phase Created	Phase Demolished	Phase Filter Column
Existing	None	Existing
Existing	New Construction	Demolished
New Construction	New Construction	Temporary
New Construction	None	New

Current view phase = Existing

Phase Created	Phase Demolished	Phase Filter Column
Existing	None	New
Existing	New Construction	New
Existing	Existing	Temporary
New	None	n/a

With a little practice, you can see how the view phase, element phases, and phase filters work together to control object display.

One more thought on view & element phases: Let's say that you're working in a view with Phase set to "New Construction" and Phase Filter set to "Show Previous + Demo". If you try to add an element to the view (like a beam or column), *you will not be able to see it*—because your current Phase is "New

Construction", so that's the "phase created" of your elements, yet "New Construction" elements are not displayed with the "Show Previous + Demo" filter. The new element will still exist in the project, but you'll have to reset its phase created/demolished properties before it will show up in the views you want it to. To avoid this, be sure to set your view's current phase appropriately before creating elements.

Demolishing objects

Each element's "Phase Created" property is set by default when you add the object, but if you want to demolish something, you have to do it after the fact. Most of the time, that couldn't be easier. Just set the Phase Demolished Property in the Properties palette or use the "sledgehammer" tool to demo items by clicking on them. (Isn't it nice when software displays a bit of a sense of humor?)

Demolishing *some* of an element is a little more difficult. There's no built-in method to cut off half of a steel beam so you can re-support it with a new one in a later phase.

One method is to split the element at the extent of the demolition. This leaves you with two elements whose "Phase Demolished" properties can be set separately. In most situations, this works just fine, at least for framing elements.

But for cutting new openings in walls and floors, or if for some reason you need to show the element intact in another view, you might need a different approach—such as Parts. Parts in Revit can be used to demolish portions of an element while retaining the integrity of the original element.
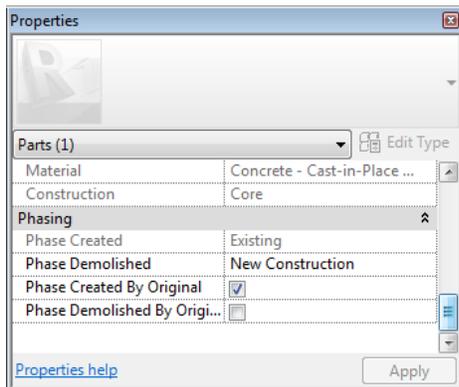
This isn't the place for a full explanation of the Parts feature. They could fill up an entire class on their own (as a Google search for "Revit parts" will show.)

Let's assume you already know how to divide an object into parts, and the features and possibilities of doing so.

Once you have your parts, check out the Phasing section of the Properties dialog. In addition to the standard "Phase Created" and "Phase Demolished" settings, you also have checkboxes for "Phase Created by Original" and "Phase Demolished by Original".

By default, both boxes are checked. But if you uncheck them, you can set the creation and demolition phases for each part independently. This gives you a lot of flexibility for displaying the element in its original state or as partially demolished later.

Trusses also require special treatment for selective demolition. That's because the truss "skeleton" is a single object, even though the webs and chords are made up of separate 3D elements. In order to demolish a single piece of a truss, you need to use "Remove Truss Family" first. Unpinning the element isn't enough. Do this with care, since it means that your truss is no longer a unified element, but is instead made up of regular beams and braces.

Graphic Overrides

Setting graphic overrides is the final step in controlling how elements are displayed based on their phase.

Here's what the default settings look like:

You can set visual overrides here for projection/surface display and for cut display, setting the lineweight, color, and pattern in a separate dialog. This one's for lines; the patterns dialog is similar.
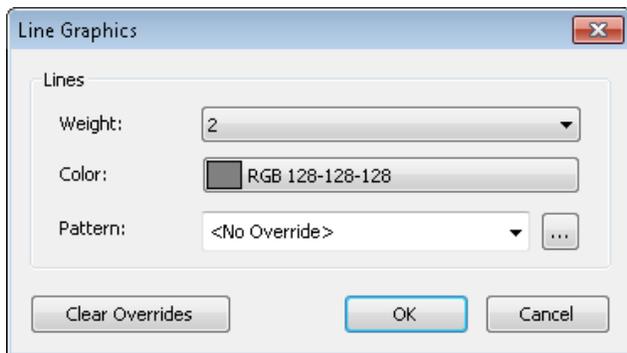
What you need to know about these overrides is that they affect *every* element in that Phase Status. So if you set Existing elements to have a lineweight of 2, *all* "existing" elements (as defined by the phase & phase filter) will have that lineweight—regardless of original object style.

It's often a good first step, but unless you're willing to have all materials represented identically, you may need to employ other techniques (such as view filters) for more control over the object display.

Two notes on this:

- You cannot use an object's phase properties as filter criteria. So you'll need to come up with something else (workset, type name, etc.) to use as an alternative.
- View Filters will override Phase Graphic Overrides, but Model Categories overrides will not. The Revit Clinic posted a nice overview of the overall hierarchy, in case you need a reminder: http://blogs.rand.com/support/2011/10/revit-graphic-overrides.html

Conclusion

Hopefully you now have a better idea of the risks, challenges, and rewards of modeling existing buildings. It's true that there are many traps waiting along the way, but with some careful planning and and understanding of the available tools, an effective and efficient model is well within reach.