Autodesk University 2007

# Advanced Revit® Families for Structural Engineering & Design

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**SE210-2** This class focuses on creating structural families to help you meet deadlines and simplify every-day engineering tasks. You'll see actual examples that have been used to overcome an obstacle encountered during a real project. Learn how to add symbology to control the look of construction documents, use type catalogs to create new content in less than 5 minutes, and author families with complicated geometric relationships. See how you can maximize the benefits of 3D engineering by creating a parametric soil tie-back family to aid design and detect conflicts with existing buildings.

**About the Speaker:**

Steven currently provides consulting services to firms in the San Francisco area. His expertise in workflow, training, templates, and family creation facilitated the transition into Revit for one of the largest single office Structural Engineering firms in the Bay Area. Previously employed as a Staff Engineer, Steven worked on over a dozen projects in Revit Structure, including hospitals, labs, recreation centers, and the office's first project completed in Revit, now in construction.

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## Outline

1. Families. What are they? Why do I need them? What do I want out of them?
2. Three quick fixes to common problems
3. Clash detection. How accurate do we really need to be?
4. Clashing with ourselves. How to use the mathematics of families for design.

## Introduction to Families & Topology

Families are the basic building blocks of all Revit models. Whether you want it or not, each element in your model belongs to a family. A similar set of *elements* belong to a single ***Family***. All members of this family must have similar geometries and constraints; I sometimes refer to this as ***topology***.

As an example of topology consider two figures made out of clay, the numbers '0' and '8'. The '0' has one hole, while the '8' has two. Without tearing or re-joining the clay, there is no amount of manipulation you can do to turn the '8' into a '0'. On the other hand, consider a coffee mug and a donut; each have one hole. If I set the mug on a table, and squish flat the portion from which you drink, I am left with a flat disk and a somewhat distorted handle. I can manipulate the clay to resemble a donut.

To relate this to Revit families, consider a Wide Flange beam. All Wide Flange beams are one *Family* because they can be defined by height, flange width, flange thickness, web thickness, and so forth. Further more, all members of this beam family have the same 'use'; that is to say they span horizontally and do not stand vertically as would a column. The purpose of a set of objects also defines their family.

As stated, all members of a family must be similar. While the values of the dimensions may differ, the number of dimensions and what they define must remain the same. These differing values create ***types***. In the example of a Wide Flange beam, some of its types are W12x19, W18x35, W24x55, etc.

Properties, such as height or width, of a *family* are called ***parameters***. *Parameters* can apply to a single element in a model (***instance parameters***) or to an entire *type* (***type parameters***). Designating a *parameter* as ***shared*** allows it to be used in *tags* and *schedules*. (As an aside, scheduling parameters typically makes it easy to control a family, but is beyond the scope of this class).

*Parameters* and *types* do not need to be entered manually into a family. A large group of them can be stored in a ***type catalog***, which you are already familiar with. Recall that when you load a wide flange family, you select which sizes you want. This is the *type catalog*. Type catalogs are text files, stored in the same directory as a family, with the same name.

## Why do we need families?

It seems a simple question: we need families because we want something in our model. Autodesk has no way to anticipate every relationship nor every object which we as designers and engineers may want to model, so they have given us the capability to author our own families. This is both a blessing and a curse. Without careful planning, creating families from scratch can waste a lot of time, and may not even be necessary. Back to the original question, I would ask: "why do we need *this new* family?"

## Engineers vs. Architects

For architects, families represent objects on their design drawings, quantities for scheduling, and costing; contain manufacturer information and thoughts on alternative substitutions; provide a background for isometric views; and can be rendered for marketing materials, client walk-throughs, or virtual construction. This is a lot of information which must be stored in a family and reflected in its definition.

As engineers we typically want two things out of a family: for it to look right on drawings and for it to provide a correct analytical model. At this time, the way a new family is sent to an analysis program is typically out of our control. This leaves only the representation in plan, elevation, and section.

Our families need not be very complicated, nor must they be perfect. In many instances, we may not even need new families at all. Consider a case where you need to represent a reduced beam section (dog boned) moment frame. In plan it is only a line. In elevation it looks the same as any other wide flange beam. The only difference is shown in the details, which may not even be modeled in Revit.

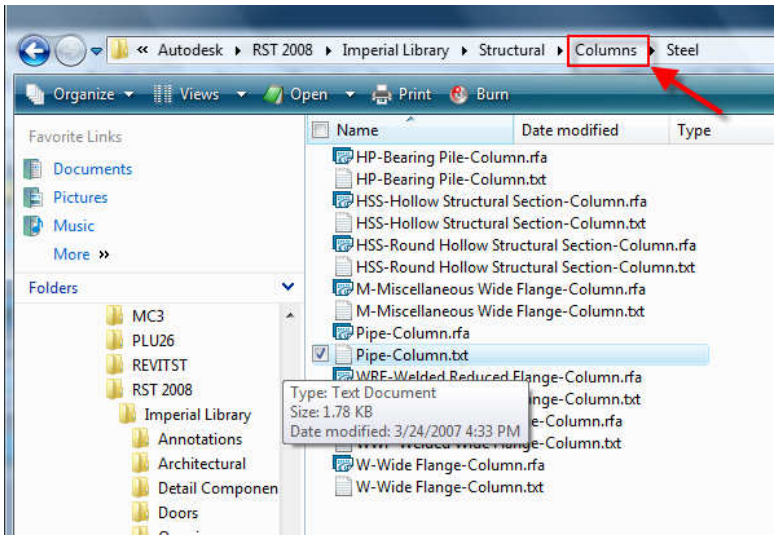
When a new family is needed, first ask yourself what specifically you need it for. Is there an abstraction already in existence that you could use? Does it simply need to look right in plan? For the purposes of this class, I will assume these questions have already been asked, and that it is determine we need a new family. This being the case, it may not need to be made from scratch. The first example will take advantage of *type catalogs* to duplicate an existing family for a new use.

## Only good for drawings?

So far, I have only discussed graphically how families can be used. In the CAD paradigm, this job typically falls on the drafters. The portion which would be considered an engineer's purview (the analysis) is mostly out of our control. However, for complicated buildings, determining and coordinating three dimensional geometry can be a time consuming task. Many of the possible issues fall by the wayside until construction. As engineers, we can use families to explore the interactions of complicated geometry and plan with it. Tasks which we might have done using complicated spreadsheets, iterated 3D drafting, or simply ignored can now be tackled in a design environment. ***This, as well as simple quick fixes an engineer can achieve, is the focus of my class.***

## Example 1: Step-by-step quick creation of Pipe Framing family using type catalogs

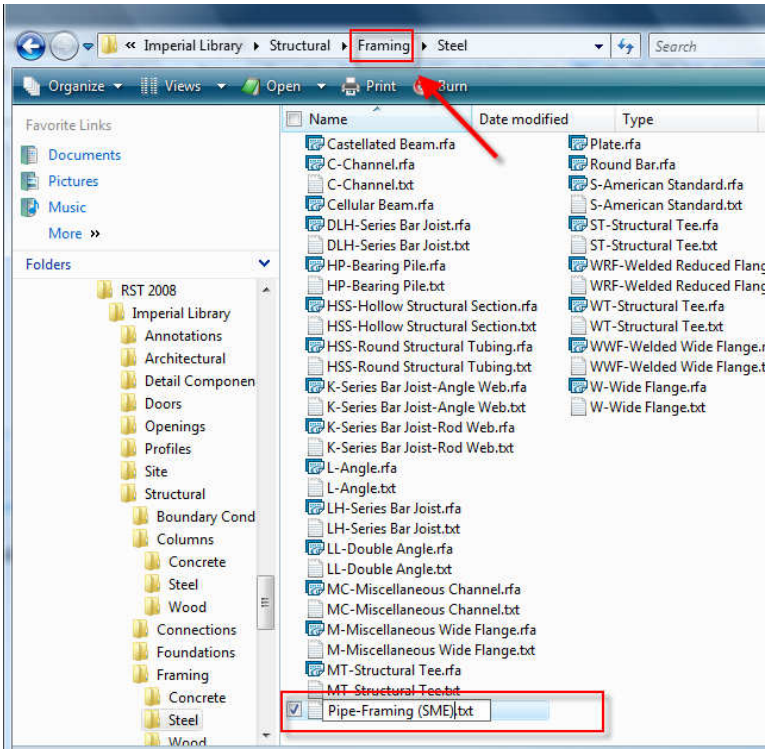
| | |
|---|---|
| Problem: | Autodesk does not supply Pipe family for framing (i.e. braces) |
| Considerations: | 1. Autodesk supplies HSS Round family for framing<br>2. Autodesk supplies Pipe family for columns |
| Solution: | Use the HSS Round family with the Pipe family type catalog<br>*(estimated time 5 minutes)* |

| | |
|---|---|
| 1. Copy the Pipe-Column type catalog from the Column folder. |  |

2. Paste it into the Framing folder.

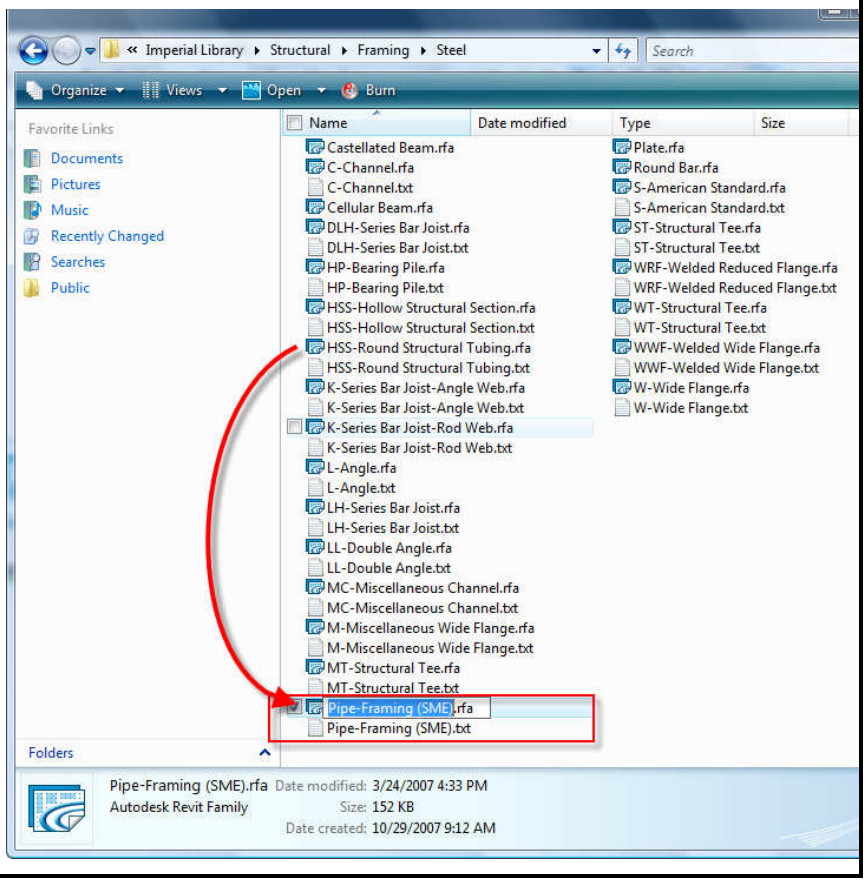
   Rename it to match your future Pipe Framing family.

   *Aside: I like to add a designation at the end of a family I create or modify (in this case, an abbreviation of my company "SME"). This comes in handy when upgrading Revit.*



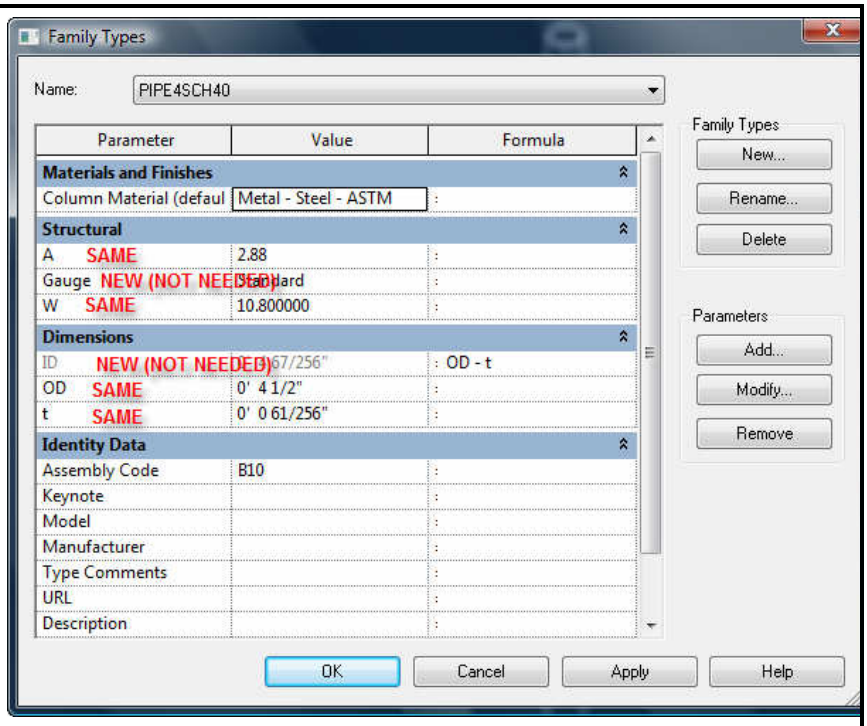

3. Copy the *HSS-Round Structural Tubing* family. Rename it.

   *Note that the name of the family matches the type catalog.*



4. Open the old *Pipe-Column.rfa* family and examine the parameters.

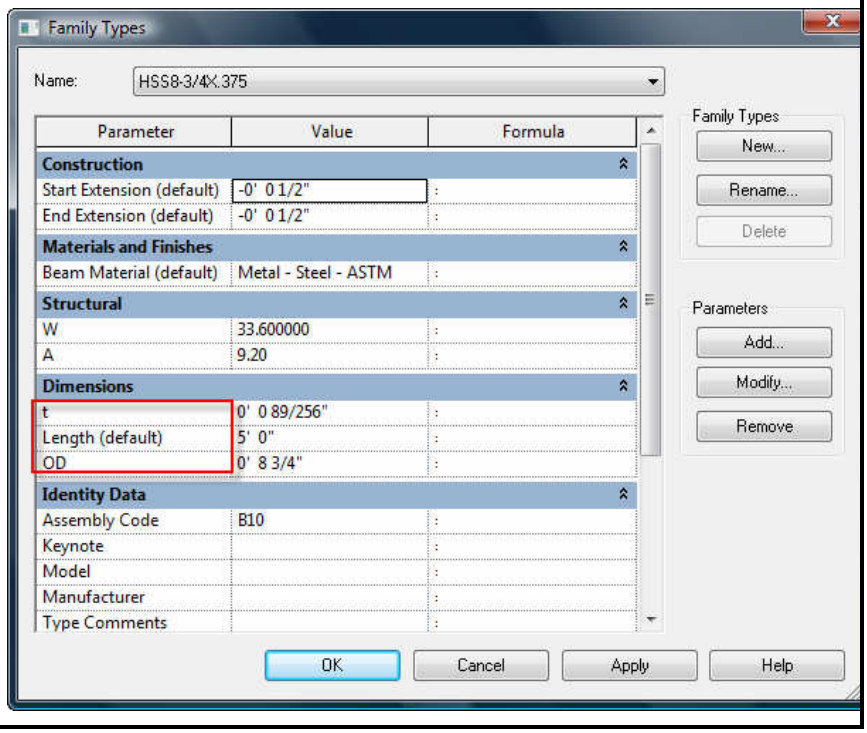
   This will indicate what parameters are in the type catalog that we may need to duplicate or rename.



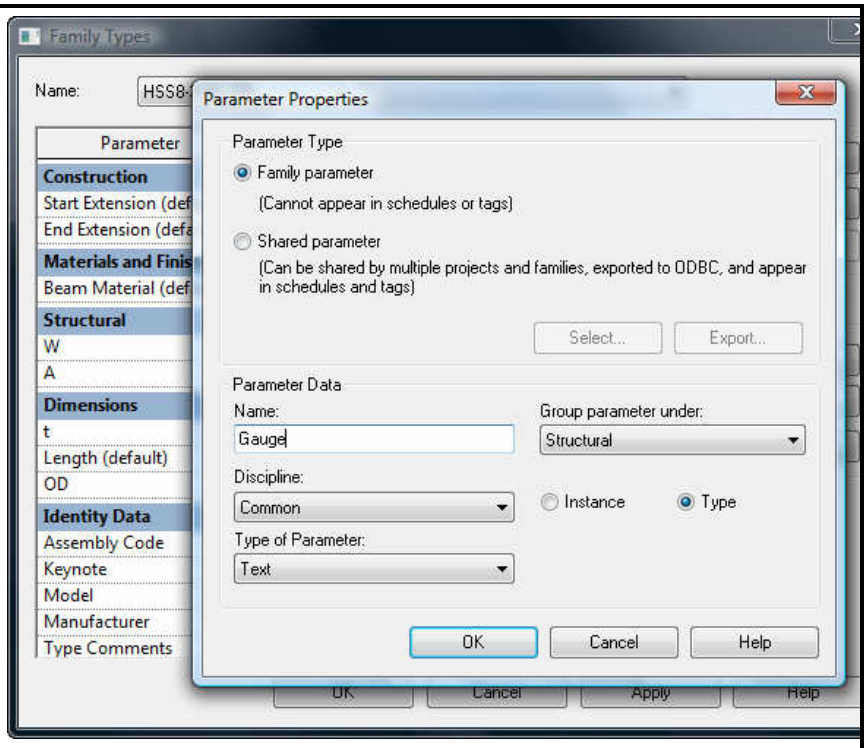

5. Open the new *Pipe-Framing (SME).rfa* and examine the parameters.

   The same parameters define the radius and thickness.

   No changes are necessary.



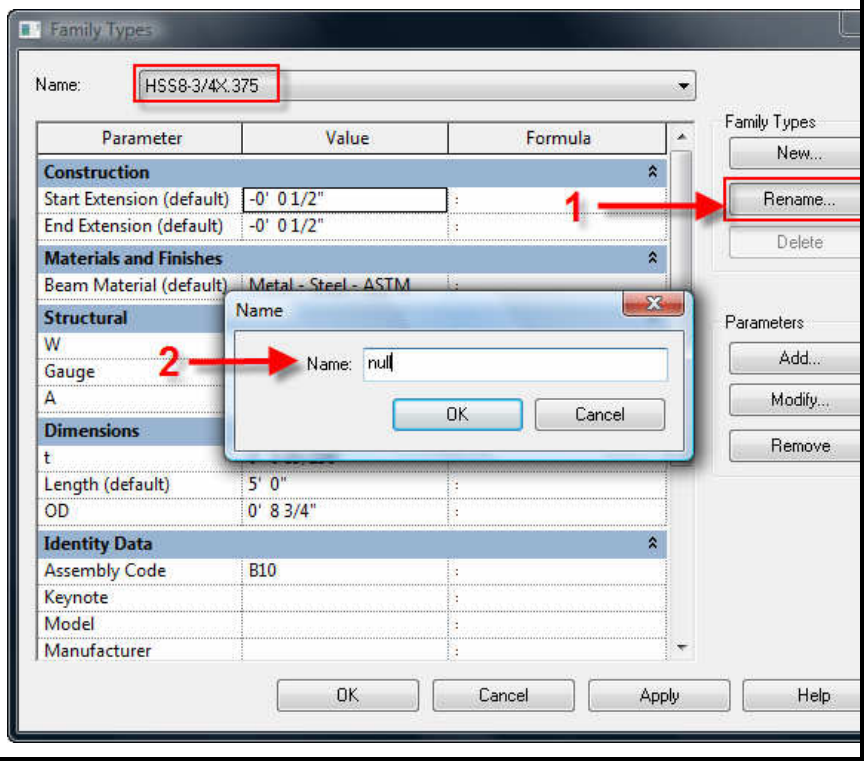
6. We will add the ‘Gauge’ and ‘ID’ parameters for completeness.

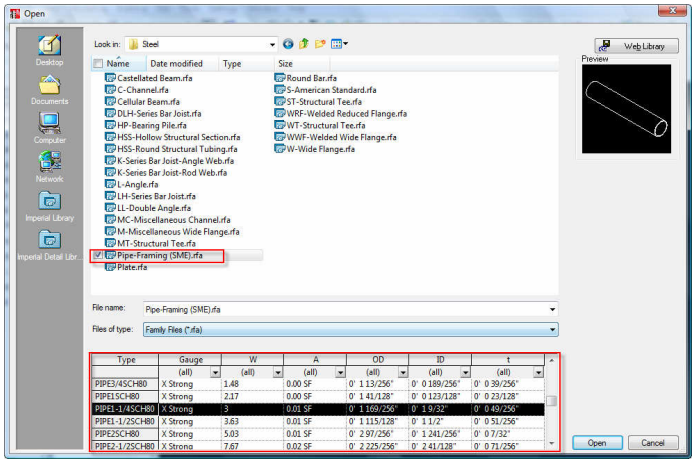
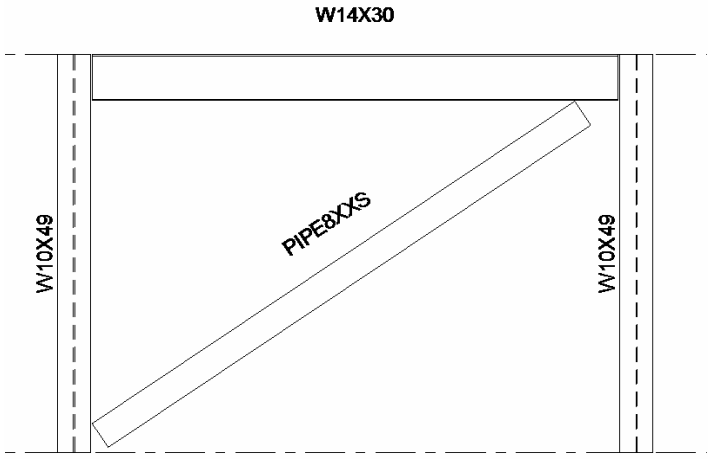



7. Finally, we will clean up the default type for completeness.

   The default type in our *Pipe* family is designated as an HSS.

   This will be confusing; we will simply call it ‘null’



| | |
|---|---|
| 8. Insert your new family into your project.<br><br>Notice that the type catalog will populate all the values for you. |  |
| 9. Elapsed time:<br>5 minutes<br><br>*Note that the hidden lines are not visible. This begins the second example.* |  |



Though the family has been modified to have the correct name and dimensions of a Pipe, the hidden lines associated with it no longer show. This is one of the common complications of creating a family. In this case, it would have been just as easy to modify the tag only. Unless highly accurate dimensions were needed for clash detection or renovation, the latter would have been an easier alternative. However, we might as well complete the family since we're halfway there.

## Example 2: Step-by-step addition of symbology to a family

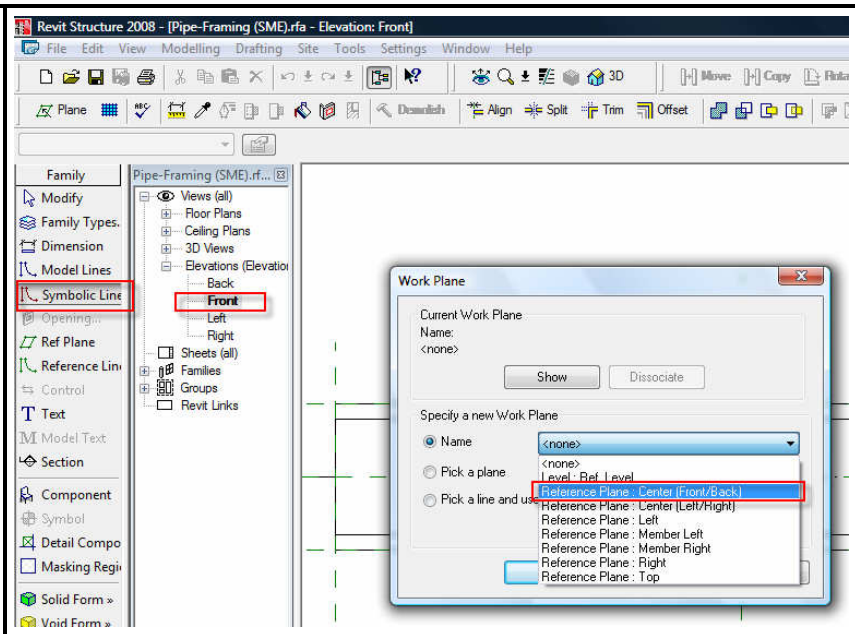
Problem: Hidden lines of new Pipe framing do not show!

Possible Solutions:
1. Live with it.
2. Fake them in at every location with detail lines
3. Add symbolic lines to family to be correct

1. Open the family (again!)
2. Click *Symbolic Lines.*
3. Select a reference plane to draw on.

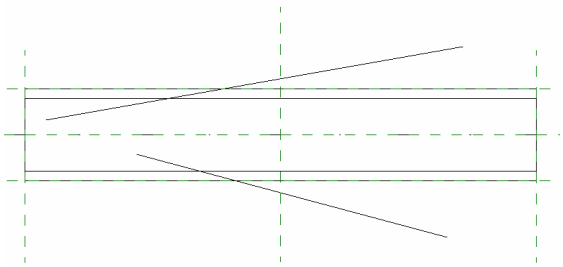
   These lines will only show in a view parallel to this plane (i.e. Elevations).

   The will not show in plans.

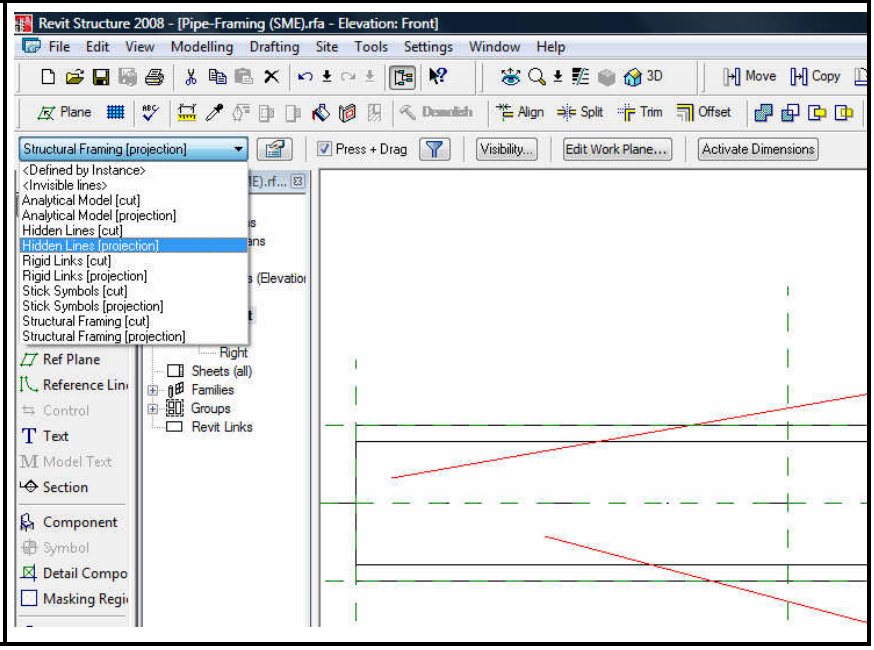



4. Draw two lines.

   I prefer to make them skew to remind me to add all the constraints.



5. Select both lines. Change their type to *Hidden Lines (Projection)*



| | |
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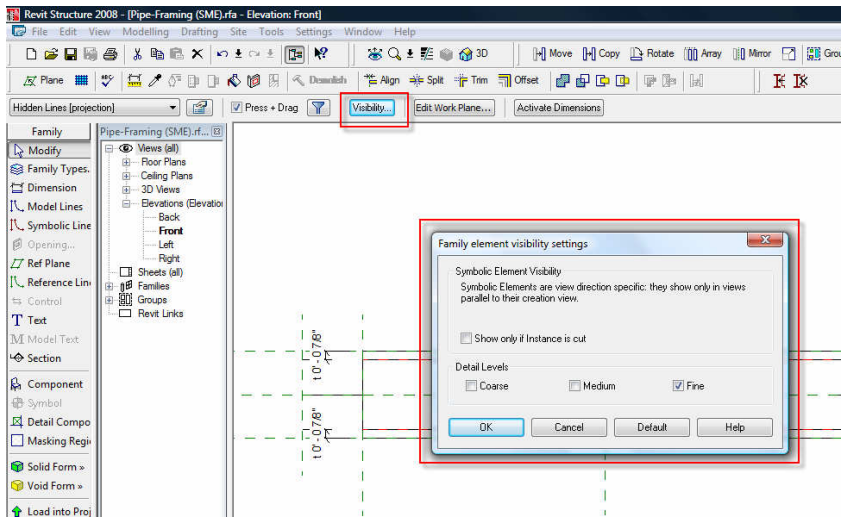
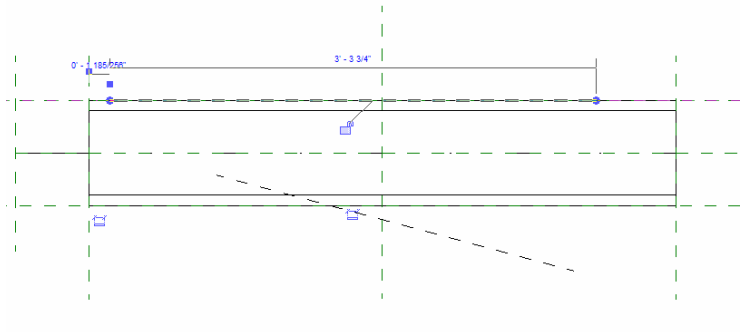
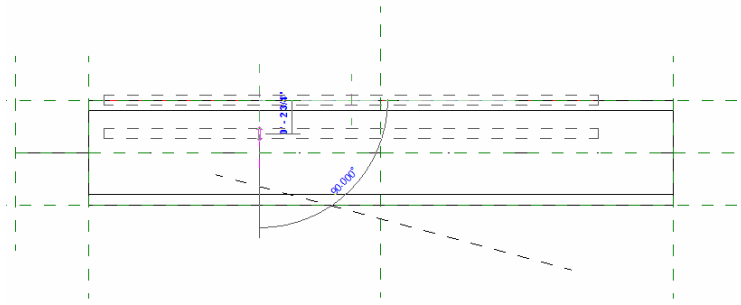
| 6. Change the visibility settings so the lines do not appear in Course views. |  |
| 7. Constrain the lines.<br><br>You'll find you cannot align the lines to the inside diameter.<br><br>Align the lines to the outside diameter to make them parallel. |  |
| 8. Move them towards the inside diameter. |  |

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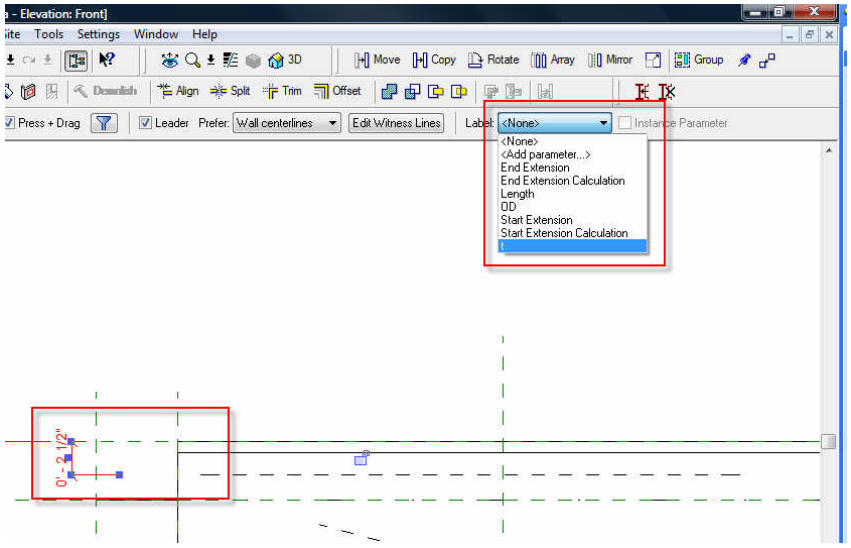
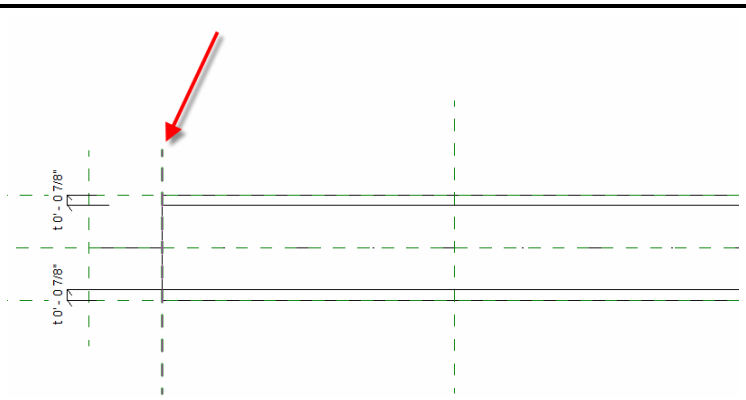
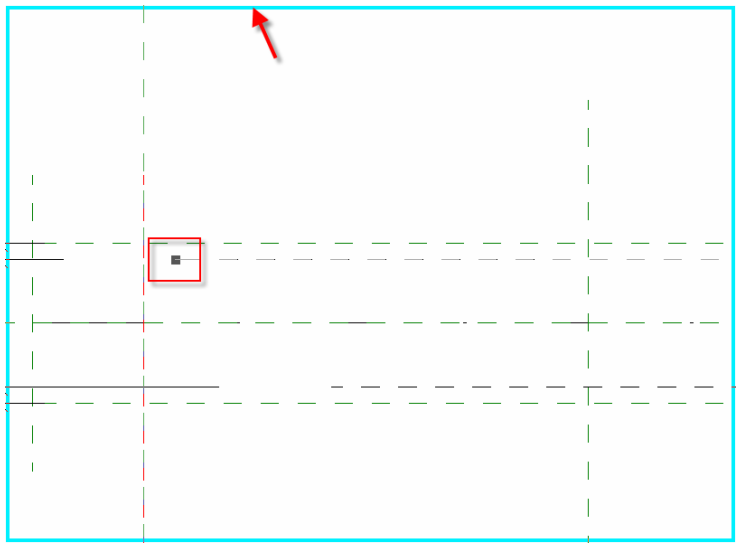
| 9. Dimension the lines a distance 't' from the outside diameter. |   |
| 10. Align & lock the ends of the lines.<br><br>First click on the reference planes. |   |
| 11. Then click on the end point of a line.<br><br>(Tab if needed)<br><br>*Note that I have hidden the solid form for ease of selection.* |  |

| | |
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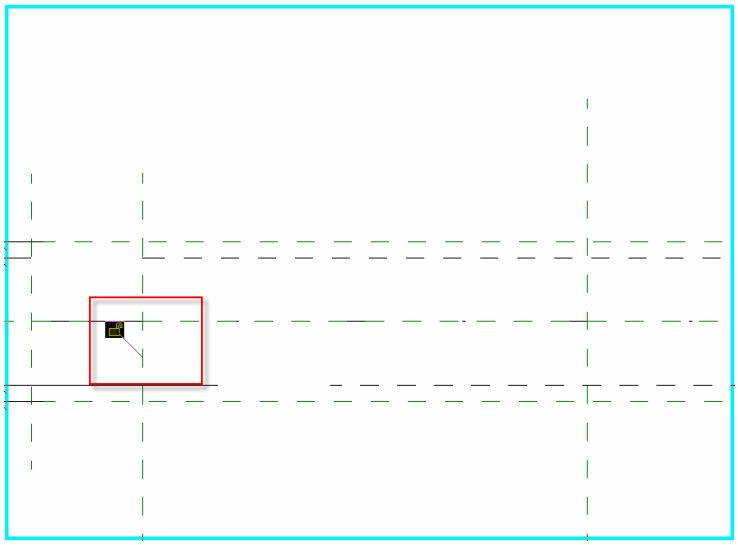
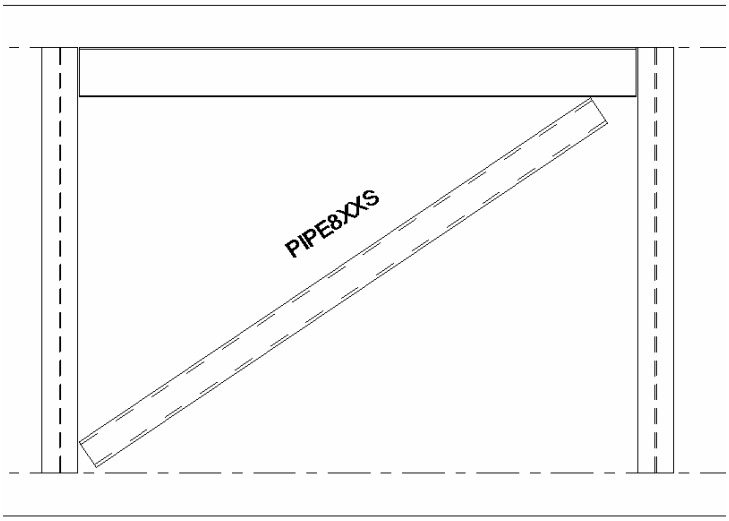
| 12. Finally, click the lock. |  |
| 13. Save the family and reload it into the project.<br><br>Elapsed time:<br>5 minutes. |  |

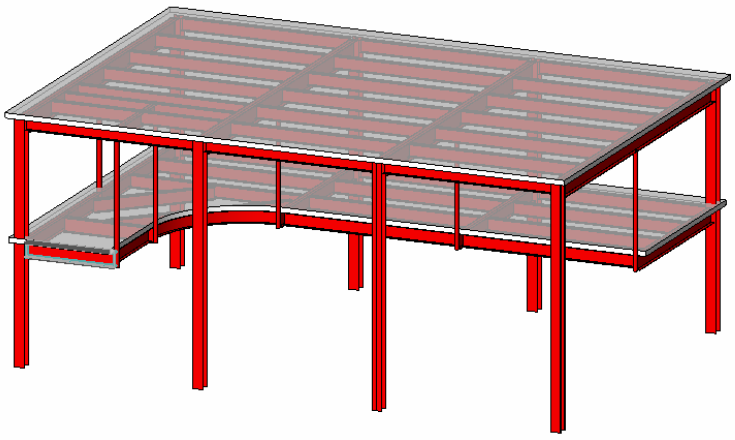
## Example 3: Step-by-step addition of symbol to hanger family

Often Revit is "too realistic" in its display of member. For instance, imagine a sloped roof girder shown in cross section. In CAD, we would only show the cross section; Revit also draws the projected lines beyond. This unnecessarily complicates our construction documents and distracts from the detail we are trying to show.

In this example, Revit shows the true size of a hanger below. It is so small, that it is almost completely obscured by the line of the beam above. In CAD, we would draw a symbol at each hanger location, or simply draw the hanger larger. We will add a symbol in the Revit family to automatically draw the symbol in each location.

Problem: Hangers obscured by beam

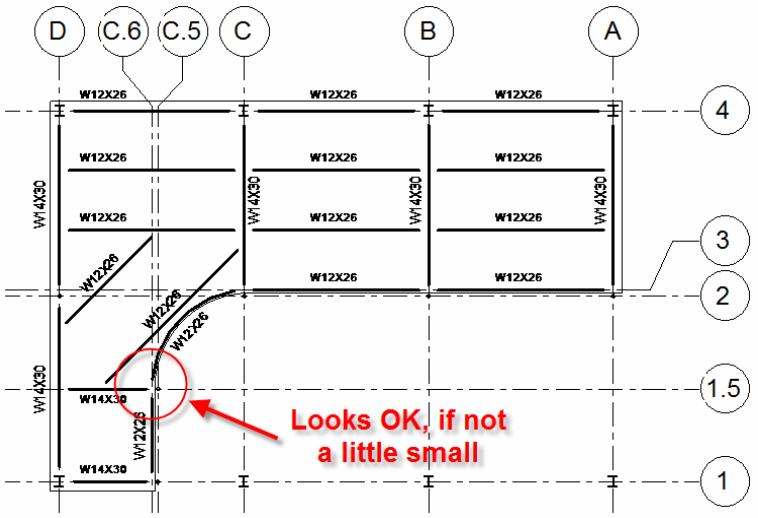
Possible Solutions:
1. Manually add symbol at each location
2. Increase line weight of columns
3. Decrease line weight of beams
4. Add symbol to family

| | |
|---|---|
| 1. In this project, a running track was suspended from the roof.<br><br>(A modified version has been re-created for simplicity) |  |

2. Second floor plan.

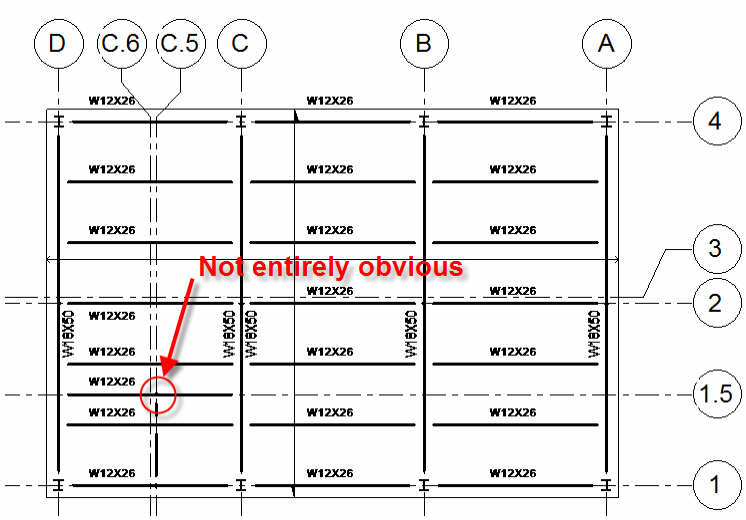
   Hanger symbol is shown at true size.

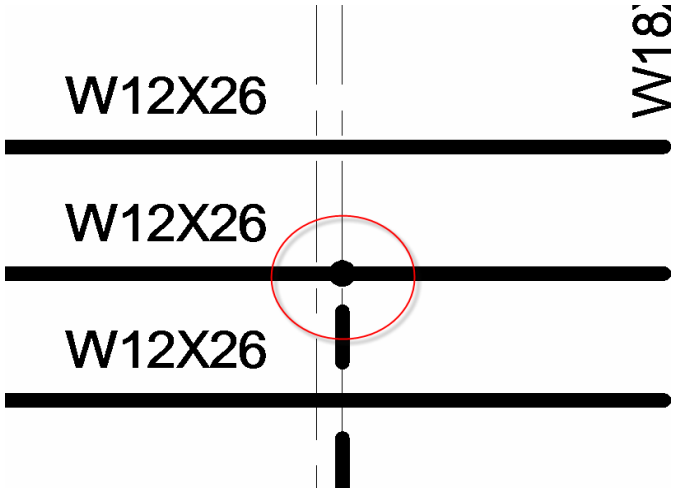
   It is a little small, but this is not a major problem for this plan.




3. Roof framing plan.

   Symbol is obscured by framing above, and barely visible because it is shown at its true size.

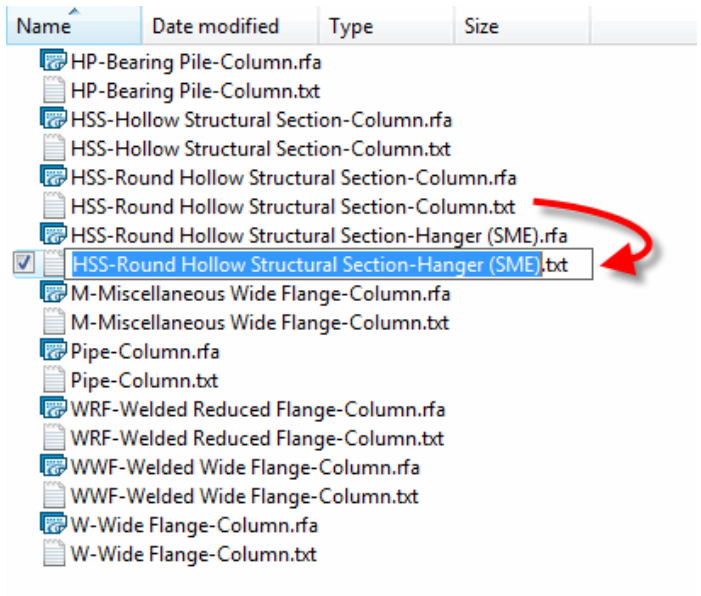


4. Open family and save with a new name: *HSS-Round Hollow Structural Section-* ***Hanger (SME)****.rfa*

5. Copy the Type Catalog associated with the original family.

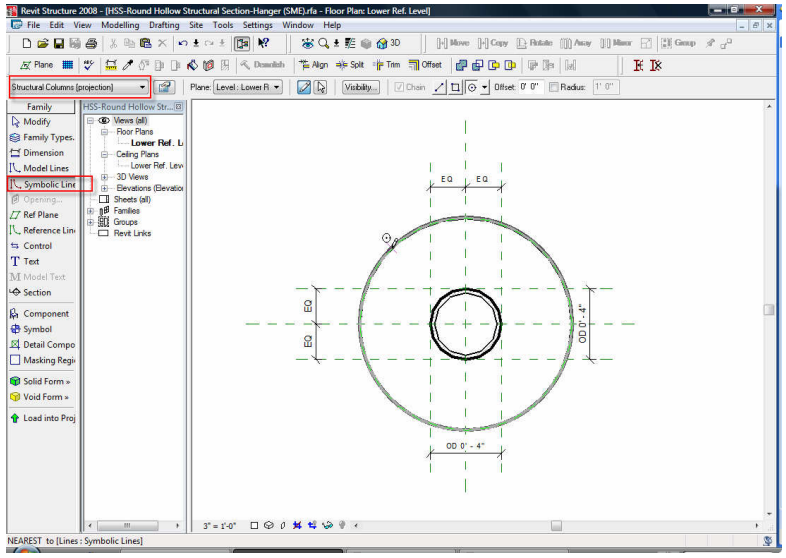
   Rename it to match the new family.




6. Open the floor plan view.

   There are already two symbolic lines which only show in Course views.

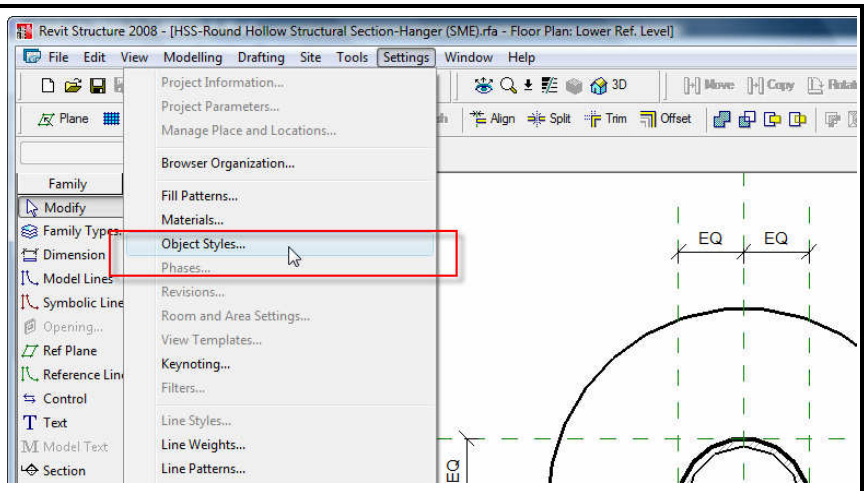
7. Create a circle using the *Symbolic Lines* tool as shown.



8. Create a new object style to control the appearance of the symbol.

   This object style will be imported with the family into the project.

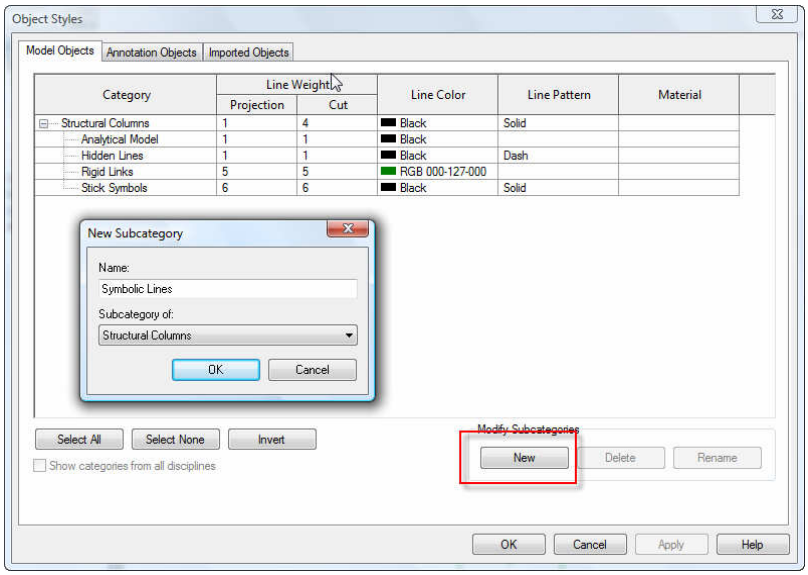
   Defaults set in the family will also be imported.




9. Create a new subcategory; mine is named ‘Symbolic Lines’.

   It could just as well be named ‘Hanger Symbol’; however I imagine that other symbolic lines may be added in the future.

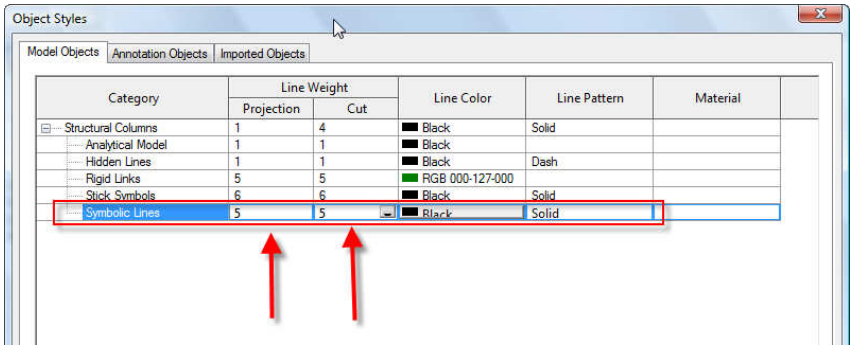
   This sets a standard for my symbols.

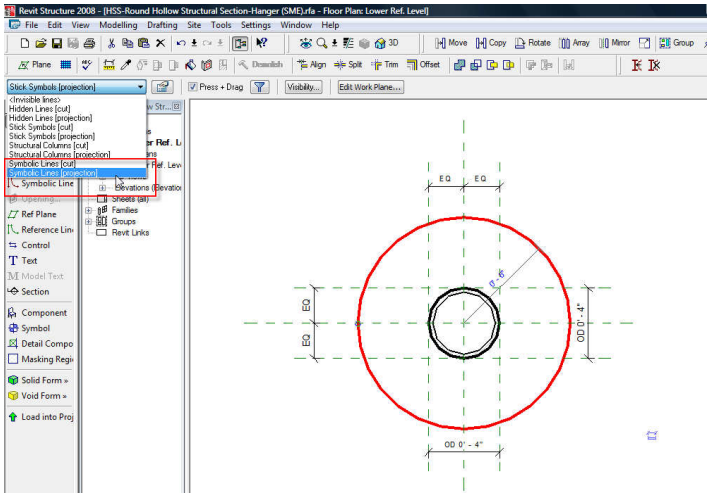
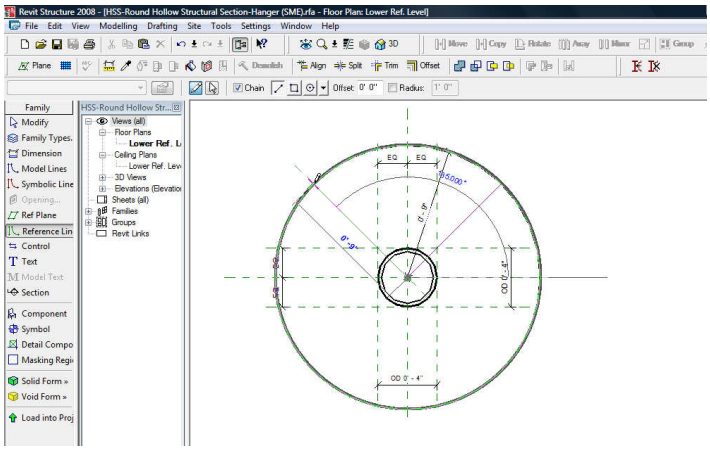
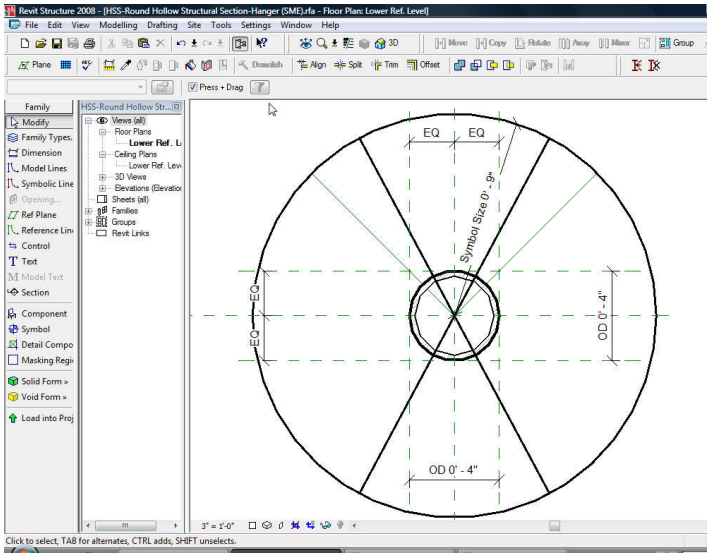


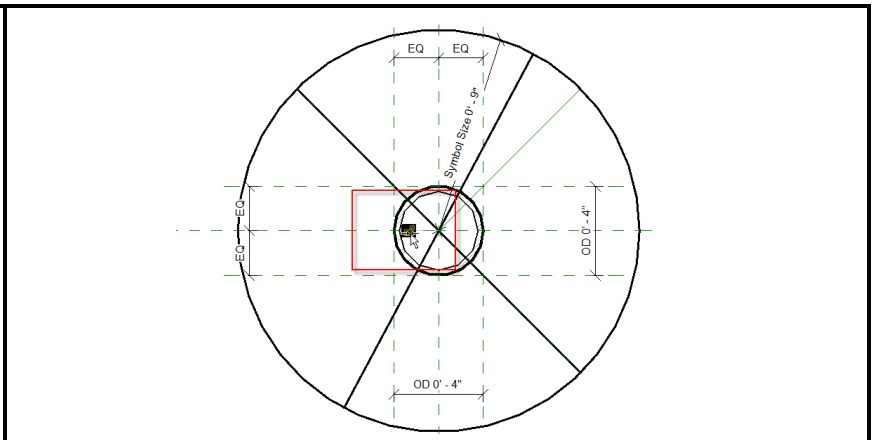
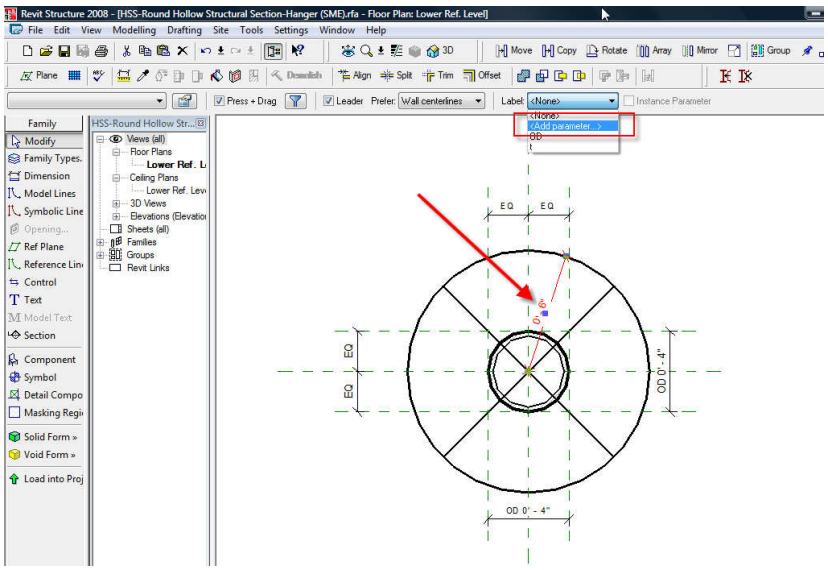
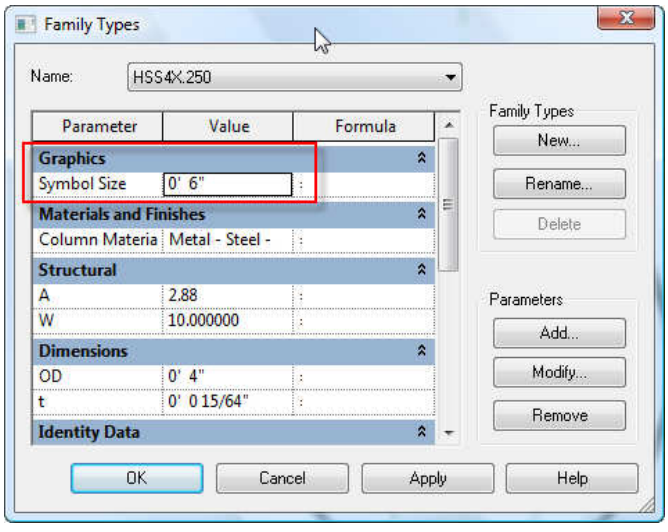

10. Set default line weights for the new style.

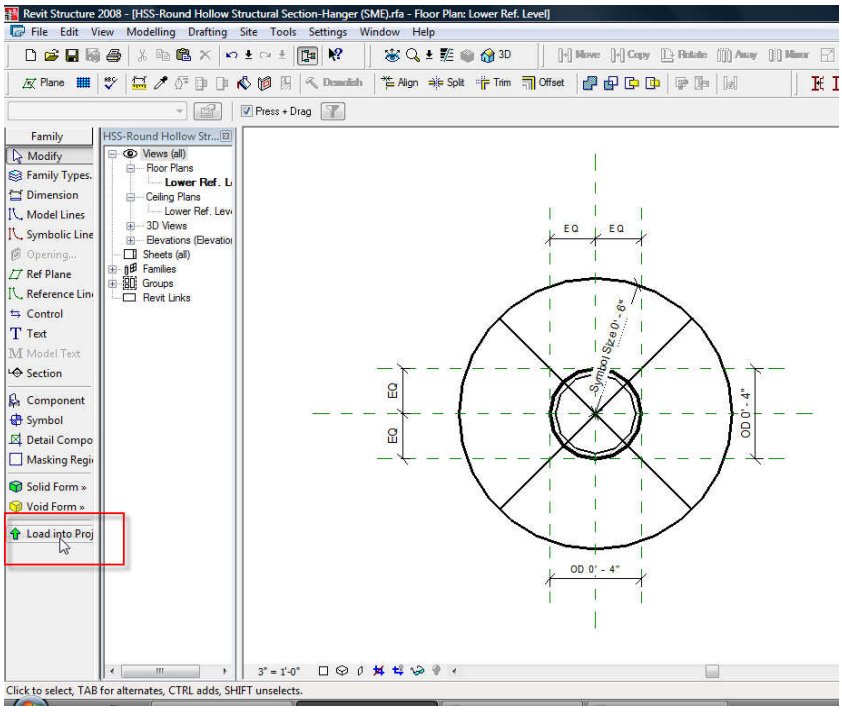
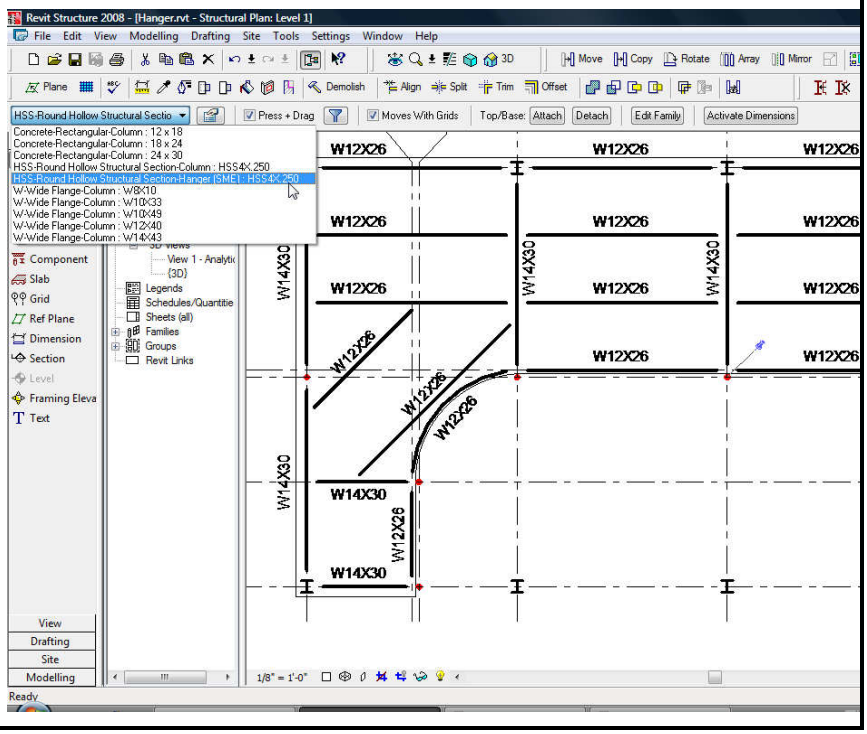
    Remember, these will be imported into the project as the default.

    These can be changed later in the project.



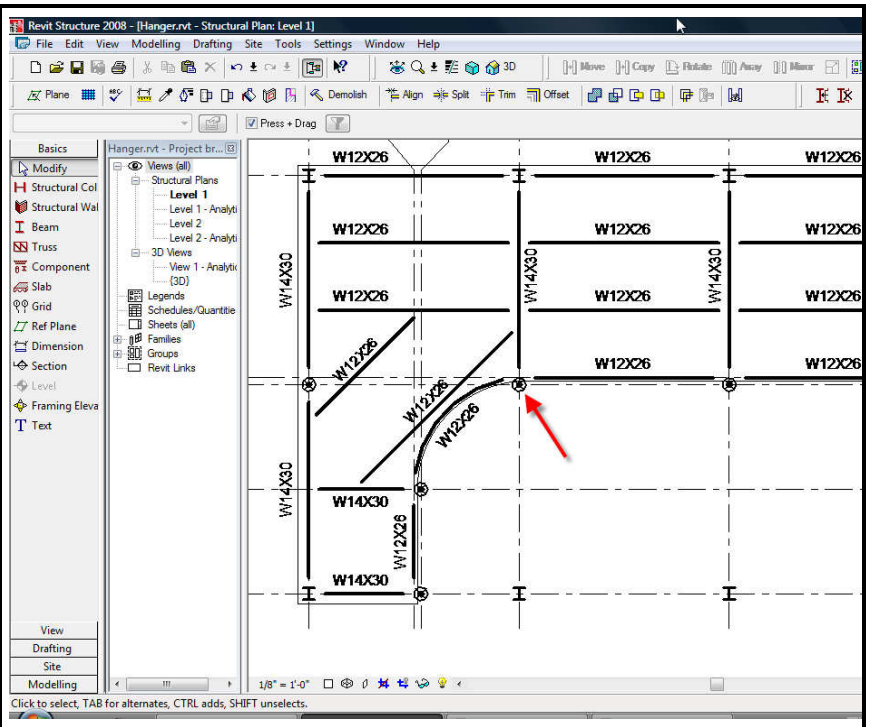
| | |
|---|---|
| 11. Set the style of the lines to use the newly created style. |  |
| 12. Create two reference lines at 45 degrees.<br><br>These will better control the orientation of some lines we are about to add. |  |
| 13. Draw two more symbolic lines, again using the newly created style.<br><br>Be careful to draw the ends at the edges of the circle.<br><br>Revit will automatically constrain them to adjust with the circle.<br><br>If it does not, constraints can be added later. |  |

| | |
|---|---|
| 14. Align and lock the symbolic lines to the reference lines. |  |
| 15. Dimension the size of the symbol, and add a parameter.<br><br>This allows us to easily adjust the size of the symbol once in the project. |  |
| 16. I placed my parameter under ‘Graphics’ and entered a default value of 6”.<br><br>This allows me to see if the symbol adjusts as I expect. |  |

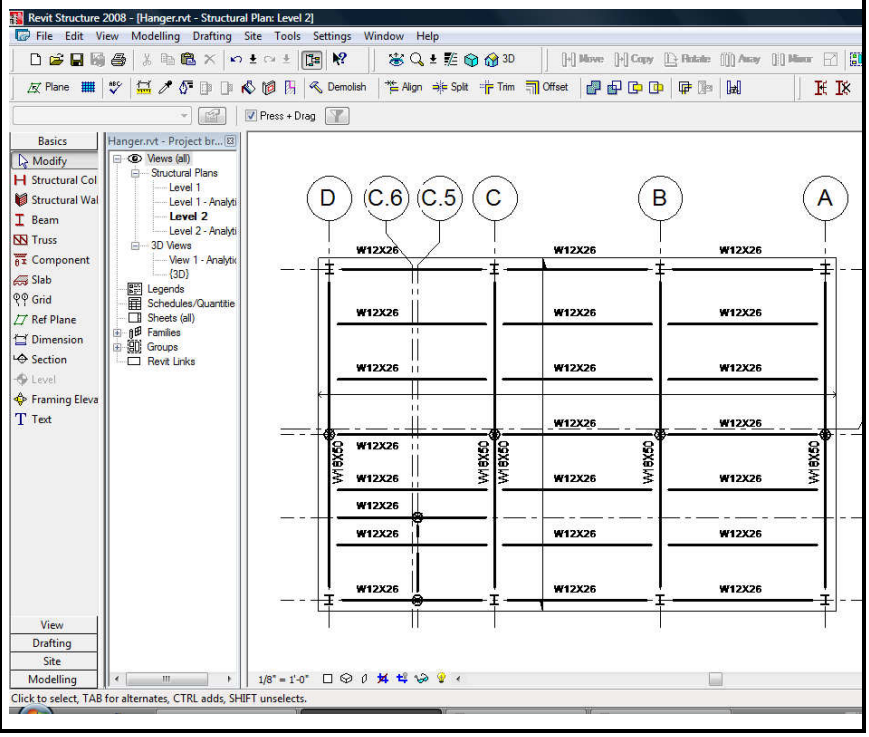
| | |
|---|---|
| 17. Once satisfied, load the new family into the project. |  |
| 18. Select all the hangers and switch them to the newly created family. |  |

19. The symbol now appears automatically in every instance.

    This has saved considerable time, and has created a standard family for future use.



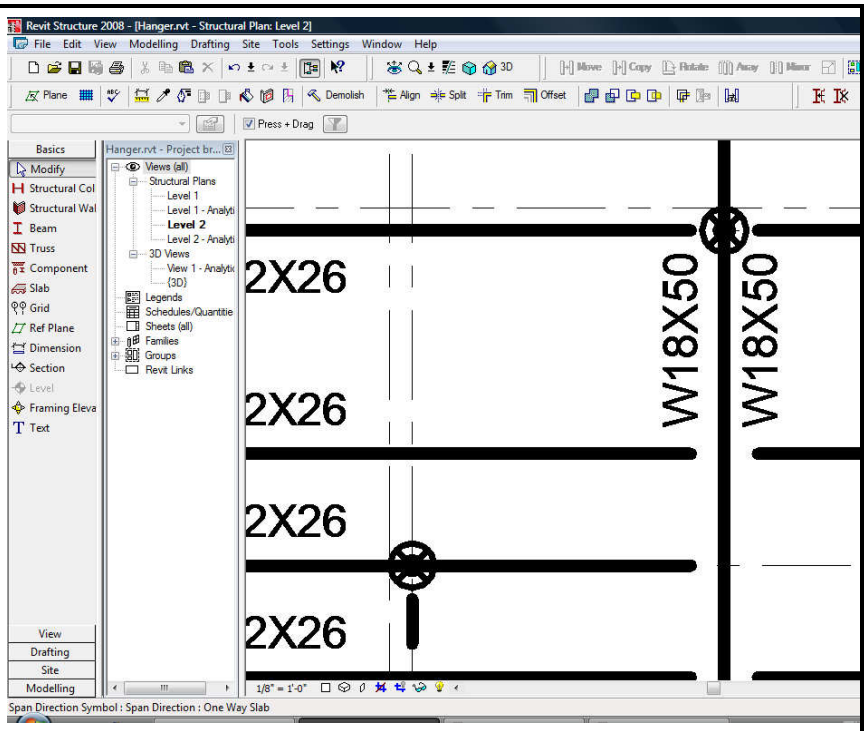

20. The hangers are now fairly apparent on the roof plan.



21. The symbol could stand to be a little larger. This is purely a matter of preference.

22. Click on an instance of the hanger.

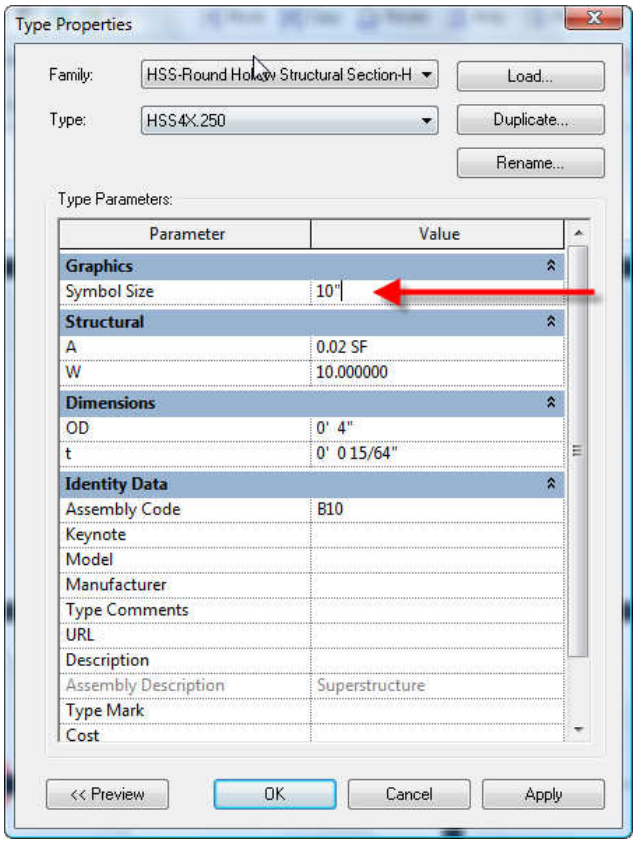
23. Go to properties, and then to type properties.




24. Modify the symbol size parameter. I'll try 10".

    Because this is a type parameter all symbols across the project will automatically enlarge.

    You could even set hangers of different sizes to have different symbol sizes.



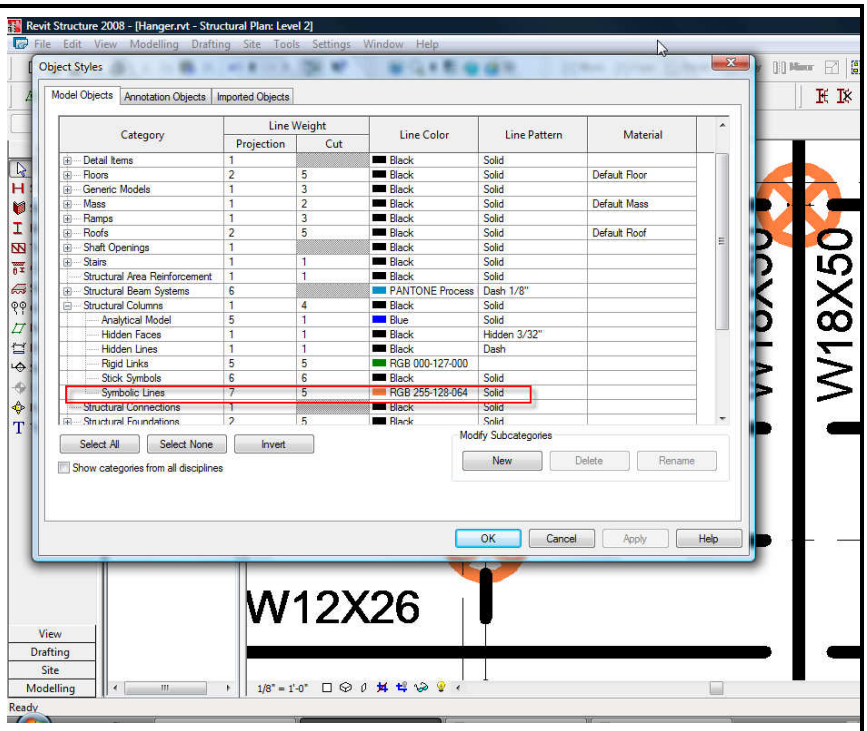
25. I will also change the line style.

26. Go to *Settings* → *Object Styles*.

    The new style appears under structural columns.

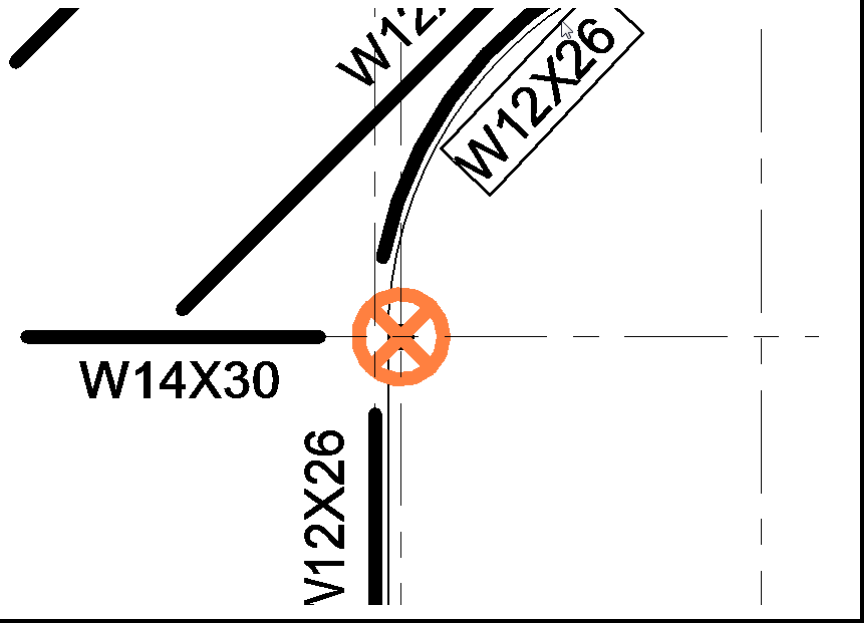
27. Change the *Projection Line Weight* to 7.

    I have also changed the color to identify any object affected by this line style.




28. The symbol now appears larger, thicker, and orange in all locations.

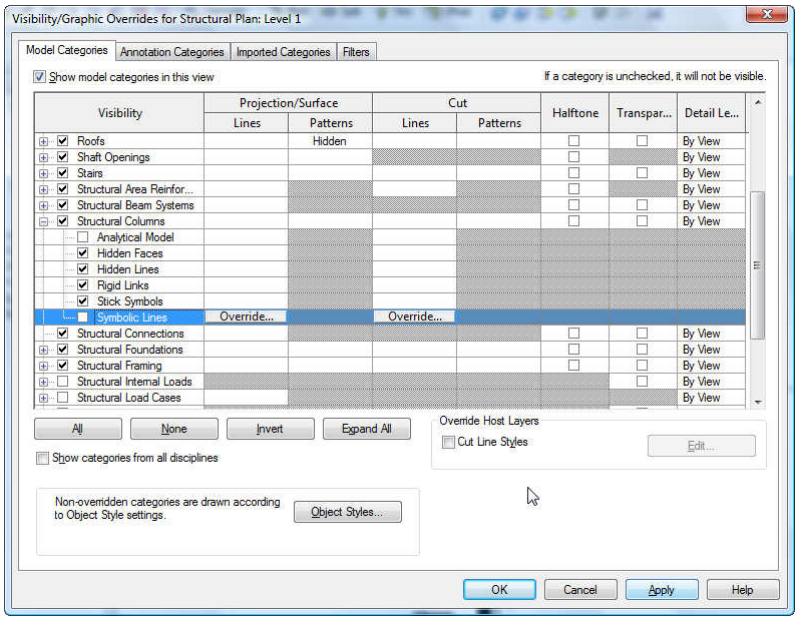
    However, we do not need the symbol on the second floor. We will turn it off.



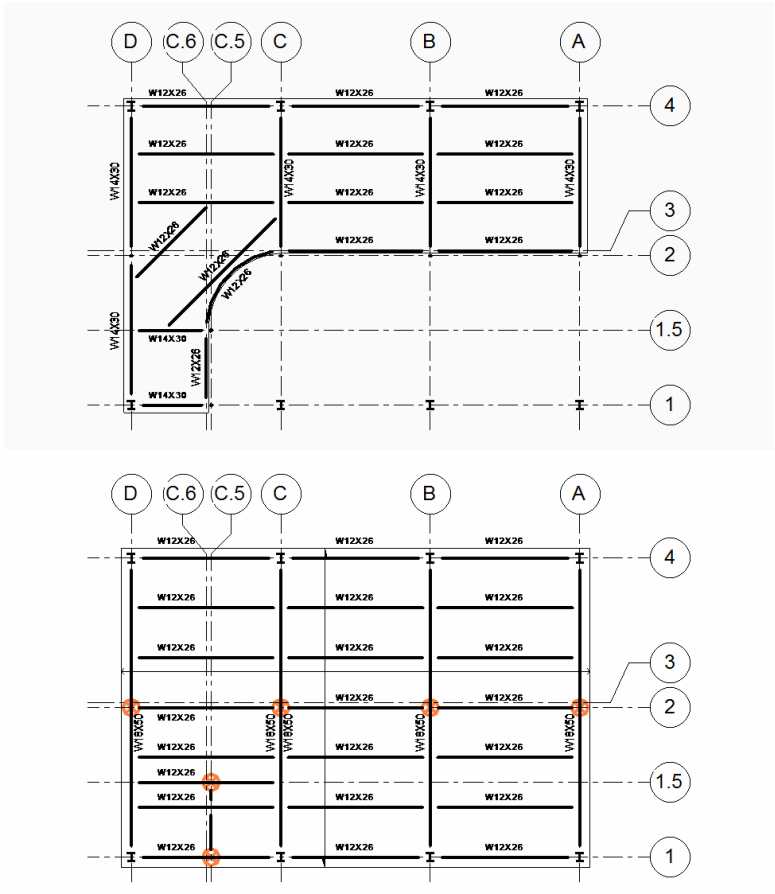
29. Browse to the appropriate floor plan.

30. Go into Visibility/Graphics.

31. Uncheck the ‘Symbolic Lines’ category.




32. The plan now returns to its original view, while preserving our changes to the roof plan.



## Clash Detection

In the last decade, California has seen a rash of hospital construction. California also has a complicated and lengthy review process for hospitals and schools. Any revisions must be thoroughly documented and proven to have no change to the seismic performance of the building. Coupled with rising construction costs and delays, it has become advantageous to avoid any changes in the field.

It is becoming more common to use Revit to model the structural systems, along with architectural skins, and mechanical equipment to determine if there will be any conflicts or clashes.

This is often one of the driving factors for the creation of a new family. In this case, it is important to model the physical dimensions of the object correctly – within reason. In our first projects, it was argued that structural steel should be model correctly within 1/8" of an inch; after all, that is the tolerance with which it is erected. Considering that fireproofing isn't even modeled, this kind of accuracy (even if it could be achieved) is a bit moot.

Before starting a family, consider carefully what level of accuracy will be needed, and where. In areas where the mechanical equipment will be sparse and can be adjusted easily, consider modeling to a tolerance of 2", perhaps even 6". In areas where it will be particularly crowded, more accuracy will be required. Do not forget that fire proofing, duct flanges, and bolts are typically not modeled; consider how this affects tolerance. Most importantly, put it in a contract.

For these purposes, only the largest occupied volume needs to be modeled. It is quite common to model open web joists and bridging so that the layout can be coordinated with ducts. There is no need for a family to indicate the varying sizes of steel angles used for the diagonals. Simply use the largest one.

## Envelopes

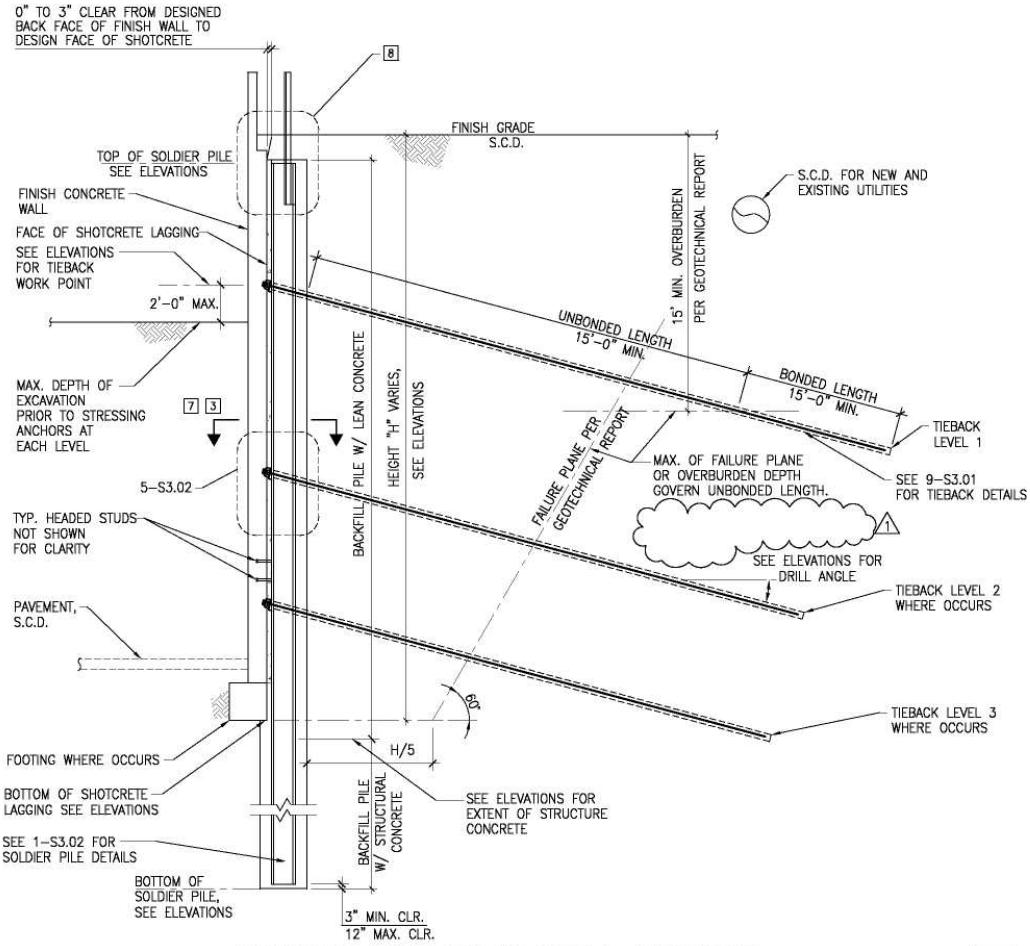
The largest possible occupied space can be thought of as an *envelope*. We successfully used this technique to find a very large number of clashes in the basement of a base isolated building.

Because the building moves relative to the basement, equipment mounted on the ground must maintain a clear space where any dampers or part of the building *may* move into. This can easily be represented by a conical envelope around any dampers, and oversized halos around objects equal to the expected movement of the building.

A second set of envelopes must also be used which represent the motion of the basement with respect to the building. This checks potential clashes for any equipment attached to the building.

## Example 4: Tie-backs

Tie-backs are a method of supporting excavated walls either temporarily or permanently. Long angled holes are drilled into the earth behind a wall; steel rods are then grouted into place. Rods must not overlap, and need to maintain a certain distance between each other for full effectiveness. A number of factors influence the length of a tie back.

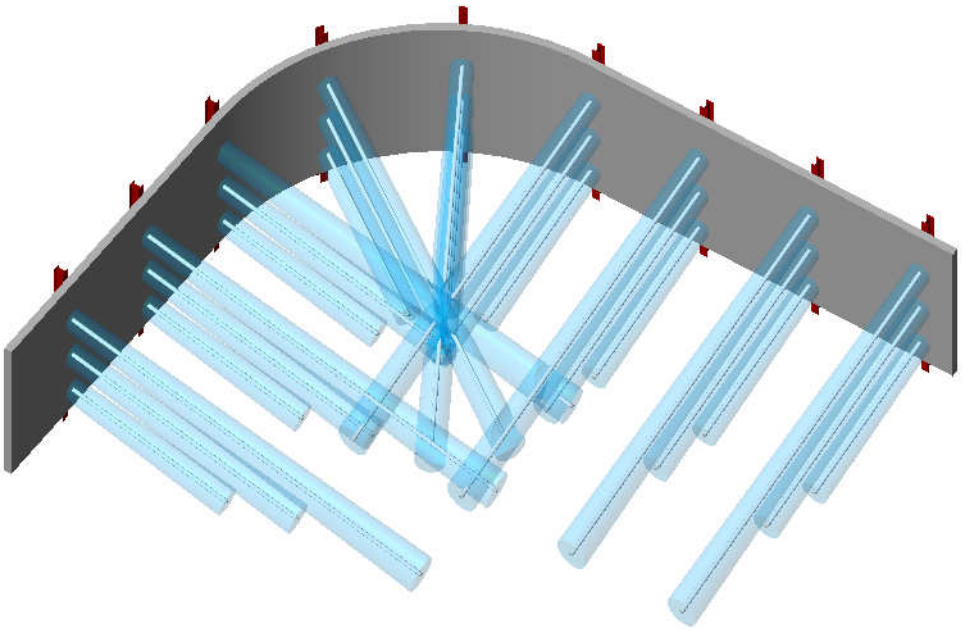



**TYPICAL TIED BACK WALL SECTION** 1

*Photo courtesy of Rutherford & Chekene*

Though complicated, this large number of factors is not normally difficult to handle. One need only calculate the worse case scenario and make sure it does affect any underground utilities. Because the tie-backs are parallel, a constant distance between them is maintained.

Traditionally this kind of quick calculation has been done in Excel and is a relatively easy hand check. That is, unless the tie-backs support a curved wall!



In this case, I created a family with all the geometric rules shown in our drawings. Based on the finished landscaping and bottom of footing, each tie back determines its own length. A halo or envelope is modeled around each tie-back reflecting any potential variations in the drill angle and half the clear distance which needs to be maintained. Where the envelopes overlap, there may be a potential problem. This could not have been accomplished easily by hand or using Excel.

A simple clash detection in Revit will locate any problem areas. As an added bonus, representations in plan can also be used to depict desired layout, orientation, and approximate drill length. Elevations may be used to clarify details.

## Summary

Revit need not only be a drafting tool. With planning and forethought Revit can be used as a design tool. The ability to author your own families, with your own rules and geometry, means anything can be modeled, in any way you desire.