Throw your Family a Curve

Taming unruly curves in parametric Revit families

Paul F. Aubin

SESSION DESCRIPTION

Have you ever tried to control the shape of a curved form parametrically in the Family Editor? If so you have no doubt discovered that flexing them sometimes throws you a curve ball. In this session, we will explore several techniques to tame your unruly parametric curves. We will look at examples of circles, arcs, quarter round, half round, arches and even throw in some splines. We will even explore some complex curves like cyma and cyma reversa profiles used in moldings. We will explore scenarios using curves directly in the sketch and also using profile families. We will work mostly in the traditional Family Editor but we'll take a brief look at the massing Family Editor environment at the end. After this session, I cannot guarantee that you will never have another misbehaving curve in your families, but what I can promise is that you come away with several useful tools to help you tame them when curve mischief strikes!

Learning Objectives

1. Understand the nuances of circles, ellipses, arcs and splines
2. Control flexing with math and rigs
3. Create compound curves that flex properly every time
4. Learn to scale families with curves proportionally

About the Speaker

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Paul F. Aubin is the author of many CAD and BIM book titles including the widely acclaimed: The Aubin Academy Mastering Series: Revit Architecture, AutoCAD Architecture, AutoCAD MEP and Revit MEP titles. Paul has also authored several video training courses for lynda.com (www.lynda.com/paulaubin). Paul is an independent architectural consultant who travels internationally providing Revit® Architecture and AutoCAD® Architecture implementation, training, and support services. Paul's involvement in the architectural profession spans over 20 years, with experience that includes design, production, CAD management, mentoring, coaching and training. He is an active member of the Autodesk user community, and has been a top-rated speaker at Autodesk University (Autodesk's annual user convention) for many years. Paul has also received high ratings at the Revit Technology Conference (RTC) in both the US and Australia and he spoke at the inaugural Central States Revit Workshop this year. His diverse experience in architectural firms, as a CAD manager, and as an educator gives his writing and his classroom instruction a fresh and credible focus. Paul is an associate member of the American Institute of Architects. He lives in Chicago with his wife and three children.

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Prerequisites

To get the most out of this paper, it is best that you have some familiarity with the Family Editor. Certain Family Editor skills are assumed. In the standard Family Editor, it is assumed that you understand:

- How to create a new Family
- How to edit and existing Family
- How to create Reference Planes
- Naming and using Reference Planes as Work Planes
- How to assign dimensions and parameters to Reference Planes
- How to flex a Family onscreen and in the "Family Types" dialog
- How to create basic 3D solids and voids

We will only look briefly at the Massing Family Editor, so it is assumed that you understand:

- The basic difference between model and reference-based forms
- Basic usage of Reference Lines
- Reference Points
- Work Planes
- Create Form button

Dataset files
You can find the dataset files in a DropBox folder at:
https://www.dropbox.com/sh/z8yyqkx4b5h6lc5/F5NboPJczV

If you are unfamiliar with any of these topics, some will be reviewed, but you are encouraged to seek out additional resources to learn about them before proceeding. You can find more on the traditional family editor at www.paulaubin.com/au and www.lynda.com/paulaubin

The basic problem with curves

Families like straight lines. I don't have this on absolute fact, but rather on personal experience. Controlling the location of straight lines is easily accomplished in the Family Editor using simple Reference Planes or Reference Lines. When you introduce curves: arcs, circles and ellipses it becomes a little more difficult to control them parametrically in a reliable and stable way. Techniques and procedures designed to address this issue are what this session is all about.

Traditional Family Editor Techniques

Most of this paper and session will take place in the traditional family editor environment. As noted above it is assumed that you have some familiarity with creating family content in the traditional family editor.

Getting Started

Prerequisites and Setup

If you were going into the shop to build some cabinetry, you'd want to make sure you had all the tools you needed and that the shop was in order before you started. Let's do the same in Revit.

All steps and screen shots here are Revit Architecture 2014, but most should work in other flavors or versions. ***Given time constraints in the lab, we will skip lessons prefixed with *****.

The Steps outlined here are meant to supplement the live presentation given in the lab. Steps have been kept brief and much of the explanations accompanying the steps in the live lab have been kept brief.

1. If Revit Architecture is not already running, launch it now.
2. From the Application Menu (big "R"), or on the Recent Files screen, choose **Open > Project**.
3. Browse to the folder containing this lab's dataset files (I will have this posted up on my screen) and open the file named: ***800 Sandbox.rvt***.
4. Minimize the active view.

The project file will remain open as we work through the next several lessons. As you build Family content, you will want to test if frequently. Having a project file open in the background is an excellent way to do this. I like to minimize it so that it stays out of my way till I need it. There is nothing special about a "sandbox" except what you put in it. You can open your standard office template, add a few Walls and other items and save it as a sandbox. It is that simple.

And now, on with the good stuff! Let's start building some Family content!

***Creating a "Seed" Family

Seed Families provide convenient starting points for more complex Families

There are many ways that we could start our explorations. No one approach is necessarily more correct than others in many cases. The best thing you can do is try a few techniques and then in each situation, choose the best technique(s) that suite the needs of the specific family that you are trying to create. In this lesson, we will employ a simple strategy of identifying some common components shared by many families. If you create a few starting families with these characteristics already built-in, it can save you time and effort when you build each family. We will call such starting families "seed" families.

800 Create a New Family

1. If Revit Architecture is not already running, launch it now.
2. From the Application Menu (big "R"), or on the Recent Files screen, choose **New > Family**.
3. Select the file named: *Generic Model face based.rft* and then click Open.
4. Type WT and then ZA.
5. Save the file as: **Family Seed (Face Based)**.

800 Set the Units

For these examples, I am going to keep the units generic. But feel free to use whatever your preferred unit is.

1. On the Manage tab, click the Project Units button.

2. Next to Length, click the button to change the setting.
3. For Units, choose **Decimal Feet**. For Rounding choose **3 decimal places**.
4. Click OK twice to finish (see Figure 1).

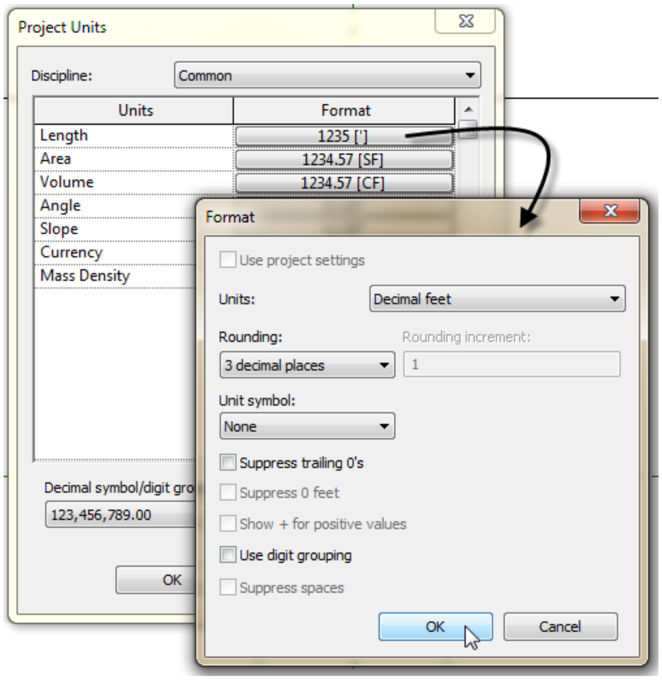


Figure 1—Set the units in your seed family

800 Adding Reference Planes

Since many families need a width and length parameter, let's add some Reference Planes, name them and create the parameters.

1. Starting in the upper left quadrant, about 1 unit away from the centerline, click the start point.
2. Draw it straight down vertically.
3. Mirror the Reference Plane to the other side.
4. Mirror them both along a 45° angle to create four total.
5. Name each one: **Left**, **Right**, **Front** and **Back** (see Figure 2).

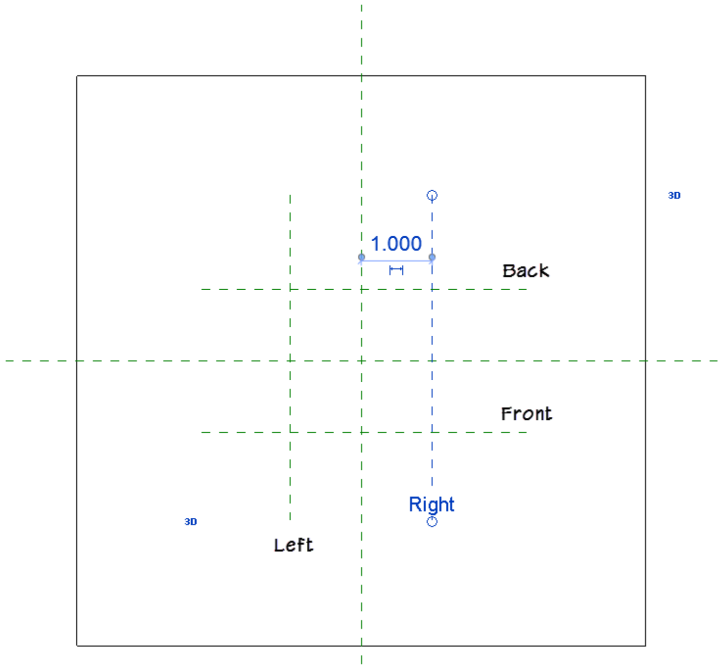


Figure 2—Create and name the Reference Planes

800 Dimension and Constrain the Reference Planes

Next we'll add the basic linear dimensions.

1. Using the Aligned Dimension tool (DI), click the first witness line on the Reference Plane Left, then Center (Left/Right) and then Right.
2. Click a point to place the dimension and then toggle ON the equality.
3. Create a second one from left to right only.
4. Repeat both dimensions in the vertical direction as well (see Figure 3).

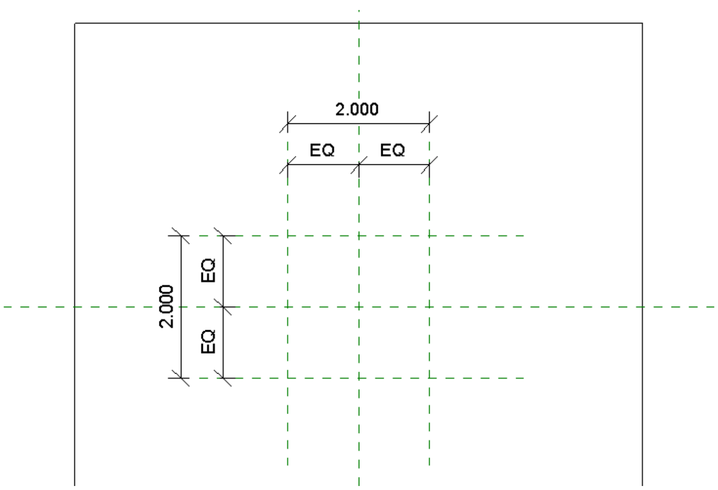


Figure 3—Add dimensions

5. Select the horizontal dimension and label it with a new Instance-based parameter named: **W**.
6. Select the horizontal dimension and label it with a new Instance-based parameter named: **D** (see Figure 4).

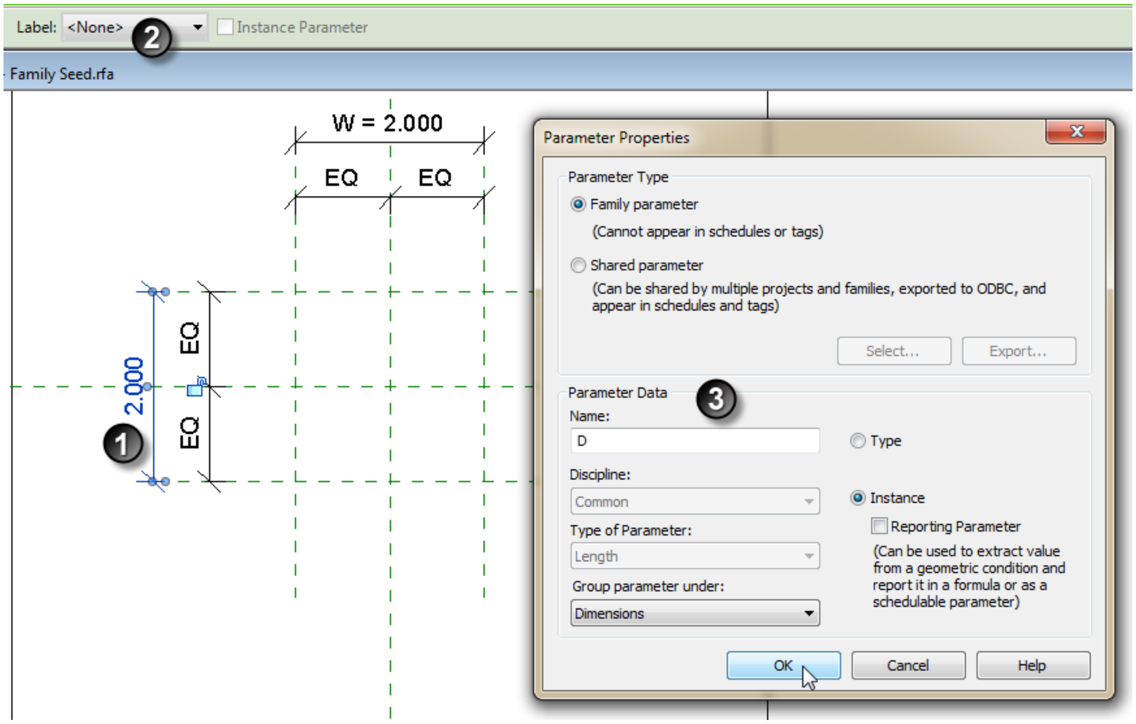


Figure 4—Create and assign parameters

7. Flex it to test it out.
8. Save the file when everything is working correctly.

800 Create an alternate non-hosted version

Sometimes you will not want the family to be face-based. So let's create a non-faced-based version.

1. From the Application menu, choose **New > Family**.
2. Select the file named: *Generic Model.rft* and then click Open.
3. Type WT and then ZA.
4. Save the file as: **Family Seed (Non Hosted)**.
5. Repeat all of the previous steps to create the same reference planes, dimensions and parameters and then save the file.

We will return to these files frequently as a way to save steps. Whenever you need a new starting Family, you can open one of these and choose Save As to create the Family. This will save the trouble of having to recreate the Reference Planes, Dimensions and Parameters each time.

CATCH UP! Files have been provided completed to this point named: ***800 Family Seed (Face Based).rfa*** and ***800 Family Seed (Non Hosted).rfa***.

Constraint and Parameter Direct Attachment

How you apply a constraint or parameter can influence its behavior

The general rule-of-thumb in family creation is to create a clear and consistent hierarchy between the references, constraints and geometry. Typically this means that you would want to lay down your reference planes and reference lines first. You would next apply constraints and parameters to these references and flex them to be sure that they function properly. Finally, you would build your geometry and lock it to this properly flexing armature of references. This is the so-called "bones, muscle and skin" analogy. It is my experience that this is often the best approach in most situations. However, as with any rule or guideline there are always exceptions. In the next few lessons, we'll look at a few examples where the dimensions (be they constraints or parameters) will be applied directly to the geometry instead of a reference. The general rule should still be followed: if you can dimension your reference lines or planes first, and then attach geometry to them, it is generally preferred. But as we will see, this is not always possible or desirable.

801 Create a parametric Circle

Two forms that will use the direct attachment method will be circles and ellipses. To parametrically flex and or reliably constrain these elements, we typically need to apply the dimensions directly the forms. (This applies in the traditional family editor environment. In the massing environment, things behave differently).

1. From the Application menu, choose **Open > Family**.
2. Select the file named: *800 Family Seed (Non Hosted).rft* and then click Open.
3. Type WT and then ZA.
4. Save the file as: **Circle**.

All solid and void forms in the Family Editor can use circles. So you can perform the following procedure on any kind of form. To keep the exercise simple, we'll use an extrusion, but feel free to practice the steps on other forms as well later on.

5. On the Create tab, on the Forms panel, click the Extrusion button.
6. On the Modify | Extrusion tab, on the Draw panel, click the Circle icon.
7. Draw the circle centered on the reference planes in the file. Snap the size of the circle to the width and depth defined by the reference planes (see Figure 5).

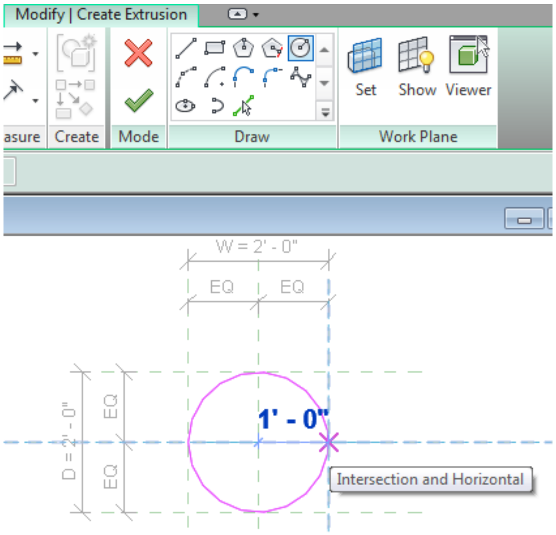


Figure 5—Draw a circle and snap it to the reference planes

Even though we snap the circle to the reference planes, it will not flex when the parameters flex. To do this, we will add a radius dimension and parameter directly to the circle.

8. Click the icon beneath the dimension to make the temporary dimension permanent.
9. Label this dimension with a new parameter and call it: **R** (see Figure 6).

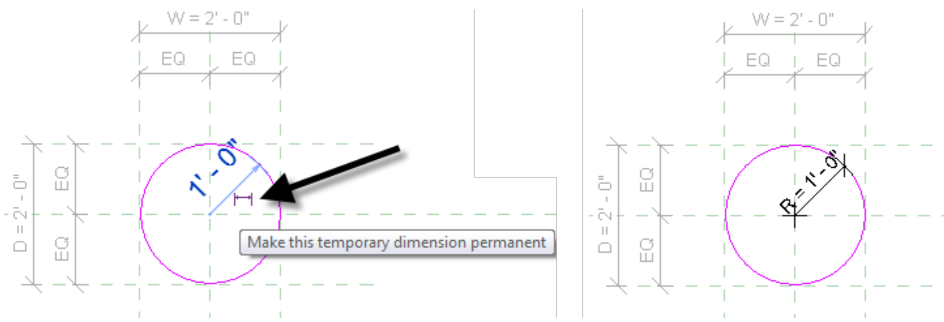


Figure 6—Create the dimension and a radius parameter

10. Finish the extrusion.

We could flex the extrusion now to be sure that it works, but since we already have the W and D parameters that represent the overall extents of the circle, let's add a few simple formulas in the "Family Types" dialog to tie all three parameters together so they flex in a logical way. We want W and D to be equal, and R to be half of W and D.

11. Open the "Family Types" dialog.
12. In the Formula column next to W, Type: **D**. For the Formula next to D, type: **R * 2** (see Figure 7).

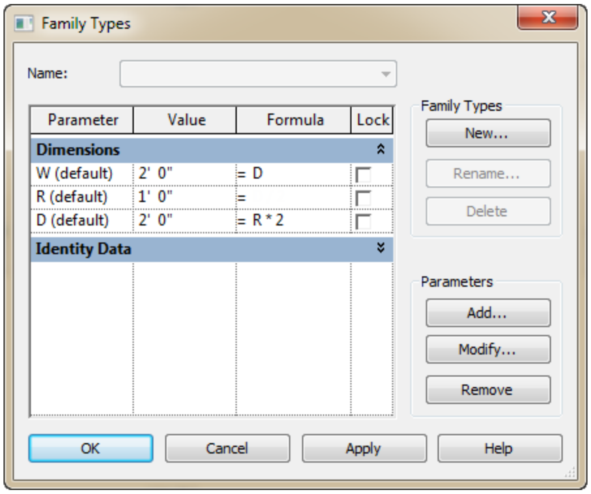


Figure 7—Link the three parameters with formulas

13. Flex the family.

The circle should change size as you flex the radius. The width and depth should also flex with the radius.

Note: If you prefer, you can use the Diameter dimension tool on the circle and thereby eliminate the need for the formula based on the R parameter. In this case, the diameter can be set equal to the either the W or D parameter directly.

CATCH UP! You can open a file completed to this point named: ***801 Circle.rfa***.

801 Create a parametric Ellipse

Creating a parametric ellipse is very similar. For this one, we'll tie the width and depth separately to each ellipse axis. Otherwise, the procedure is nearly the same.

Continue in the previous file or open the catch-up file.

1. Save the file as: **Ellipse**.
2. Open the "Family Types" dialog. Clear the formulas.
3. Select the R parameter and then click Modify.
4. Rename it to: **X** and then click OK. For the Formula, type: **W / 2**.
5. Add another Length parameter named: **Y** and then click OK. For the Formula, type: **D / 2** and then click OK (see Figure 8).

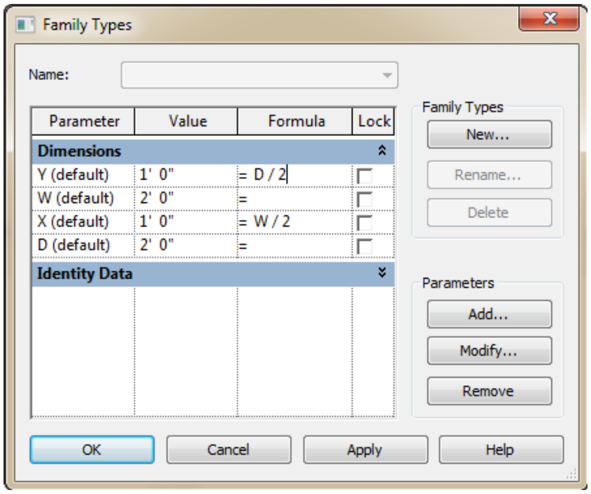


Figure 8—Edit the parameters to prepare them for the ellipse

The parameters are now ready, let's edit the extrusion next.

6. Select the circle extrusion and then on the ribbon, click the Edit Extrusion button.
7. Select the circle sketch and delete it.
8. On the Draw panel, click the Ellipse icon and then click the center point at the center of the square.
9. Snap the first ellipse axis to the intersection of the Center (Front/Back) and Right reference plane. Snap the other axis to the intersection of the Center (Left/Right) and Back reference planes.
10. Make both dimensions permanent (see Figure 9).

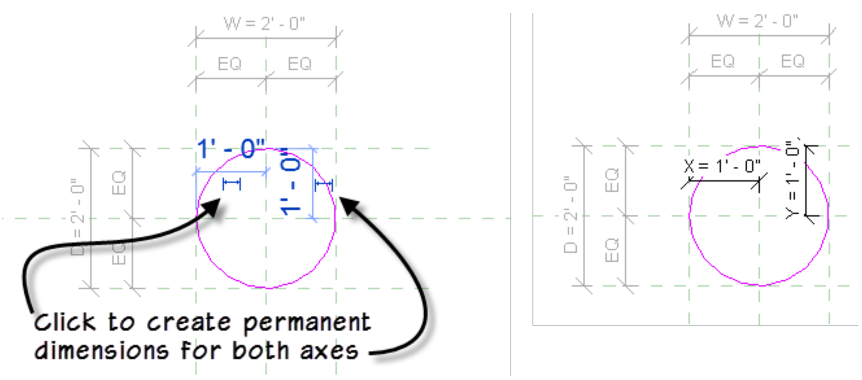


Figure 9—Draw an ellipse and make the dimensions for both axes permanent

At the moment, this ellipse looks like a circle. Mathematically, a circle is really just a special case of an ellipse. So you can actually use an ellipse all the time if you prefer and when you need a circle just flex it so that both axes are equal. Let's finish it and flex.

11. Label the vertical dimension with the Y parameter and the horizontal one with the X parameter.

12. Finish the extrusion and then open the “Family Types” dialog and flex.

You should be able to input values for any of the four parameters. If you make the width and depth different, you will get an ellipse. Make them the same to get a circle.

CATCH UP! You can open a file completed to this point named: ***801 Ellipse.rfa***.

Center Mark Visible

For curved objects like circles and ellipses you can display the center mark. This can be helpful to ensure that the element flexes in the way you expect and intend. Any curved object has this setting including arcs. For ellipses, you can also display the foci. To display either, look for the checkbox on the Properties palette (see Figure 10).

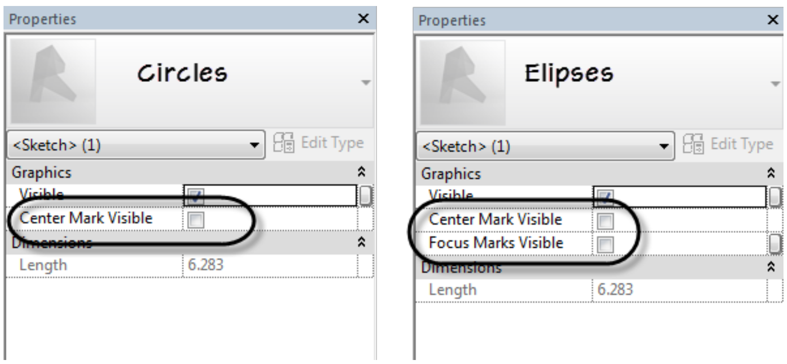


Figure 10—Enable the Center Mark or Focus Marks for Circles and Ellipses on the Properties palette

We'll look at some examples in the next topic.

Automatic Sketch Dimensions

You may have noticed that when you flex Revit families certain parts may be constrained automatically. Sometimes it behaves exactly as you want and expect, but not always. Revit does not always automatically constrain the points you expect. So how do you determine what automatic constraints are applied? The answer is Automatic Sketch Dimensions. Automatic Sketch Dimensions can be made visible in the Visibility/Graphics Overrides dialog. Use the VG shortcut to open the dialog just like you would in a project. Once there, the Automatic Sketch Dimensions are a sub-component of Dimensions.

801 Enable Center Mark

1. Open the file: ***801 Circle.rfa***.
2. Tile the windows and then save the file as: **Circle (Sketch Dims)**.
3. Open the “Family Types” dialog. Clear the formulas and then click OK.

This means that the width (W) and depth (D) parameters are no longer linked together.

4. Make the *Ref. Level* Floor Plan active.
5. Select the extrusion onscreen and then on the ribbon, click the Edit Extrusion button.

6. Select the circle onscreen. On the Properties palette, check the Center Mark Visible checkbox (shown above in Figure 10).

CATCH UP! You can open a file completed to this point named: ***801 Circle (Sketch Dims).rfa***.

801 Enable Automatic Sketch Dimensions

7. On the View tab, click the Visibility/Graphics button (or type VG).
8. Click the Annotation Categories tab.
9. Beneath the Dimensions category, check the Automatic Sketch Dimensions checkbox and then click OK (see Figure 11).

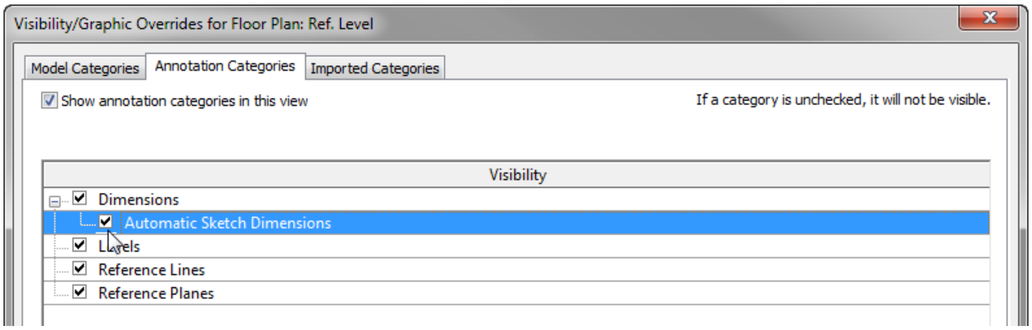


Figure 11—Enable the display of Automatic Sketch Dimensions

Notice the two blue dimensions near the center of the circle. These are the Automatic Sketch Dimensions and by default have associated the center of the circle to the intersection of the two reference planes at the origin of this family (see Figure 12).

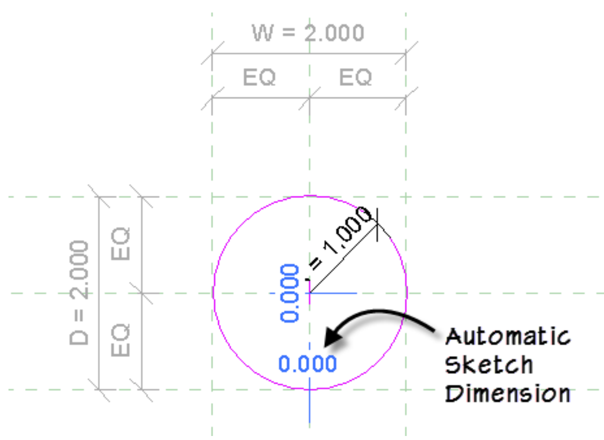


Figure 12—Automatic Sketch Dimensions display in a blue color

10. Return to the "Family Types" dialog and flex the W and D parameters.

As noted above, without the formulas, these two flex independently.

11. Flex the radius (R) parameter.

Notice that the circle stays centered on the reference planes.

12. Click OK to dismiss the "Family Types" dialog.

Revit is always looking to establish logical relationships in your families. It does this by placing Automatic Sketch Dimensions in logical locations. In this case, Revit assumed we wanted to keep the center of the circle aligned to the reference planes at the origin (maintain a zero distance in each direction). This may seem pretty logical. For a circle, there aren't too many other logical assumptions to make, so constraining the center is a good bet. However, this simple example does not tell the whole story. Automatic Sketch Dimensions are not identical to constraints. They will adjust on-the-fly as you edit your family. Let's try another example.

13. Drag the circle down about **.5** units (it does not have to be exact).

Notice that the vertical Automatic Sketch Dimension no longer reads zero, but now displays .5 or whatever amount you dragged it. If you flex now, it will keep the center of the circle offset from the reference planes by this amount. Again, this may be your intent and may seem logical, but in some cases it may not be what you wanted.

14. On the ribbon, click the Finish Edit Mode button.

Let's return to our Ellipse family and see another example.

15. Open the file named: ***802 Ellipse (Sketch Dims).rfa*** and tile the windows.
16. Open the "Family Types" dialog.

Note that the formulas here have already been removed.

17. Flex the W and D parameters.

Notice that this time, the object does not stay centered. Let's edit the extrusions and take a look at the Automatic Sketch Dimensions. They have already been turned on in this file.

18. Select the extrusion onscreen and then on the ribbon, click the Edit Extrusion button.

Notice that the Automatic Sketch Dimensions are attached to the left side horizontally and to the center vertically. Logical? Perhaps; perhaps not. The point is, that if you do not like the assumptions that Revit makes with the Automatic Sketch Dimensions, you cannot edit them directly. Instead you have to add your own constraints and dimensions to make your intent known to Revit. As soon as you add a dimension or constraint of your own, the Automatic Sketch Dimension will be removed. You cannot simply delete them. You *must* add your own constraints or parameters to override (and therefore make unnecessary) the automatic behavior.

19. Select the ellipse onscreen. On the Properties palette, check the Center Mark Visible checkbox (shown above in Figure 10).
20. Using the Align tool, align and lock the Center Mark to the Center (Left/Right) and Center (Front/Back) reference planes.

Notice that as soon as you lock the alignment, the Automatic Sketch Dimension disappears. The same is true if you add your own permanent dimension; even if you don't lock it. Any dimension, constraint or parameter will have a higher priority than the corresponding Automatic Sketch Dimension and as a consequence will disable it.

21. Flex the ellipse after aligning and locking and note that it now flexes around the intersection at the origin.
22. Finish the Edit Mode, and close the Ellipse file. You do not need to save.

Automatic Sketch Dimensions are an important factor in being successful in the Family Editor. If you are unaware of them, it can make your work in the Family Editor frustrating as you make guesses on how to force Revit to behave the way that you need. There are a few schools of thought on the use of Automatic Sketch Dimensions. The first is to have the goal of eliminating them in all families. To do this, you would need to add your own constraints and parameters at all locations where Automatic Sketch Dimensions appear. This can be easy to accomplish in simple families, but in more complex ones, it can become quite difficult to achieve. So an alternate approach is to replace only those Automatic Sketch Dimensions that run counter to your design intent. In other words, if the family is flexing properly with the Automatic Sketch Dimensions, you can leave them alone. It is really up to you.

In general, I prefer to eliminate the Automatic Sketch Dimensions where possible, but try not to become consumed by the task. If Revit insists on applying some Automatic Dimensions and they are not preventing my family from flexing properly, then I leave them alone. Your results may vary.

As you work in the Family Editor, you may find yourself enabling and disabling the display of Automatic Sketch Dimensions frequently. While tempting to leave them on all the time, sometimes they get in the way, so you'll want to turn them on and off as needed. However, going in and out of Visibility/Graphics can get tedious. If you are familiar with the Revit API, you can use a macro to toggle the display of the Automatic Sketch Dimensions. There is a terrific blog devoted to the Revit API complete with many code snippets for you to try. It is called Boost Your BIM at **boostyourbim.wordpress.com**.

Here are some links to the code and instructions on how to make a macro from it to toggle the Automatic Sketch Dimensions:

http://boostyourbim.wordpress.com/2013/03/28/how-to-toggle-the-visibility-of-automatic-sketch-dimensions/
http://boostyourbim.wordpress.com/2013/02/15/how-to-use-boost-your-bim-source-code-to-create-working-macros/
http://boostyourbim.wordpress.com/2012/12/23/using-statements/

Quarter Round and Half Round (Astragal and Torus)

Constraining a simple curve

If you have successfully constrained, parameterized and flexed a circle or ellipse, you might next want to do the same for an arc. Arcs can be very similar to circles, but they do introduce an additional wrinkle; they have endpoints. If your center remains at a fixed location, arcs are pretty easy to control. If the center moves, you have the additional challenge of parameterizing the movement of the center. Let's consider the case where the center is fixed first.

801 Locking Endpoints

1. Open the file: ***800 Family Seed (Sketch Dims).rfa***.
2. Tile the windows and then save the file as: **Arc (Centered)**.

This file is a copy of the seed families created above. It has the W and D parameters and has Automatic Sketch Dimensions enabled. There are no formulas in Family Types.

To keep this example quick and easy, we'll build a model line. This way we can focus on just the arc instead of creating an entire form.

3. On the Create tab, click the Model Line tool.
4. On the Draw panel, click the Center, Ends Arc tool.
5. For the center, click at the intersection of the Center (Left/Right) and Center (Front/Back) Reference planes.
6. Snap the first endpoint to the intersection of the Center (Front/Back) and Right Reference planes. Snap the other point to the intersection of the Center (Left/Right) and the Back Reference planes.

Two lock icons will appear.

7. Close both locks (see Figure 13).

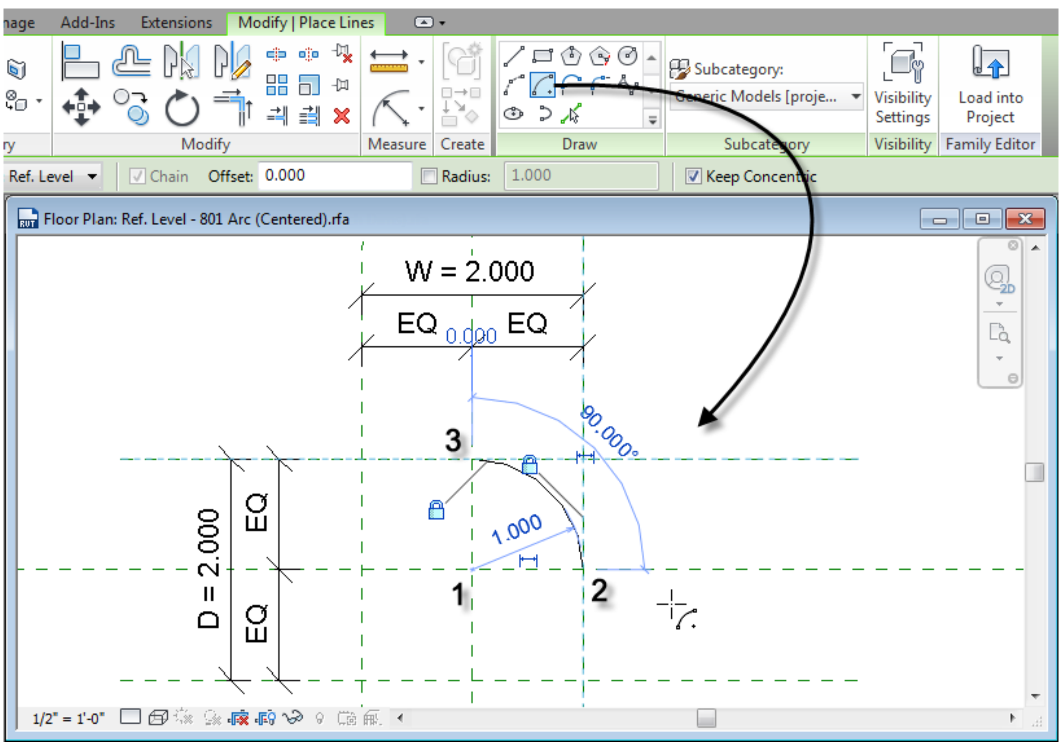


Figure 13—Create a Model Line arc centered on the Reference Planes

When finished, you will see an Automatic Sketch Dimension for the center of the arc. If you had not closed the two lock icons, we would also have had Automatic Sketch Dimensions at the ends of the arc. As noted above, the Automatic Sketch Dimensions try to anticipate how you intend to flex the object. They take into account the kind of geometry that you have. So in this case, since we have an arc, if the endpoints are constrained, only the center requires the automatic dimension.

The more dimensions and constraints that you apply, the less automatic dimensions will be required. Of course there is a fine line we walk here. If you are not careful, it is easy to get the dreaded “this would over constrain the sketch” error.

8. Add a radius dimension to the arc.

Notice that the Automatic Sketch Dimensions disappears. Let’s add a parameter to the radius so we can flex the size of the curve. There are a few approaches. Let’s look at two variations.

9. Select the radius dimension and label it with the existing D parameter (see the left side of Figure 14).

Notice how this move the center out to the lower left. This is because the curve currently has its endpoints constrained to the back and Right Reference planes. If we had not locked them above, Revit would tend to favor the center point location instead. So in this case, the sequence that you apply the constraints and parameters matters. You can flex the curve without linking up the D and W dimensions, but it will seem more logical if you add a simple formula to keep the two parameters equal to each other.

10. In Family Types, in the Formula column for W, type **D**.

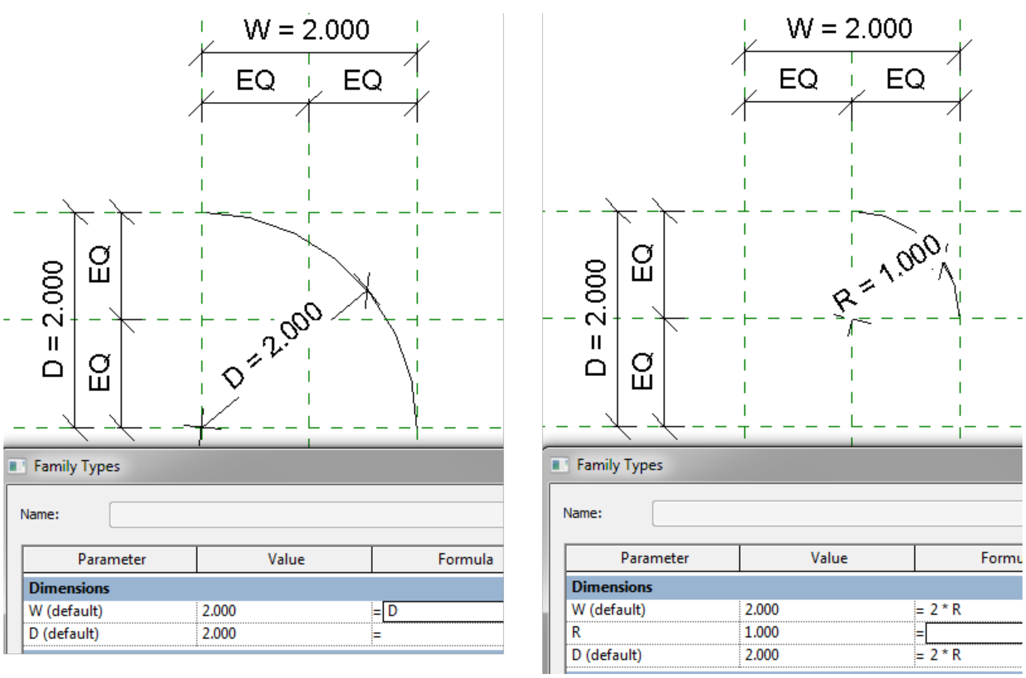


Figure 14—Two approaches to applying a parameter to the radius dimension

Alternate:

11. Undo the last two steps and instead, create a new parameter for the radius dimension and name it **R**.
12. In Family Types, add a formula to both W and D: **2 * R** (see the right side of Figure 14).

This time, the center will not move. When you flex, the arc will remain centered in the overall box. Ultimately the precise approach you use is a matter of preference. You can also try dragging the arc's endpoints to produce a different angle. 90° increments should be very stable. But even other angles should work well since the main controlling parameter here is the radius. To add even more stability, turn on the center mark (see above) and then align and lock the center in both directions to the reference planes. To do this successfully, you may need to remove the endpoint constraints first.

801 Control the Arc Angle Parametrically

If you want to be able to control the angle of the arc parametrically, first make sure you have constrained the center and are parametrically controlling the radius. Next we can add an angle parameter to the arc.

13. Select the arc onscreen.
14. Click the icon to make the temporary dimension for the angle permanent.
15. Select this new dimension and label it with a new parameter. Flex (see Figure 15).

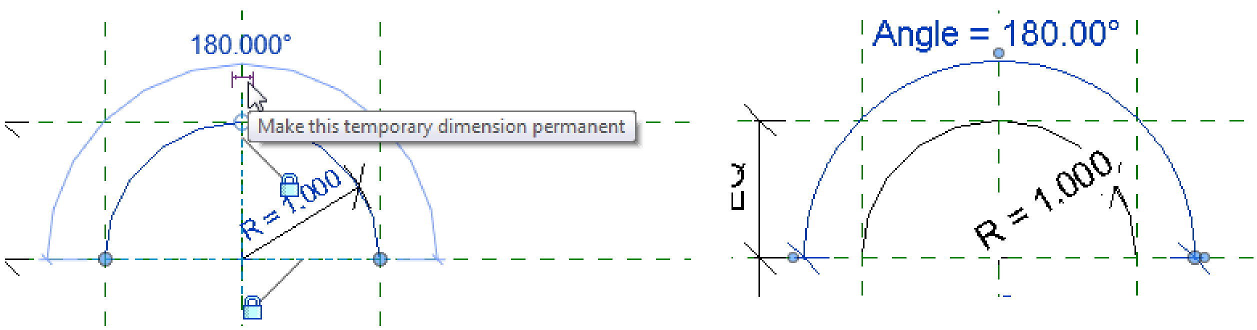


Figure 15—Add an angular parameter

You can use the previous techniques to create an astragal, a torus, quarter-round and half-round shapes. You can also use the half-round shape to create Roman arches.

CATCH UP! You can open a file completed to this point named: ***801 Arc (Centered).rfa***.

Controlling Rotation

While not directly related to curves, controlling rotation in a family reliably is another important skill. Many families require rotational parameters. Reference Planes do not rotate reliably. To add an angular parameter to a Family, you need to use a Reference Line instead of a Reference Plane. Even though Reference Planes appear on screen to have a start and end point, they are really infinite. This makes it difficult to use them to control rotation in a Family. A Reference Line on the other hand has a finite length and both a start and end point. You can assign angle parameters to them. Also, Reference Lines have built-in work planes, so you can also use them to control the rotation of other elements within a Family. A very common application for this is to control the swing of a door. However, we can also use this technique in conjunction with the previous lesson to control the angle of a variable arc at both its start and end points.

In order to use a Reference Line to control a rotation parameter effectively, you need to establish two things: first, you must constrain the end of the Reference Line that you wish to be the point of rotation. If you do not, the rotation parameter will behave unpredictably. Second, you must set one of the work planes of the Reference Line current and then add your solid geometry to this plane. Alternatively, you can lock geometry to the rotating Reference Lines in some cases as well. Reference Lines can be drawn in a variety of shapes. However, a simply linear Reference Line is the most useful for rotational parameters.

802 Create a Door Family with Variable Swing

Many Families can benefit from parametrically controlled rotation. But perhaps one of the most common is a door with variable swing. The following steps show a simple example.

1. From the Application Menu (big "R"), or on the Recent Files screen, choose **New > Family**.
2. Select the file named: *Door.rft* and then click Open.
3. Save the file as: **Door w Variable Swing**.

802 Add and Constrain a Reference Line

In this tutorial, we will create an angular parameter and associate it to a Reference Line for purposes of defining a variable door swing parameter in the Door Family. The trick to making the Reference Line work properly is being sure that you apply the constraints and parameters to it very carefully. In the Family Editor, it is sometimes easier to do this if you hide some of the geometry.

1. Select the Wall and on the View Control Bar, from the Temporary Hide/Isolate pop-up, choose **Hide Element**.
2. Repeat for the Frame/Mullion component.

There are three horizontal Reference Planes remaining on screen where the wall was. One is at the center and one each for the two edges of the wall. These two are named: Exterior and Interior. This is a standard feature of the *Door.rfa* template (see Figure 16).

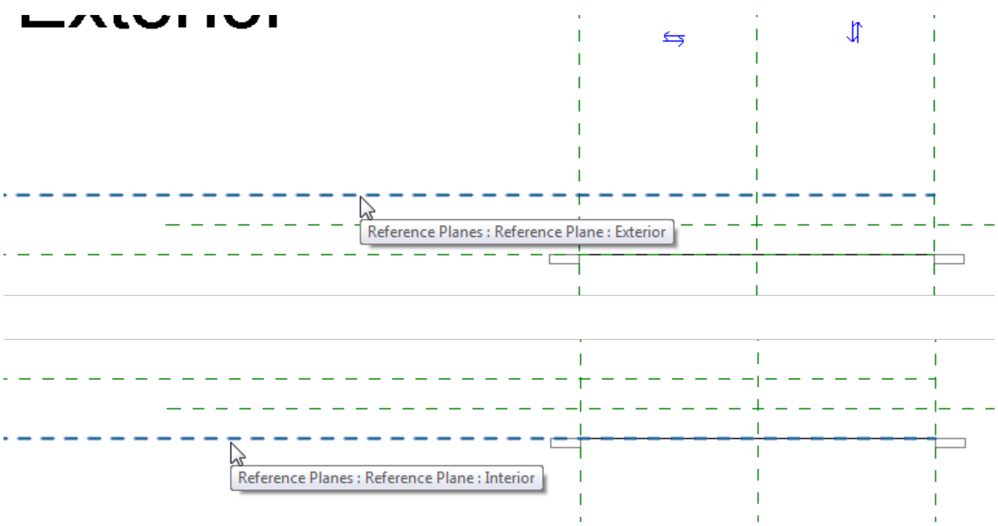


Figure 16—Reference Planes are included at the faces of the wall

We need to decide where we want the door's hinge point to be. If you want the hinge to always be at the face of the wall, we can use one of these two Reference Planes. Otherwise, you would want to create a new Reference Plane for the hinge.

The point of considering this issue is to realize that there can be much deliberation that goes into the creation of any Family. For simplicity's sake and to focus on the rotation parameter, we will use the Exterior Reference Plane for our hinge point in this exercise. Once you understand the procedure outlined here, you can take the technique and apply it differently in your own Families.

802 Create the Reference Line and Constrain it

The basic process required is as follows: Draw a Reference Line, lock one endpoint to the intersection of two Reference Planes (this is the location of the hinge point). Then assign a rotation parameter to the Reference Line. The easiest way to do this is to draw the Reference Line at an angle first.

1. Draw a 45° Reference Line starting at the intersection of Left and Exterior Reference Planes. Make it 3'-0" long (see Figure 17).

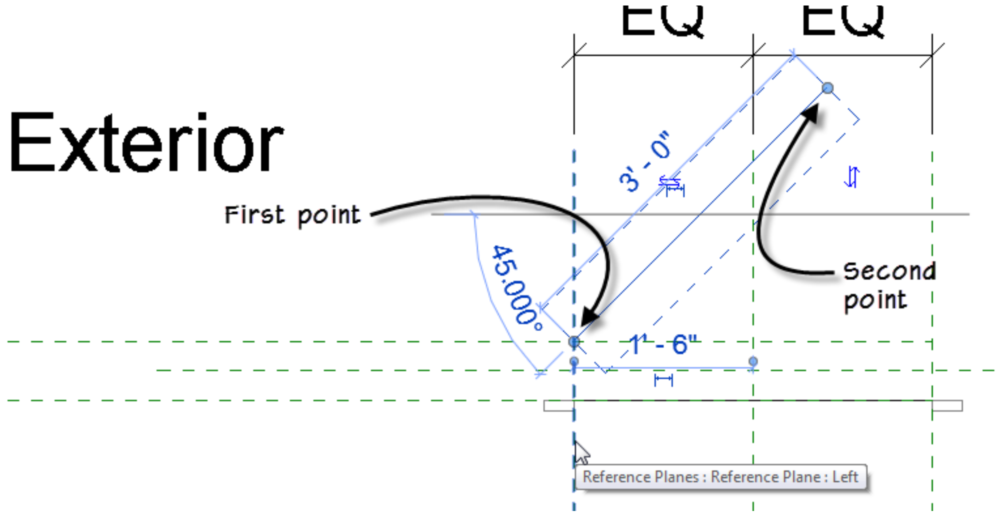


Figure 17—Draw a Reference Line from the hinge point at 45°

The order that you click the two points determines the direction of the face normal of the work planes (see Figure 18).

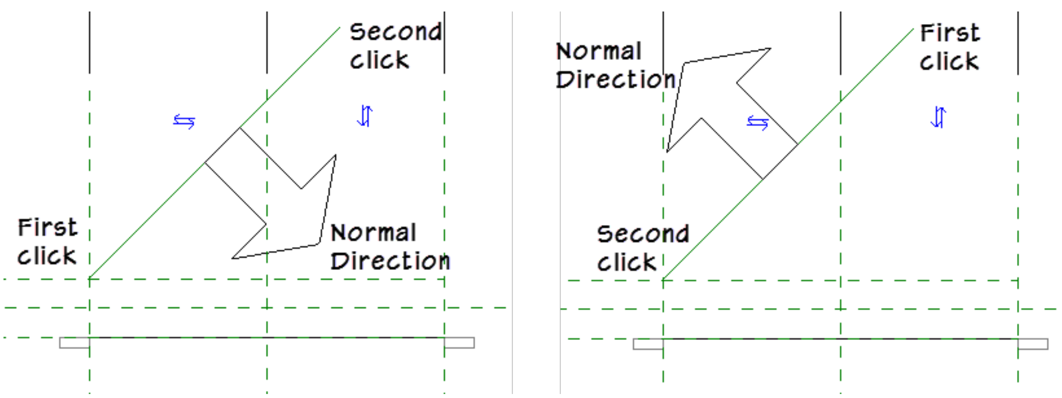


Figure 18—The normal direction (positive direction) of the faces of the Reference Line is determined by the direction you draw it

2. Select the Reference Line. On the temporary dimension that appears, click the small icon to make the temporary dimension permanent.

Adjust the position of the dimension if you like.

3. Select the new dimension and from the Options Bar, label this with the existing **Width** Parameter.
4. Use the Align tool and the TAB key technique to align and lock the end of the Reference Line to the Ref Plane: Left (see Figure 19).
5. Repeat on the Ref Plane: Exterior.

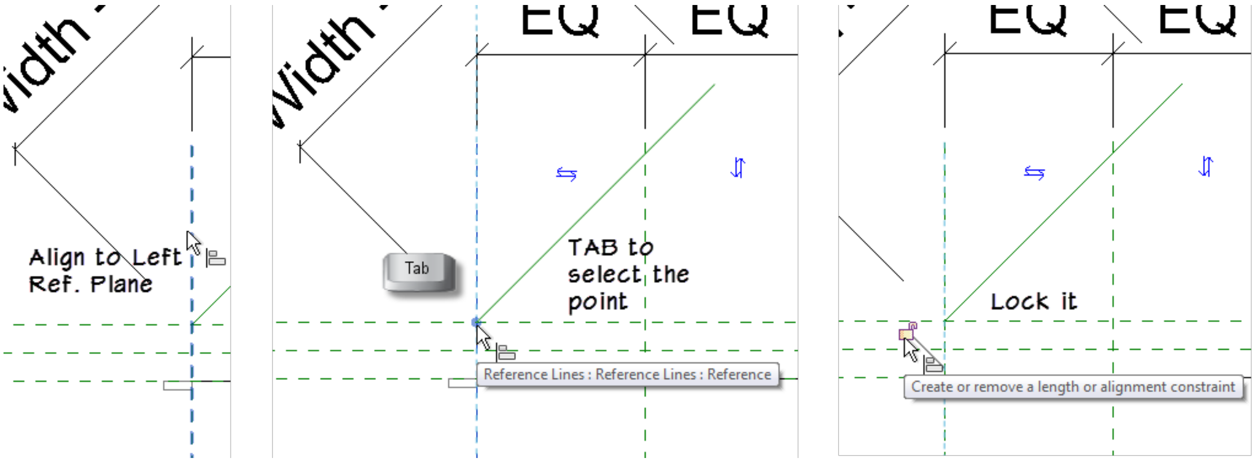


Figure 19—Align Reference Lines to lock them to the Ref Planes

This step is important. By locking the end point (hinge point) of the Reference Line in both the horizontal and vertical directions we ensure that the hinge point of the Door will move with the Door as expected. Having applied the Width parameter above further ensures that the Reference Line will flex as expected with the rest of the Door.

6. Flex the model. Modify the Width and then set it back to 3'-0" before closing the "Family Types" dialog.

802 Add a Swing Parameter

The final step is create the rotation parameter.

1. On the Modify tab, on the Measure panel, click the drop-down on the dimension too and choose **Angular Dimension**.
2. Click on the Reference Plane:Exterior first and then click the Reference Line.
3. Place the Dimension (See Figure 20). Cancel the command.

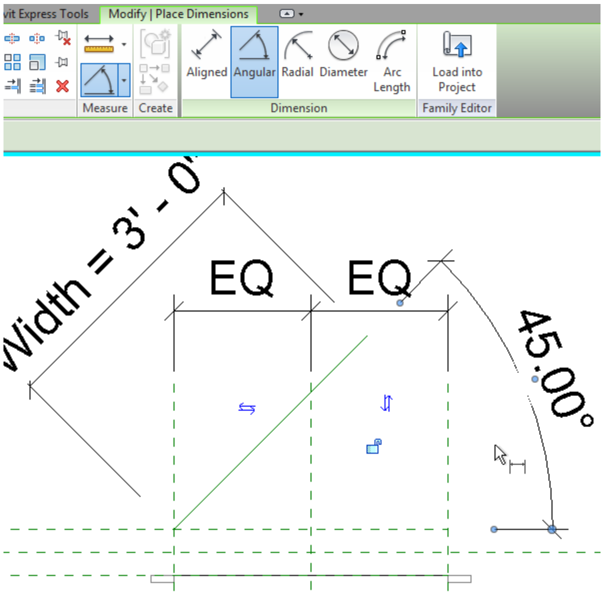


Figure 20—Create an angular dimension between the Exterior Reference Plane and the Reference Line

4. Select the angular dimension and then on the Options Bar, from the Label drop-down, choose **<Add parameter>**.
5. Name the parameter **Door Swing**, group it under **Graphics**, make it an **Instance** parameter and then click OK.

Group Under can be anything. We chose Graphics here, but if you prefer another grouping it will not affect its behavior at all. It is a matter of personal preference and/or office standard. Likewise, this parameter will function equally well as either a Type or Instance parameter. You can decide which will serve your needs best.

6. Flex the Model. Try different Widths and different Swing angles.
7. When satisfied that everything works properly, reset the Width to 3'-0" and the Door Swing to 45°.

The main focus of this paper is techniques to control curvature in families. Therefore, we will just give a brief summary of the steps to follow next to create the solid geometry required for a door panel. This should give you the basics you need to complete the door family if you wish. Otherwise, the technique outlined above can be used to control rotation of nearly any element. (We will also create a more complete door later on in the “Combining Strategies” topic below).

Create the Door Panel Geometry

To draw door geometry and constrain it to the Reference Lines is simple. The Reference Line has four integral Work Planes (see Figure 21). There is one horizontal, one vertical and one at each end point. You simply click the Set Work Plane tool, choose the “Pick a Plane” option and then select the plane upon which you wish to draw. It is recommended that you leave the Reference Line oriented at 45° for this. Cut a section at 45° as well, parallel to the Reference Line. Then open this view to work. If you work in one of the orthographic views, you can accidentally constrain your geometry to other nearby Ref Planes and geometry making it difficult to later flex the model. If you build your door panel extrusion on the 45° you can easily avoid this. Another technique often employed is to nest in another family for the door panel. The choice is a matter of personal preference and/or office standards.

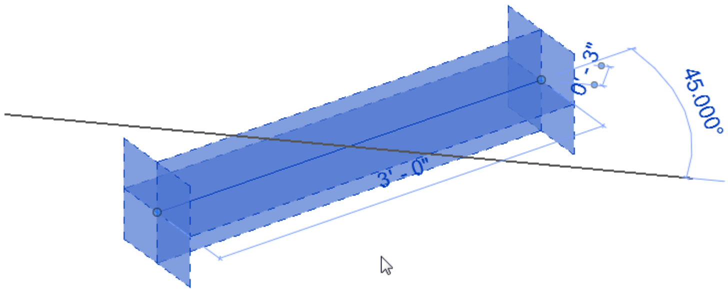


Figure 21—Reference Lines have four integral Work Planes

Create the section, open it and then set the vertical work plane of the Reference Line current. Draw a solid extrusion on this plane. Snap it to the ends of the Reference Line. Use the Thickness parameter for the height of the extrusion. To create a 2D plan version, draw Symbolic Lines using the pick lines option and constrain them to the edges of the solid extrusion.

Rotating a Curve

In the "Control the Arc Angle Parametrically" topic above, we took our quarter-round and half-round arc and applied a parameter that allowed the angle to flex to any value. However, the arc always started at zero degrees and flexed counter-clockwise. What if you want to be able to rotate the entire arc along its center? In other words, we can set a start angle and an end angle. To do so, we can combine the previous lesson on rotation with the skills covered in the "Quarter Round and Half Round" topic. The basic process involves creating two parametrically rotating Reference Lines and then constraining the arc between them.

802 Build the Reference Lines and Parameters

1. Open the file: ***800 Family Seed (Sketch Dims).rfa***.
2. Tile the windows and then save the file as: **Rotating Arc (Centered)**.
3. Following the procedure in the "Controlling Rotation" topic above, create a 45° Reference Line starting at the two center Reference Planes and make it **2** units long.
4. Make the temporary dimension permanent and label it with the **D** parameter.
5. Align and lock the endpoint at the center.
6. Add an angular dimension and label it with a new parameter named **A**.
7. Repeat the procedure creating a second Reference Line at 135° (see Figure 22).

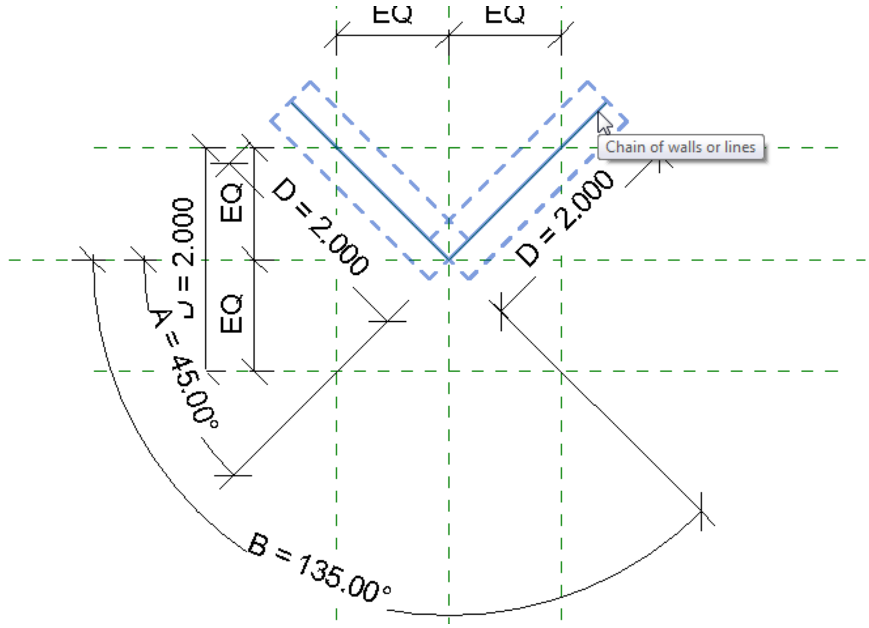


Figure 22—Create two Reference Lines constrained at the center with length and angle parameters

Be sure to flex everything and make sure it is working. For the geometry, we can make a Model Line again, or build an extrusion, or even create a curved path for a sweep.

CATCH UP! You can open a file completed to this point named: ***801 Rotating Arc (Centered).rfa***.

802 Create Geometry on the Rotating Curve

Whichever type of geometry you decide to build, the process is similar. Make sure that the arc is centered on the reference planes (at the rotation points of the Reference Lines). Constrain the radius using the existing D parameter. Lock the ends of the arc to the Reference Lines.

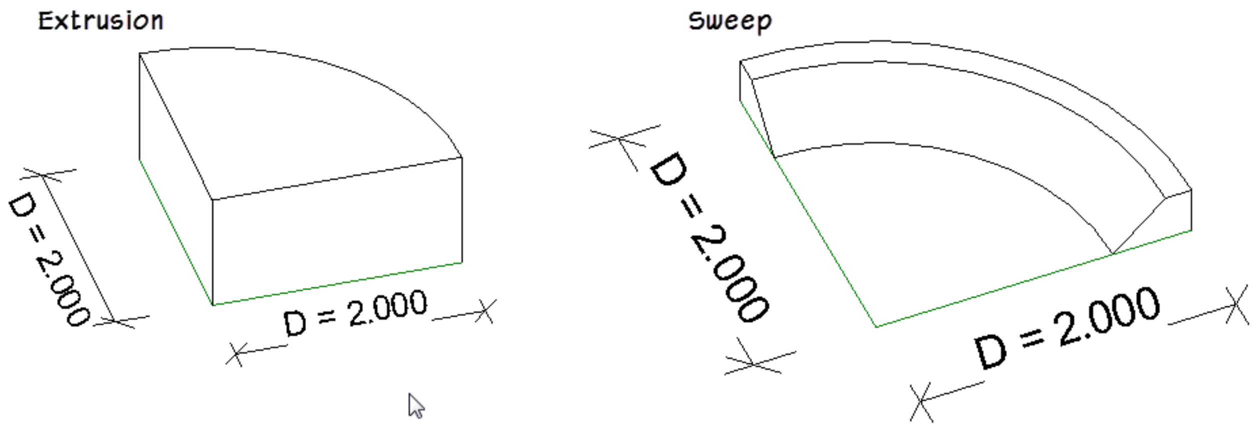


Figure 23—A variety of forms can be built on this armature such as extrusions or sweeps

CATCH UP! You can open files completed to this point named: ***802 Rotating Arc (Extrusion).rfa*** and ***802 Rotating Arc (Sweep).rfa***

Arches

Using curves to create building arches

The previous examples all had the center point located at and constrained to two reference planes. But what do you do when the center of your arc does not land on such a convenient location? This is the case for many types of arches. Look around the town you live and you are bound to find many different types of arches used in the buildings.

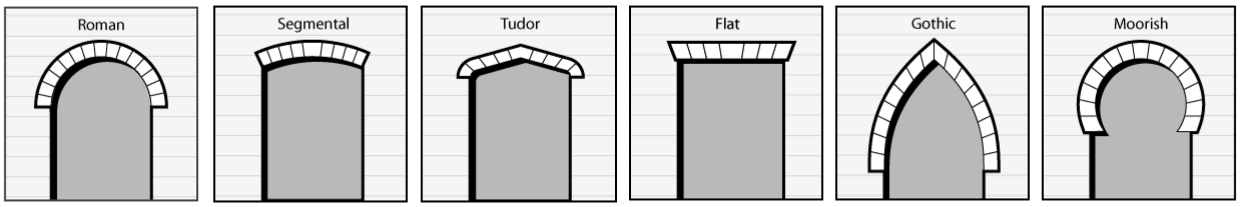


Figure 24—Types of arches

Image Credit: http://www.realtor.org/rmoprint.nsf/pages/arch36

Face-Based or Free-Standing

One of the first things you might want to do when planning your arch family (or really any family actually) is to decide how you want its insertion point to behave and if you want to leverage the built-in features of the family template file such as the built-in elevation parameter. I hope to do a full inventory of all family templates in the future, but time and space here do not allow for it. So let's consider just a few of the most common templates:

- *Generic Model.rft*
- *Generic Model wall based.rft*
- *Generic Model face based.rft*

Each of these is very similar. They use the Generic Model category and you can use them to model most anything. Naturally the major difference is that the face-based one will be hosted to a surface (or face) of another object in your model. The wall-based one will be similar, but the face *must* be the surface of a wall. No other object type will be allowed. The *Generic Model.rft* family is free-standing and requires no host. Using the face-based template and inserting a family on the faces of other geometry can be very useful, and unlike the more restrictive "wall-based", "ceiling-based" and "roof-based" versions, face-based allows the object to be inserted on *any* kind of face; wall, floor, ceiling, roof or even the faces of other component families. You can even insert it on the face determined by work planes like grids and reference planes. The face hosting makes the family automatically orient itself to the face of on which you insert it, but by not requiring a certain kind of face, it is nearly as flexible as its free-standing brethren.

There is one more very useful feature of the *Generic Model face based.rft* template. This template includes a built-in parameter called: Default Elevation. When you insert a face based component, this Elevation parameter controls its height. By default, this is measured from the level of insertion to the origin point of the family. The default origin of the family is the intersection of the two center reference planes. However you can change this (see Figure 25).

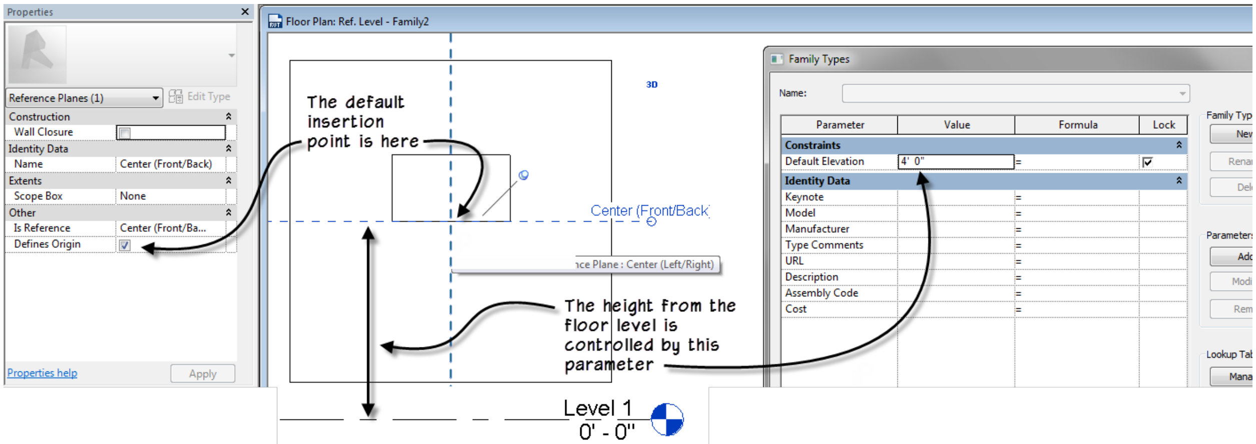


Figure 25—The Default Elevation parameter can control the height of insertion in a face-based family

If you plan your geometry with respect to this location and behavior, it can be very useful. For example if you plan to insert on a vertical face, plan it so that the Default Elevation locates the object to the top or bottom edge as appropriate. On sloped or horizontal surfaces, the measurement is still to the insertion point of the family, only now it is the "Z" direction within the family. In other words, the host surface in the family editor should be planned as the bottom of the object (see Figure 26).

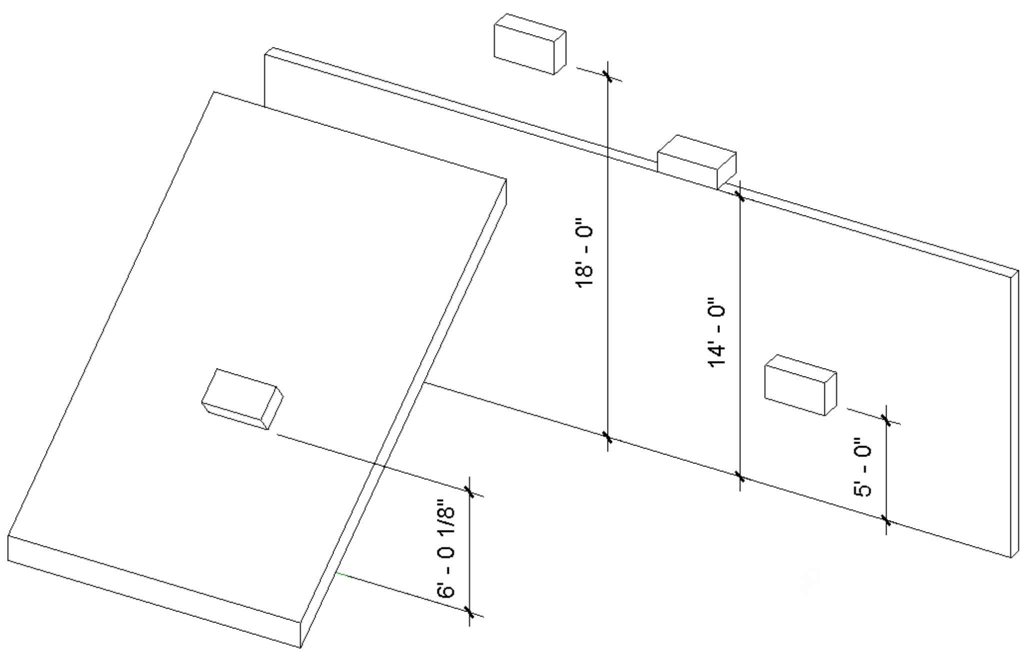


Figure 26—The Default Elevation parameter as measured in different insertion conditions

Note also in the figure that unlike other hosted families, a face-based family can become "disassociated" from its host face without being deleted. Notice the top most insertion is above the wall plane. Its

Default Elevation is still measured from the level, but the Host will show as <Not Associated>. Could all of this be achieved with a wall-based template instead? Mostly. But there are a few differences. The wall-based template does not have the Default Elevation parameter built right into the template. Instead it has a system parameter that is very similar called simply: Elevation. This parameter does not show up in the family editor but does appear when the family is inserted. It is measured from the level to the lowest geometry in the family. So it *can* move if you edit the geometry of the family! The other major difference is that the object must be inserted on a wall and while it can be moved off of the wall like the one in the figure, if the wall is deleted, the hosted element will also be deleted. It cannot become disassociated from its host. Both the wall-based and face-based can be good choices for an arch family. In these examples, we'll use face-based.

803 Create a Parametric Segmental Arch

So, getting back to the subject of arches, let's consider a few common shapes. If you have a Roman arch, you can simple use the techniques covered above. A Roman arch is a semicircle, so the techniques discussed above will work well. If you have one of the other forms, you might have a tougher time making the arch behave as it flexes using the above techniques. For example, let's consider a Segmental arch. This one has an eyebrow shape and as its name implies is a segment of a circle. The main issue with such an arch is that the center point moves as the arch flexes. So since the techniques above relied on locking the center point, they will not yield good results. Let's look at what must be done to make a segmental arch behave. Here we must break one of the "rules." The key to success is applying the labeled dimension directly to the geometry of the curve rather than the traditional approach of dimensioning the reference planes and then letting them flex the geometry.

1. Open the file: ***800 Family Seed (Face Based).rfa***.
2. Tile the windows and then save the file as: **Segmental Arch**.

Our seed families all have the two default reference planes at the center. In this case, let's use the Center (Front/Back) reference plane as the spring line of the arch, so we'll need to delete the bottommost one.

3. Delete bottom reference plane.

When you do this, you will be left with a single unlabeled vertical dimension.

4. Select the vertical dimension.
5. On the Options Bar, label it with a new instance parameter and call it: **Rise**.
6. Select the top reference plane and on the Properties palette, rename it to Top.
7. Flex the family to ensure everything is working.

With this framework in place, we are ready to build our geometry. While it is possible to use an extrusion here, it takes a little more effort to constrain it. This is because an extrusion would require two parallel curves. Instead, let's create a sweep. It is the path of the sweep that will form the arch shape.

8. On the Create tab, click the Sweep button. Choose the Sketch Path option on the ribbon.

9. From the Draw panel, choose the Start-End-Radius arc.
10. Snap the start and end points to the intersections where the left and right reference planes cross the Center (Front/Back) reference plane.

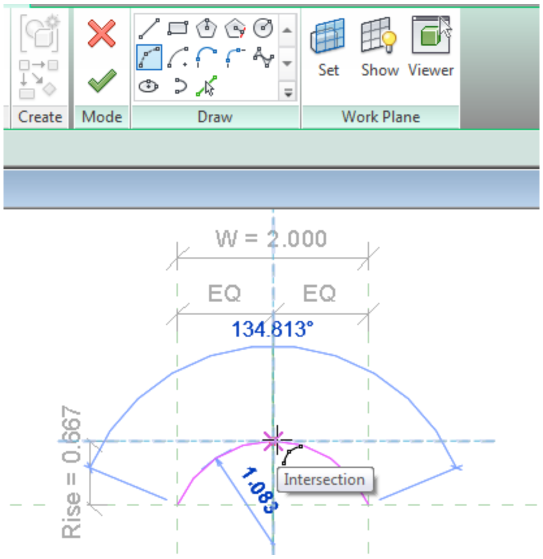


Figure 27—Create the path of the sweep with a start-end-radius arc

11. Snap to the intersection of the Top and Center (Left/Right) reference planes for the radius (see Figure 27).
12. Using the Align tool, align and lock the start and end points of the arc to the reference planes in both directions (see Figure 28).

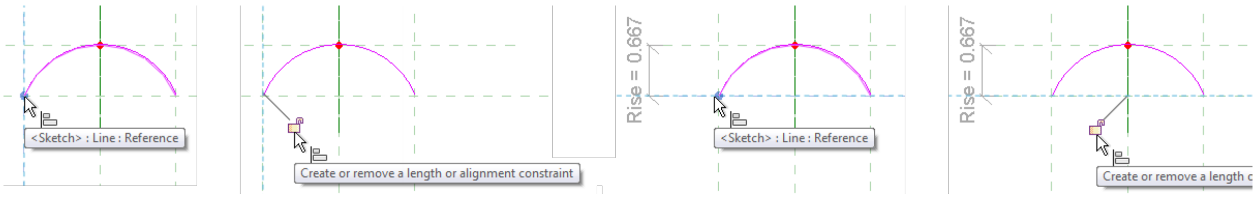


Figure 28—Align and lock the endpoints of the arc to the reference planes in both directions

Aligning and locking works fine for the endpoints. Unfortunately we cannot align and lock the midpoint of the arc. But just the same we always want the midpoint of the arc to stay with the top reference plane. To do this, we'll dimension the sketch line directly.

13. Create an aligned dimension. For the first witness line, click the Center (Front/Back) reference plane.
14. Click directly on the arc next to add the second witness line (see Figure 29).

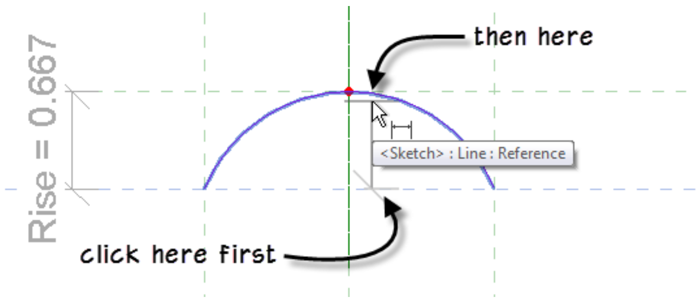


Figure 29—Dimension the arc directly

15. Label this dimension with the existing Rise parameter.
16. Flex.

That's it! The arch can now have nearly any rise value you like to create segmental arches of various shapes and proportions. If the value of Rise is equal to half of W, you will get a Roman arch. If you go larger than this it will make an arch that has a Moorish shape. An arc must be curved, so you cannot use a value of zero. Therefore, to make a jack arch simply make a separate family with a rectangular form.

To complete the arch, just edit the sketch for the sweep profile and create a simple rectangle. If you prefer, you can use a more complex shape, but a rectangle will do the trick (see Figure 30).

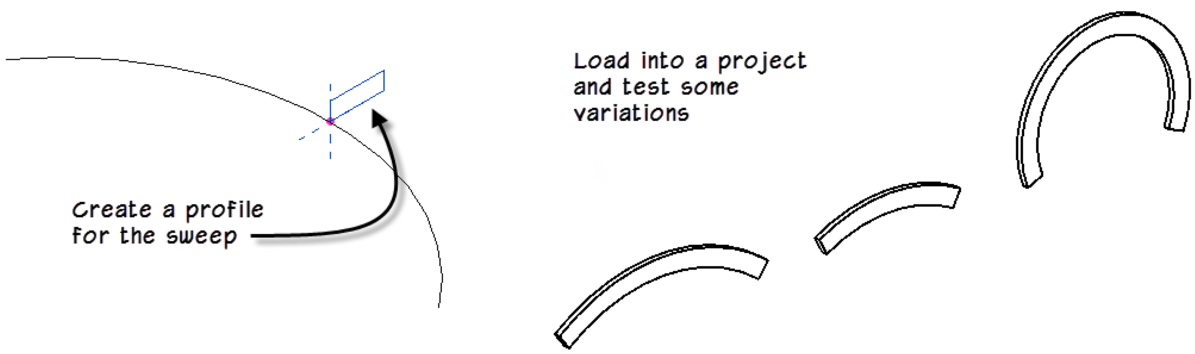


Figure 30—Complete the arch family and load it into a project

CATCH UP! You can open a file completed to this point named: ***803 Segmental Arch.rfa***.

***803 Gothic Arch

As noted, the previous family will yield many of the common arch forms, but not all. To create some of the others, we can leverage the same basic concepts. For example, a gothic shaped arch can be achieved by taking two segmental arch rigs and placing them in a triangular construct. I won't detail all of the steps here, but instead simply describe the overall process (see Figure 31).

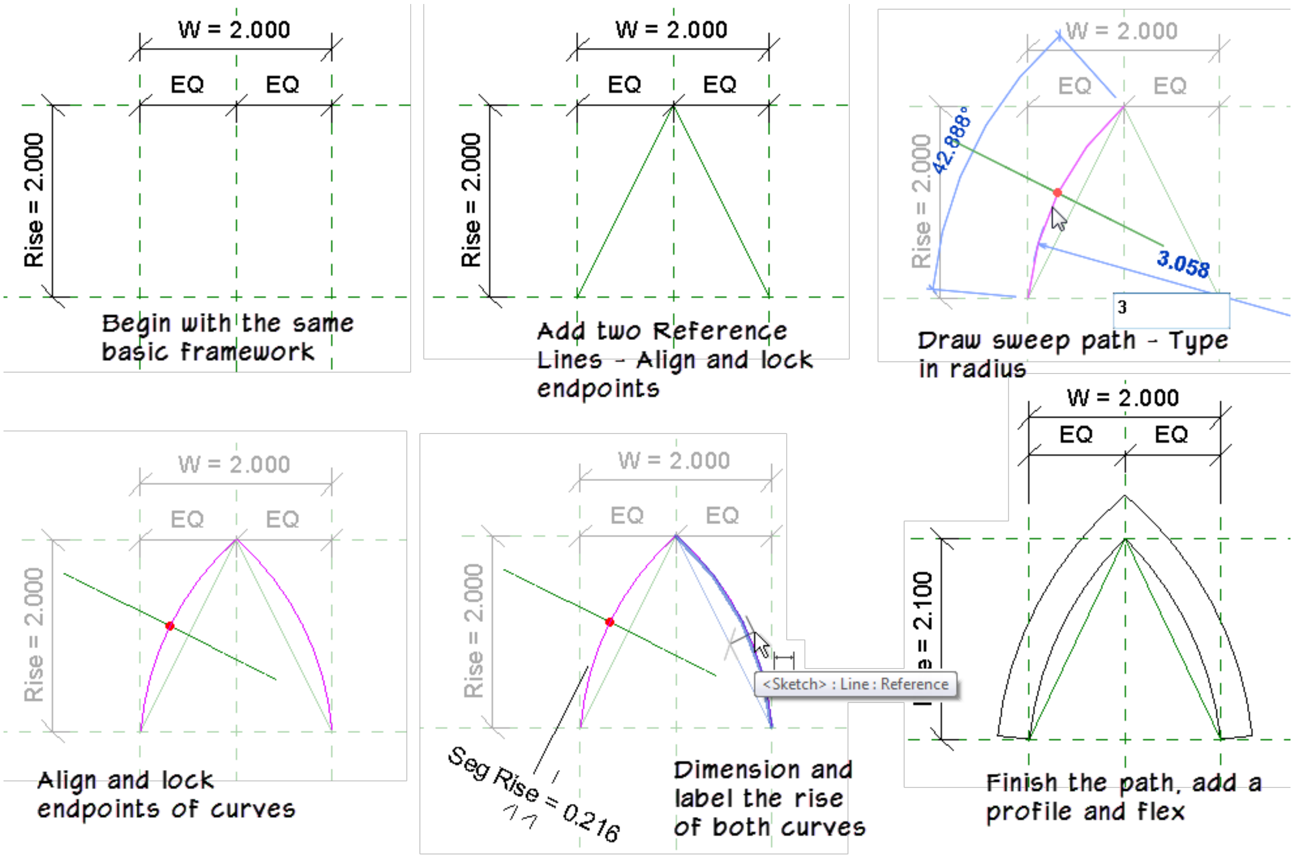


Figure 31—A gothic arch can be formed using essentially two segmental arches

Start with the same seed family and set it up the same way. You can even save the Segmental Arch family as a new name and just delete the sweep. Usually a gothic arch will have a higher rise, so flex the rise parameter to at least the same value as W. Draw two Reference Lines forming a triangle. This will form the spring lines of each side of the arch. Use the Align tool to align and lock the endpoints of the Reference Lines to the intersections of the reference planes. Make sure you align and lock all four endpoints in both directions (eight total). It is a good idea to flex at this stage.

Begin your sweep and choose the Sketch Path option. Draw two Start-End-Radius arcs. The endpoints should snap to the ends of the Reference Lines. The radius can be anything, but they should be the same for both arcs. You can begin eyeballing the curve, and before clicking, type in a whole number value based on the temporary dimension displayed. This makes it easy to get the same radius on both sides. Align and lock the endpoints of the curves to the reference planes.

Create a new dimension between the *Reference Line* and the rise of each arch. Make sure to set the first witness line at the Reference Line, then click the curve. Label each of these with a new parameter called: **Seg Rise**. Flex and then Finish the path.

Finally, sketch the profile. You can also load in a profile family for the profile if you prefer. (We will explore profiles below). Flex the completed form. Be careful in flexing as certain combinations of Rise, Seg Rise and W will cause it to fail, but it should work well for many combinations.

CATCH UP! You can open a file completed to this point named: ***803 Gothic Arch.rfa***.

803 Elliptical Arches

If you would rather use an ellipse to form the path of your sweep, much of the process remains unchanged. You draw the ellipse using the partial ellipse shape on the Draw Panel, align and lock its endpoints just like the arc. However, when you try to dimension the elliptical arc, Revit will stubbornly refuse to highlight it like it did for the arc. So instead of placing the dimension with the Aligned Dimension tool, the trick is to first select the partial ellipse onscreen, then click the small "Make this temporary dimension permanent" icon. This will make the dimension for you and then you can label it. All else will work the same way (see Figure 32).

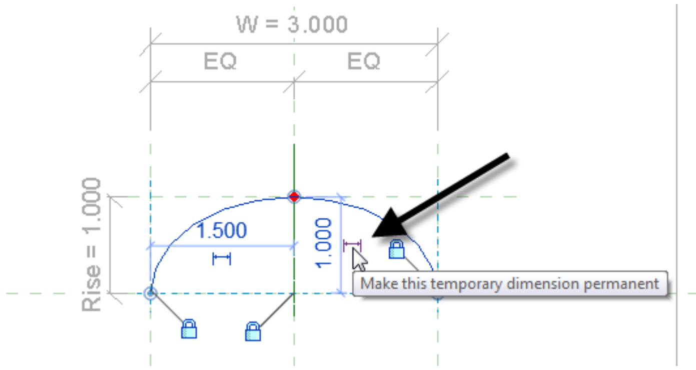


Figure 32—Make the temporary dimension permanent to create a flexible elliptical arch

Rather than list all the steps here, some time ago I showed this to a class I was teaching and I recorded a quick video to illustrate. So I have included that video here:

http://www.screencast.com/t/ghTDIjUtRWN

CATCH UP! You can open a file completed to this point named: ***803 Elliptical Arch.rfa***.

Compound Curves

All of the examples so far have been single curves; in other words, there has only been one curve that we were trying to flex. In such cases, if you ensure that you constrain and/or parameterize the key geometric aspects of the curve, you will usually get good results. For example, with a circle or arc, if you constrain the center and radius, it will usually flex properly. With an ellipse, the center and axes usually give good results. However, as the forms that you wish to flex become more complex in shape, sometimes even constraining the center and radius will not be enough.

Consider situations where there is more than one arc segment making up a compound curve. Or even situations with a curve meeting a straight line at a tangent. There are endless possible examples. In this topic we'll consider a few of the more common examples. In similar fashion to the examples above, the key is going to be carefully constraining the curves so that you remove any ambiguity. **You want to make it very clear to Revit what your intentions are.** If you do this, everything *should* flex properly.

Profile Families

Profile families contain simple two-dimensional shapes that when nested into other 3D families are used to produce more complex three-dimensional geometry. For example, when you create a sweep in a Family or project, you can sketch the shape of the cross-section to be swept, or you can use a pre-defined profile family instead. The use of profiles gives a few advantages:

- They are simple families drawn outside the project and can be saved as RFA files and used in any project or family.
- Like other families, a profile family can contain flexible parameters and locked constraints. This allows more power and control over the profile shape than a simple "one-off" sketched shape would allow.
- Like other families, a profile family can contain multiple types; each predefined to flex the parameters in a certain way.
- Profile families behave like other nested families. Since they are self-contained, they will not distort in unexpected ways when the parent family flexes.

Several profile family templates are provided including: Mullion, Rail, Reveal and Stair Nosing. There is also a generic "Hosted" template and finally a simple *Profile.rft* template to use if none of the others is appropriate. So if you are creating a profile for use on stair treads, you would use the stair nosing template. Use the mullion template if creating a custom curtain wall mullion shape and so on. Otherwise, you would choose the basic profile template instead. You can even choose the basic one and then later change the usage to something more specific.

When you work in the traditional Family Editor, there are two solid forms that can use a nested profile family rather than a sketched shape. These are the Sweep and the Swept Blend. Using a profile to build these forms affords many of the same benefits listed above. To use a profile in a model family that you are creating, first create a new family based on the *Profile.rft* template. Draw your shape; add any parameters, constraints and types. Save the family and then load it into the model family that you are creating. Once the profile is loaded, you can use it to create sweep and swept blend solid forms.

Sweeps and Swept Blends can be used in place of Extrusions and Blends in almost all cases. You can even build a sweep that closely approximates a Revolve, making it theoretically possible to make almost any form using a nested profile family. The remaining examples will use profile families.

Some challenges do exist. Profile families can contain reference planes, but not reference lines. Since we discussed the importance of using reference lines above when making a family that requires parametric rotation, this presents us with a bit of challenge.

There are some acceptable solutions. For example, you can use trigonometry to derive X and Y coordinates from any angle. This is very effective and very stable, however, trig can be challenging and introducing many formulas can have a detrimental effect on overall performance. Another solution that we will explore is using a nested rig family. Nesting can also be detrimental to performance, so you will have to consider each use case carefully. We'll see a few examples below.

804 Ovolo

Using trigonometry to model traditional molding forms

Let's start with some common molding shapes. In his excellent book on classical architecture: *The Classical Orders of Architecture, Second Edition*, Robert Chitham details how to construct many traditional forms including all five architectural orders and many common moldings, balustrades and other forms. I highly recommend the book and it has been an invaluable resource in developing the ideas in this paper and other similar projects in which I am involved. The book is out-of-print, but you can get a Kindle edition or perhaps find a copy in the second hand market. In Figure 33 I have included the first moldings we will consider. Both use a single curve, but constructing them introduces a challenge that once solved, will help us create the more complex compound curves that follow.

Consider the shapes shown in Figure 33. The left side comes from Chitham and shows how to construct the curves using traditional drafting tools. The most likely way to flex this curve would be to ask for the depth and the height of the curved portion of the molding. This is shown on the right side. As you can see in the image, this width and depth of the curve portion are normally not equal, meaning that the construction axes are along angled paths and as the dimensions flex, the center point is not always in the same location. As we mentioned above, reference lines are the best choice for controlling angles in families. However, reference lines are not available in profile families, so we could abandon our use of profiles and resort to building each molding with its own integral sketch. This would not be ideal since we would lose all benefits of using profile families. One of the most important being that they can be reused in multiple families. Without them, we would have to rebuild this shape and its parameters in each new family. Since these are common molding profiles, this would not be ideal. Therefore, if we can define them once in a good flexible profile family, we can then reuse them in almost unlimited ways in other content. So, we will have to resort to other techniques to control the shape of this family in order to build it as a profile family.

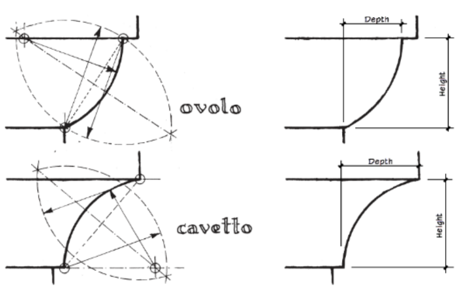


Figure 33—Constructing Ovolo and Cavetto profiles

Image Credit: The Classical Orders of Architecture Second Edition by Robert Chitham – from Plate 76

As noted at the start of this topic, there are two viable options here. In the examples that follow, we'll look at both. Let's start with trigonometry. Depending on the complexity, the trig might be simple or complex. In this case, we have a simple case of similar triangles. You will be asking your user to input the desired height and depth of the molding. We will call these X and Y in the profile family. When you make a triangle from X and Y, you can easily derive the hypotenuse which we will call D (for Diagonal). Using trig, and these values, we can easily derive one of the angles which we will call A. Let's go with the ATAN function performed on X and Y: **ATAN(Y/X)**. This new value, coupled with half of D (we'll call this HD) can be applied to the second triangle and using COS, give us the length of the radius: **HD / COS(A)** (see Figure 34).

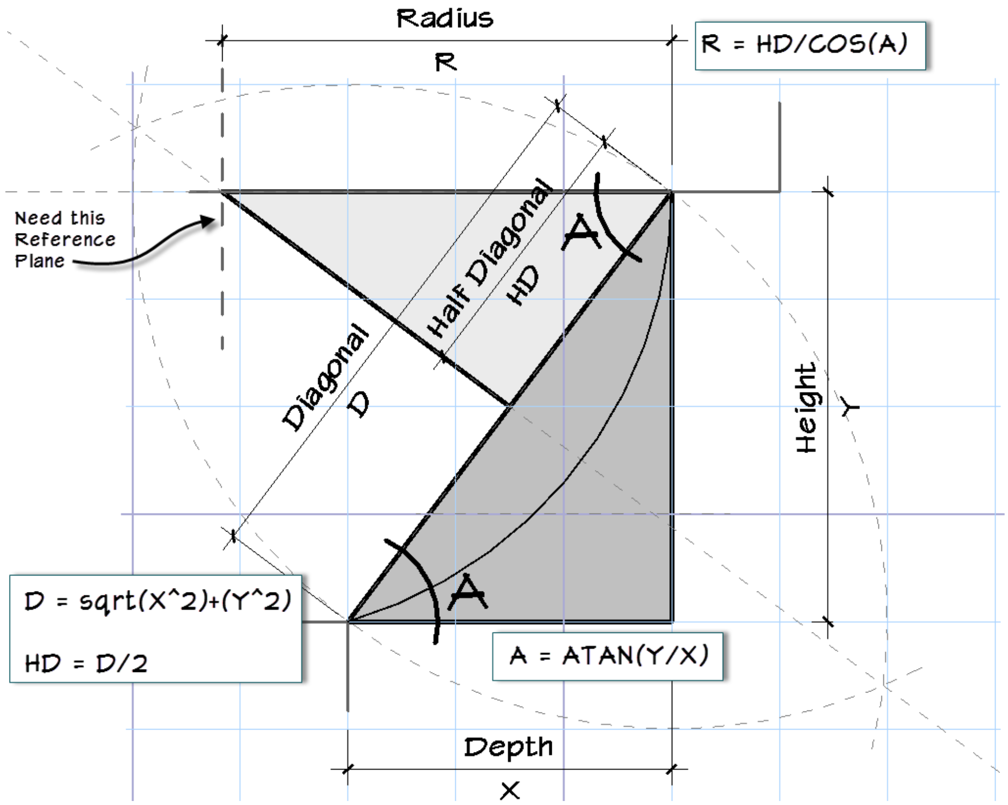


Figure 34—Applying trigonometry to locate the required reference planes

Provided with the dataset is a seed file for a profile family. It has the two default center reference planes positioned at the lower left corner. Two additional reference planes named: X Mid and X Max, and Y Mid and Y Max are placed above and to the right of these. They are dimensioned and constrained already. To this framework, we need to add a vertical reference plane to left for the radius location indicated in the figure. Our formulas will help us locate it.

1. Open the file: ***800 Profile Seed.rfa***.
2. Tile the windows and then save the file as: **Ovolo Profile**.
3. To the left of the Center (Left/Right) reference plane, draw a vertical Reference Plane. Name it **Radius**.
4. Add a dimension between the X Max reference plane and Radius.
5. Dimension and Label it with a new Type parameter called **R**.

6. Open the “Family Types” dialog.
7. Using the Add button on the right, create two new Type-based Length parameters: **D** and **HD**. Also create one Type-based Angle parameter called **A**. Group all of these under Constraints.
8. Input the formulas as follows:

Parameter	Formula
D	sqrt((X ^ 2) + (Y ^ 2))
HD	D/2
A	atan(Y / X)
R	HD / cos(A)

9. Flex the family by creating a few Family Types (see Figure 35).

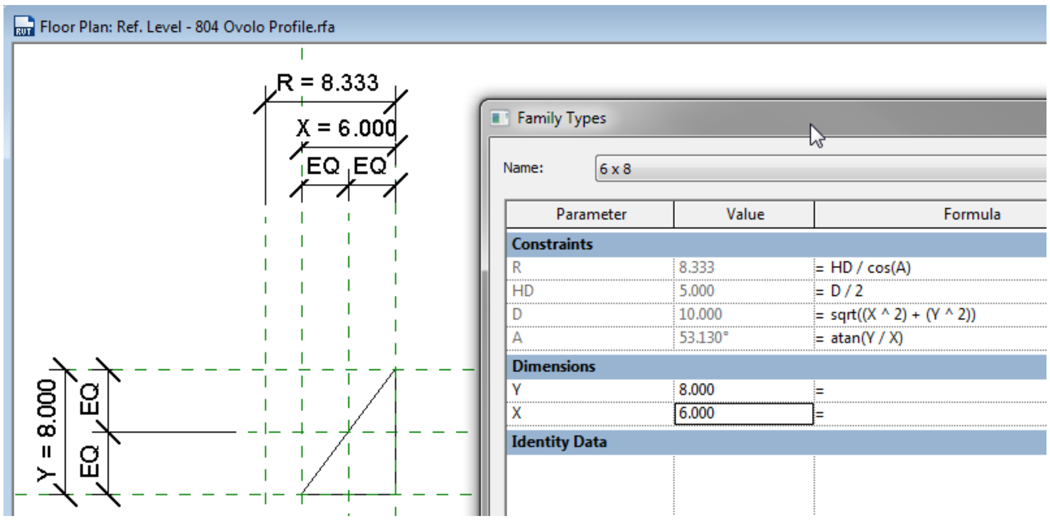


Figure 35—Create the parameters and Family Types

Catch Up! You can open a file completed to this point named: ***804 Ovolo Profile (Ref Planes).rfa***.

There is a simple triangle in this family already just to facilitate flexing. We can now delete this and draw the actual profile shape that we need.

10. Delete the triangle onscreen.
11. On the Create tab, click the Line tool.
12. For the right side, draw a Center-Ends arc with the center at the intersection of the Y Max and Radius reference planes. Be sure to lock the center in both directions as well as the endpoints.
13. Draw vertical and horizontal lines locked to the reference planes for the leftmost edge and the top and bottom (see Figure 36).

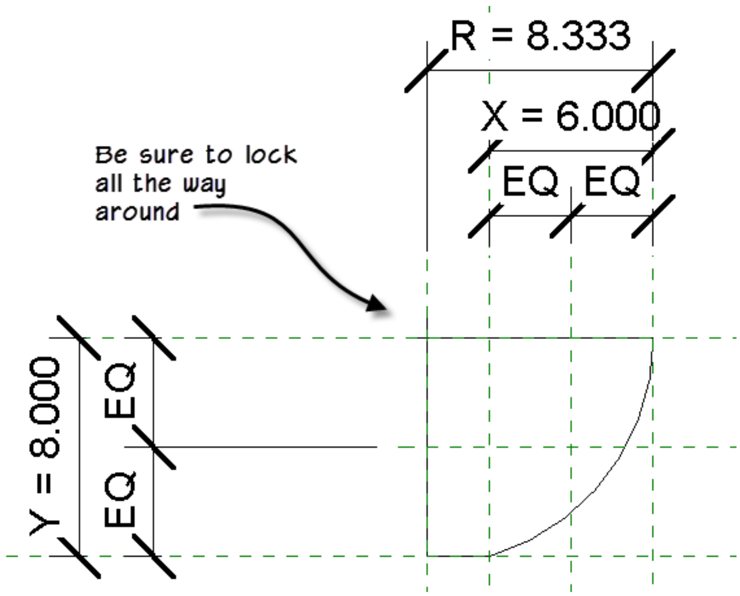


Figure 36—Create the profile lines

CATCH UP! You can open a file completed to this point named: ***804 Ovolo Profile.rfa***.

14. Flex the completed version when done.

You can load this profile into any project or family now and use it shape anything from sweeps, to wall profiles to railings. A simple family file is provided here to test it out.

15. Open ***804 Ovolo Sweep Flex.rfa***.

A version of the profile family is already loaded, but if you prefer, you can load your version instead.

16. Select the sweep and edit it. On the ribbon, click the Select Profile button and then from the drop-down list, choose one of the types you previously defined.
17. Finish the sweep and flex the family.

804 Cavetto

Using a nested rig to model traditional molding forms

The previous example used formulas and trigonometry to locate the shifting center point of the curve. This allows us to have just two user inputs: X and Y and let the curve adjust to those inputs. For various reasons, you may wish to avoid formulas. Some folks find them cumbersome and complex. They also can certainly impact performance if there are many of them in use. In this example, we will look at the cavetto curve. It is exactly the same construction as the ovolo with the curve reversed. So the radius reference plane needs to be on the right with the center of the curve at the intersection of the radius and Center (Front/Back) reference planes. In all other ways, we could use the same strategy and formulas. But in this example, we'll look at an alternative: using a "rig" on which to build the curve form.

The starting family in this case uses the same seed we used for the ovolo profile above. It has one extra reference plane to control the depth of the form.

1. Open the file: ***804 Cavetto Profile (Rig - Start).rfa***.
2. Save the file as: **Cavetto Profile**.

We'll also need our rig family. This one is a Detail Item family. We cannot use Reference Lines in Profile families. And while we can Reference Lines, as we saw above, they do not work well in controlling angles. So since we cannot use a Reference Line, we will simply draw lines instead. However, if we draw the lines directly in the profile family, they will be seen by Revit as part of the profile. If we instead draw our guide lines in a Detail Item family they can be used for our framework or "rig" and not be seen as part of the profile.

3. Open the file: ***800 Detail Item Seed.rfa***.
4. Tile the windows and then save the file as: **Single Curve Rig**.

This seed was created from the *Detail Item.rte* template. Reference planes were added and a few dimensions and parameters to save time.

5. On the Create tab, click the Line tool. Snap the first point to the intersection of the Left and Front reference planes and the second point to the Right and Back.
6. Align and lock the endpoints to the reference planes in both directions on each end. Flex to be sure it adjusts with the reference line length.
7. Draw a second line starting at the midpoint of and perpendicular to the first line. Make it approximately the same length as the other one.
8. Select the line and then click the small "Make this temporary dimension permanent" icon for both the length and angle dimensions (see the left side of Figure 37).
9. Select the new linear dimension and label it with the parameter called **P**. Lock the angle dimension (see the right side of Figure 37).

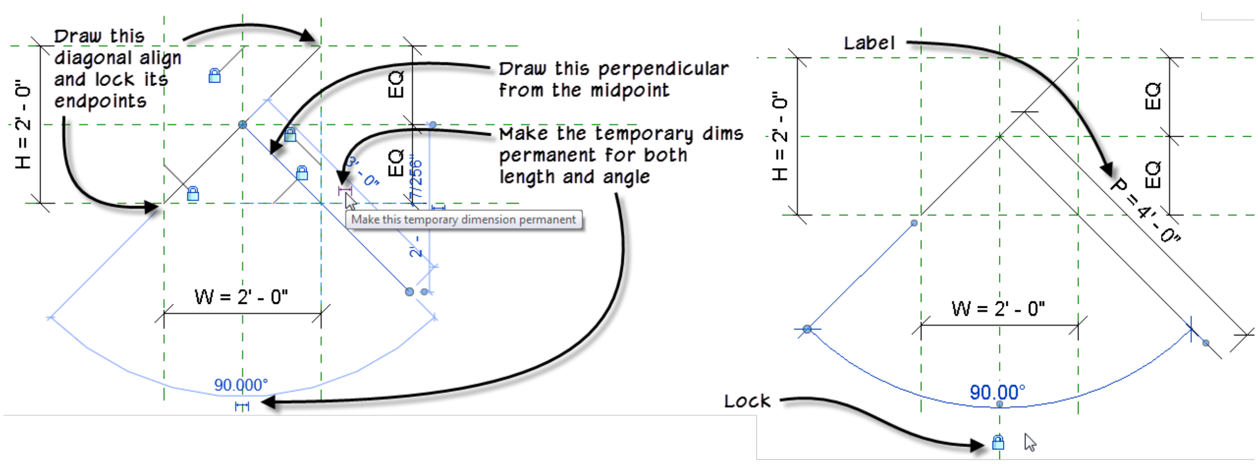


Figure 37—Build the rig in a Detail Item family

Optionally you can open Object Styles and create a new subcategory. Call it Guide Lines and then set the color to a light blue. This will help the rig stand out when nested into other families.

10. Save the family and then click the Load Into Project button.
11. Click to place it onscreen. Align and lock it on all four sides.

For each alignment, first click one of the reference planes in the host family, and then click the nested shape handle edge in the detail item family. Use TAB if necessary to get shape handle each time (see left and middle of Figure 38).

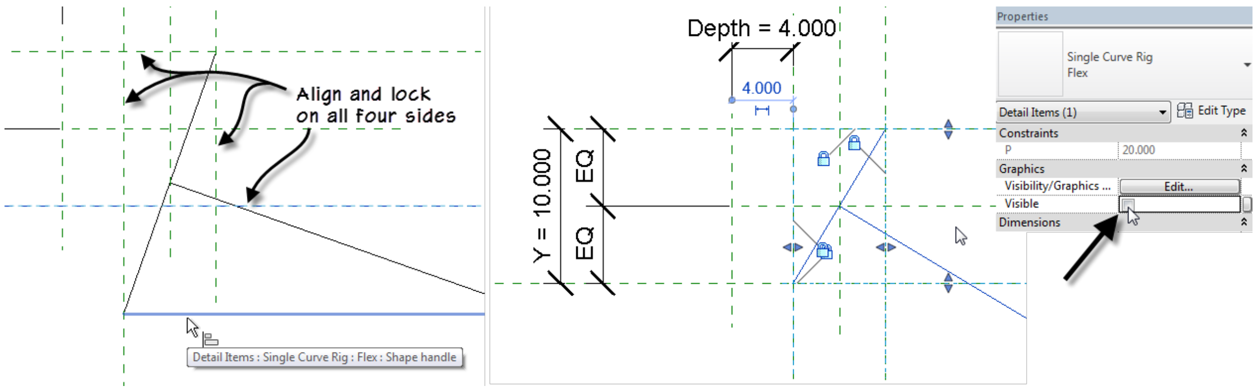


Figure 38—Nest in the rig, align and lock it on all four sides

12. Flex the family.

Notice that the nested detail item family changes shape with the host family. The diagonal line stays aligned with the flexing reference planes and the perpendicular line remains perpendicular. The intersection of the perpendicular line and the Center (Front/Back) reference plane is the center of our curve for this profile.

13. Select detail item and on the Properties palette, uncheck the Visible checkbox (see the right side of Figure 38).

This makes the rig invisible in all families that use or profile in. We will only see it here were it is needed.

CATCH UP! You can open a file completed to this point named: ***804 Cavetto Profile (Rig - Intermediate).rfa***.

Draw the lines that make the profile shape next.

14. Draw the curve as we did above for the ovolo. Use the intersection of the perpendicular line and the Center (Front/Back) reference plane as the center.
15. Align and lock the endpoints of the curve.

Pay attention to the Status line as you align. You want to align to the reference planes in the profile family, *not* the references or shape handles in the nested family. Use TAB as necessary.

16. On the left, top and bottom, draw straight lines. Align and lock anywhere an Automatic Sketch Dimension appears (see Figure 39).

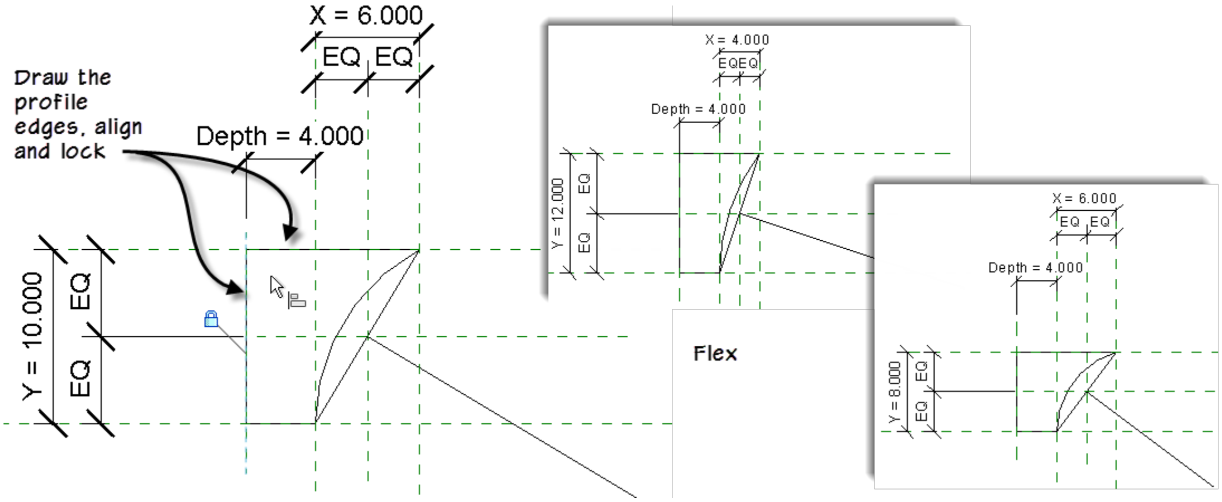


Figure 39—Create the profile shape and align and lock as necessary

CATCH UP! You can open a file completed to this point named: ***804 Cavetto Profile (Rig).rfa***.

17. Flex the family and then load it into the ***804 Cavetto Sweep Flex.rfa*** file to test it out in a sweep.

There are pros and cons to each approach. If you get the formulas right using formulas and trigonometry is very stable. But as noted, it can impede performance. Using the rig is a clever work around to some built-in limitations. It can be quite stable as well, but you have to be careful about which points you align and lock and make sure you do not inadvertently create bad references that prevent the families from flexing. You are encouraged to try both approaches and compare and contrast your results. With these techniques in hand, let's move on to more complex curves: the Cyma and Cyma Reversa.

805 Cyma

Figure 40 shows another portion of the figure from Chitham. Looking at the way that the Cyma and Cyma Reversa profiles are constructed, a circle is created whose diameter matches the diagonal between the X and Y (Height and Depth). This circle is intersected with two arcs of the same radius which when intersecting perpendiculars are drawn, creates four equal spaces along the diagonal. The points where the arcs intersect the circle are the centers for the arcs used to create the Cyma profile.

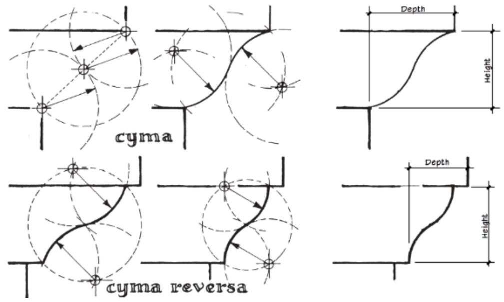


Figure 40—Constructing Cyma and Cyma Reversa profiles

Image Credit: The Classical Orders of Architecture Second Edition by Robert Chitham – from Plate 76

It just so happens that this construct also can create a regular hexagon whose vertices intersect the circle at these points. Compare the gray dashed construction arcs in Figure 41 with the superimposed hexagon. A regular hexagon can be divided into six equilateral triangles. The sides of these triangles are each equal to half the length of the diagonal (between the height and depth). This distance (the side of the equilateral triangle) is the radius of the arcs used for the cyma and cyma reversa profiles.

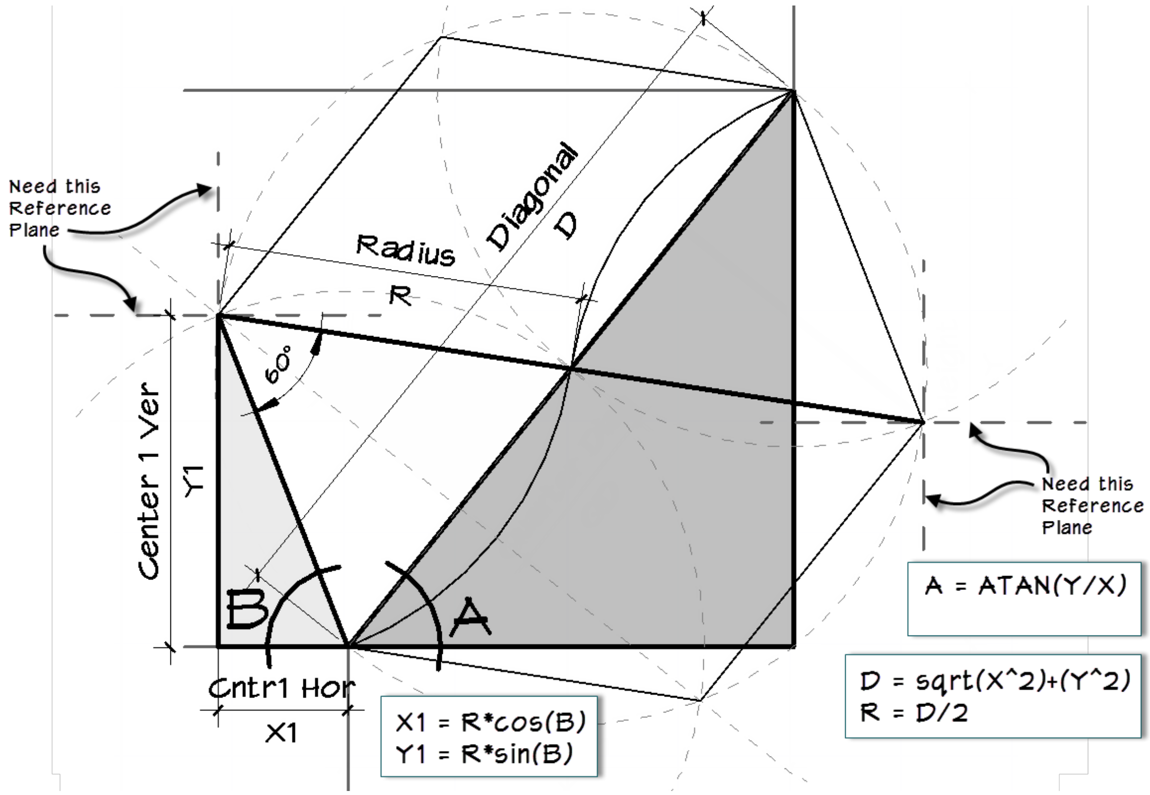


Figure 41—Applying trigonometry to locate the required Cyma reference planes

Once again, we can use trigonometry or nested detail components to construct this profile family. The trigonometric formulas are shown in the figure and in the table below.

The basic idea is that the user input is the height and depth. This is used to determine the angle of the diagonal which is in turn used to locate the center point of the two arc of the compound curve and their radius. We'll start with a file based on the Ovolo example above.

1. Open the file: ***805 Cyma Profile (Start).rfa***.
2. Save the file as: **Cyma Profile**.

Some of the work has been done here already. To create this file, a copy of the Ovolo file created above was saved. This means that some of the reference planes and some of the formulas were already in place. This includes the insertion point at the lower left corner, the X Mid, X Max, Y Mid and Y Max reference planes, and the parameters X, Y, A, R and D. HD was not needed and has been removed. Additional reference planes have been added: Center Right Ver, Center Right Hor, Center Left Ver and

Center Left Hor. And additional parameters listed in the table above. The parameters X1 and Y1 are applied to the reference planes already (see Figure 42).

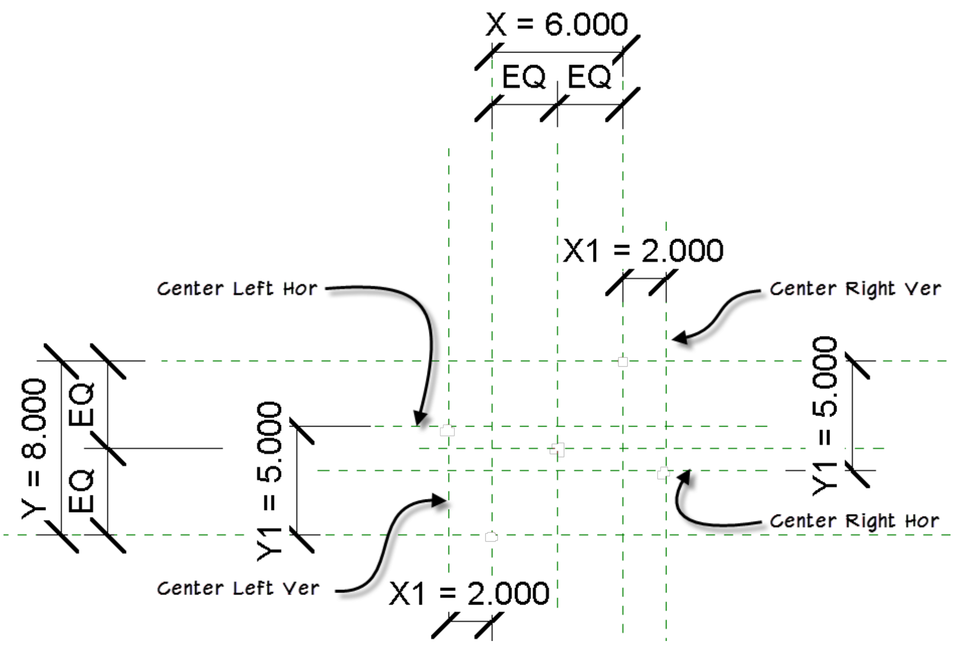


Figure 42—Starting family contains the reference planes and parameters

The formulas have not yet been added except those that came from the ovolo family. We will do this task now.

3. Open the "Family Types" dialog. Using the following table, input the formulas shown for each parameter.

Parameter	Formula
Y1	R*sin(B)
X1	R*cos(B)
R	D/2
D	sqrt((X ^ 2) + (Y ^ 2))
B	120 – A
A	atan(Y / X)

4. Click Apply to test the values.

The reference planes should adjust slightly.

5. Try flexing with each of the types in the family already. Click OK when finished.
6. On the Create tab click the Line tool and then click the Center-Ends arc icon.
7. Snap the center of the arc to the intersection of the Center Left Hor and Center Left Ver reference planes.

8. Snap the one endpoint to the intersection of the Center (Front/Back) and Center (Left/Right) reference planes and the other to the intersection at X Mid and Y Mid (see the small dots at locations **a**,**b** and **c** on the left side of Figure 43).

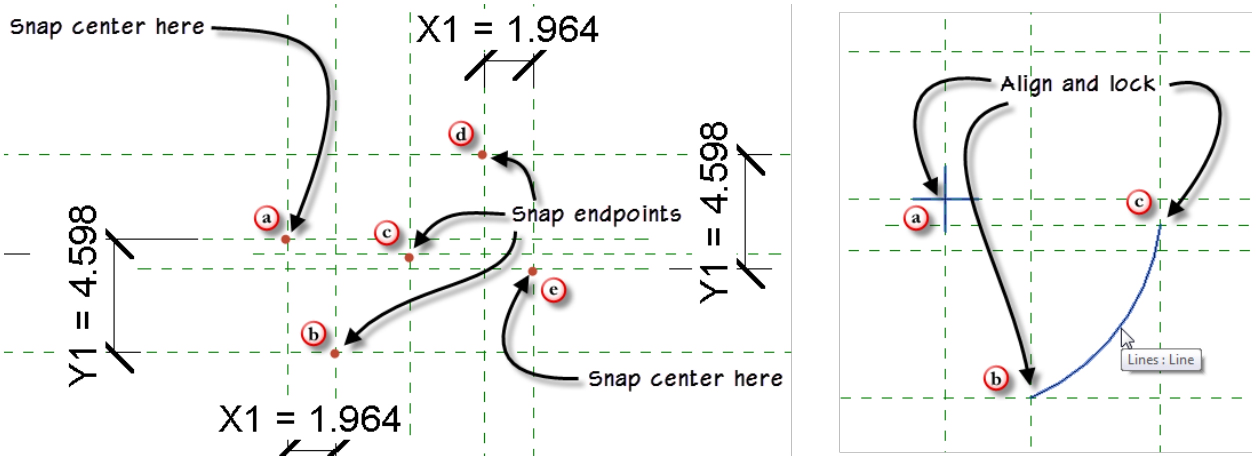


Figure 43—Draw the curves

9. Select the arc and on the Properties palette, check the Center Mark Visible checkbox.
10. Align and lock the center point and each arc endpoint to the reference planes in both directions (6 alignments total) (see the right side of Figure 43).
11. Repeat the process by drawing a second arc with center at point **e** (the intersection of the Center Right Hor and Center Right Ver reference planes) and endpoints at locations **c** and **d**.
12. Turn on the center mark and align and lock all points.
13. Open "Family Types" and flex the curve.

The curves should flex properly and remain constrained to the reference planes.

14. Draw vertical and horizontal lines locked to the reference planes for the leftmost edge and the top and bottom.

CATCH UP! You can open a file completed to this point named: ***805 Cyma Profile.rfa***.

15. Flex the completed version when done.

You can load this profile into any project or family now and use it shape anything from sweeps, to wall profiles to railings. A simple family file is provided here to test it out.

16. Open ***805 Cyma Sweep Flex.rfa***.

A version of the profile family is already loaded, but if you prefer, you can load your version instead.

17. Select the sweep and edit it. On the ribbon, click the Select Profile button and then from the drop-down list, choose one of the types you previously defined.
18. Finish the sweep and flex the family.

805 Cyma Reversa

The Cyma Reversa is essentially the same shape just with the arcs reversed. So all we need to do to create one is save the Cyma family with a new name and redraw the arcs facing the opposite direction. However, the formulas do need adjustment due to the changed locations of the arc center points. The overall strategy and form is largely similar (see Figure 44). You can try your hand at one if you like, or you can simply open the example provided here.

CATCH UP! You can open a file completed to this point named: ***805 Cyma Reversa Profile.rfa***.

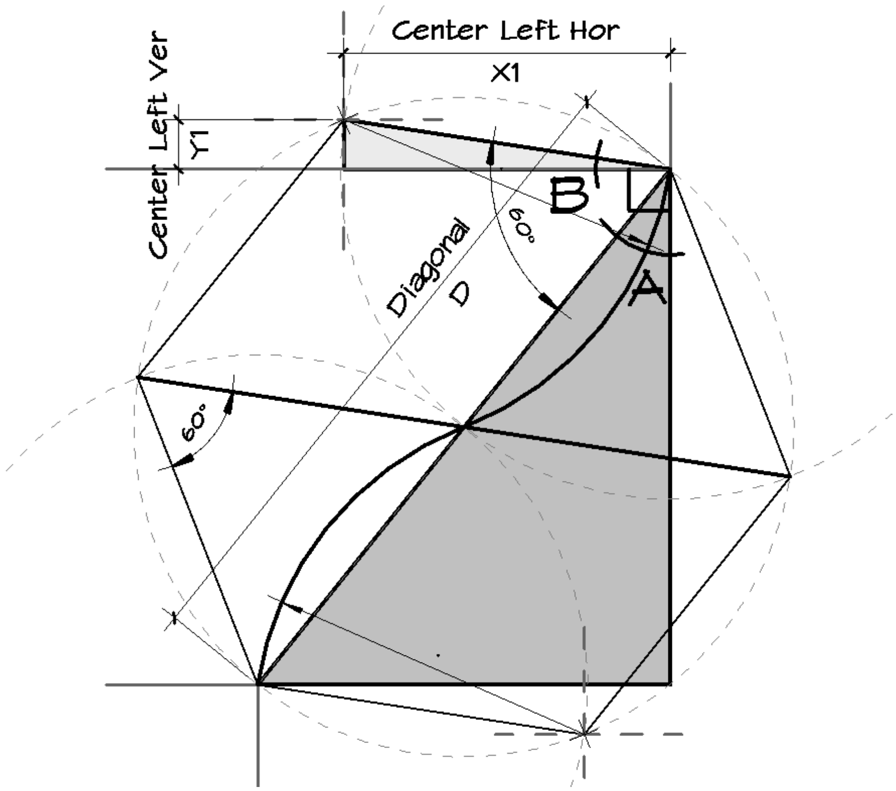


Figure 44—Cyma Reversa Construction

The critical angle is angle B. There are two known angles in its vicinity, the right angle between the reference planes X Max and Y Max and the angle between the diagonal and the top edge of the implied hexagon. The diagonal, as we saw above, is derived from the Height (Y) and Depth (X) parameter inputs and the Pythagorean Theorem. As the diagrams in Figure 41 (above) and Figure 44 illustrate, the diagonal's endpoints form two vertices and becomes the bisector of an implied hexagon. The hexagon's other four vertices determine the locations of the center points of the arcs of Cyma and Cyma Reversa curves. Since a regular hexagon is easily divided into six equilateral triangles, we also know that the angle between the diagonal (bisector) and the hexagon's top edge is 60°. These known angles make it easy to calculate angle B, which in turn gives us the values X1 and Y1 and the locations of the required reference planes.

Cyma and Cyma Reversa Rigs

If you look on the Families branch in the two testing files: *805 Cyma Sweep Flex.rfa* and *805 Cyma Reversa Sweep Flex.rfa* you will find two versions of the nested profile families. The ones with the (Trig) suffix use the trigonometry formulas and the ones with (Rig) suffix use a 2D detail item family rig nested in them. Feel free to experiment with each one.

Proportional Scaling Strategies

Configuring curved forms so that they can be reshaped parametrically in a predictable and stable way has been the focus of all the examples in this paper so far. Many of the examples have allowed for flexibility in both the X and y directions, but so far we have not discussed strategies to scale the X and Y dimensions proportionally. Naturally, you could just take great care to always make sure your inputs to X and Y match the desired proportions, but of course, this approach is hardly foolproof. With the framework we already have in place for most of the examples created so far, it is very easy to apply an additional constraint to the parameters to force them to flex proportionally. For example, if you like the proportion achieved when X = 4 and Y = 5, simply add a formula in “Family Types” for X that reads **Y * .8**. Other formats work as well, such as **Y * 5/4**, or a formula for Y instead reading: **X * 1.25**. It doesn’t really matter which one you use, as they will all yield the same results. In fact, simple arithmetic formulas work bidirectionally. So if you can edit the value of either X or Y and the other will update accordingly automatically.

To add another level of flexibility, albeit with a touch more complexity, you can introduce a multiplier. This will enable you to establish the proportion of two or more parameters to one another, but also scale the entire family based on a single multiplier value. This is especially important when building classical architectural forms like Doric, Ionic or Corinthian columns. A few additional profile families have been added to the dataset that utilize some various scaling and proportional strategies.

806 Corona

A Corona is really just a variation of the Cavetto that we considered above. It has a similar curve with a projection beneath it. I have made the projection flexible and variable. However, I have made the curve portion proportional. In addition, I have tied everything together so that a single parameter can scale the entire shape. So when flexing this family, you can choose different heights and depths for the rectangular portion, but when you scale, the curve always maintains its proportion (5/6 of Y in this case).

SAMPLE! You can open a sample file named: ***806 Corona Profile.rfa***.

Feel free to open the file, and consider Figure 45. Y1 and X1 drive the size of the lower rectangular portion of the profile. Y1 and X1 are derived formulaically from user inputs to **Y Projection Mult** and **X Projection Mult**. These two parameters are formatted as Number parameters. This means that they cannot drive lengths directly. To make them drive the length parameters Y1 and X1, they are multiplied by a length parameter called **Base Diameter**. In classical architecture, the Base Diameter of a column drives the proportions of all the other dimensions, thus the name chosen here. Depending on the use of any moldings created from this profile, you can input appropriate values for the multipliers to yield a molding of the required size. The third numeric parameter: Multiplier is used to control the size of both Y and X. It is applied directly to Y in its formula and indirectly to X since X is derived from Y.

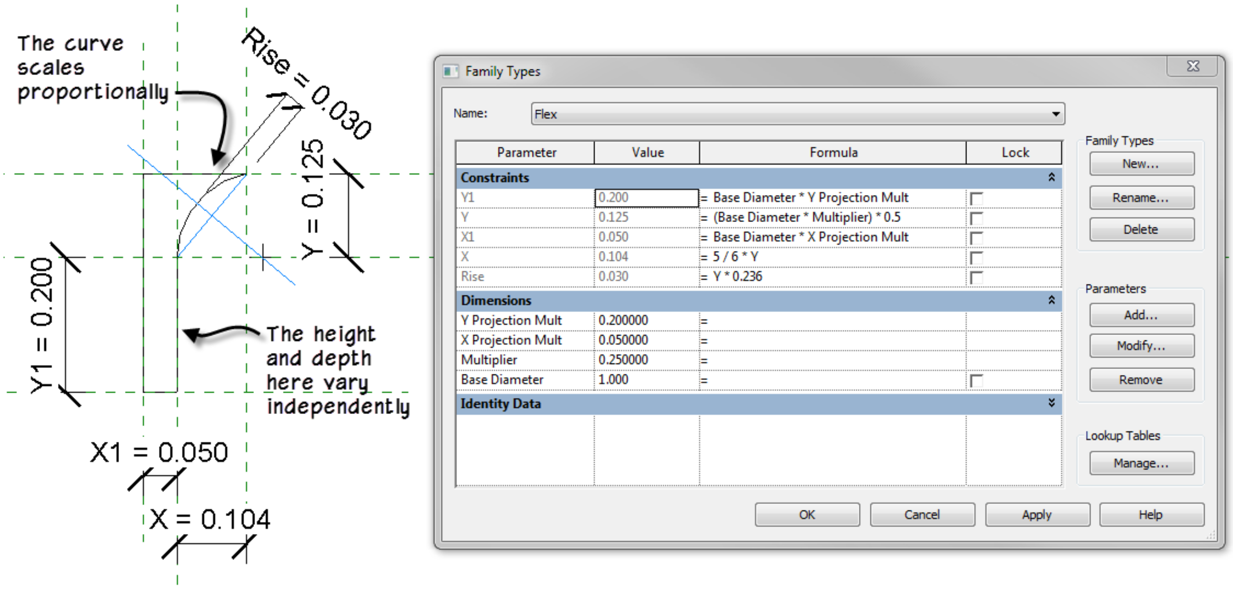


Figure 45— Construction of a Corona Profile

The additional innovation in this family is the use of a Line-based Detail Item rig. We looked at several examples of Detail Item rigs above. The rigs above were designed to allow disproportional scaling. In other words, the rig can flex differently for X and Y. A Line-based family is handy as you place it by clicking two points instead of one. This means that you can build it to scale proportionally based on the length between the two clicks. However, once the rotation is established with the two clicks, flexing it to a different proportion will often break it. So such rigs are best used in proportional scaling families like this one. Feel free to open the nested Line-based family and explore. This rig gives us a stable chord for our arc, so we can apply a parameter to the arc rise in much the same way that we did in the “Create a Parametric Segmental Arch” topic above.

806 Scotia

The Scotia profile shown in Figure 46 is also fully parametric and scales proportionally. It uses some of the same techniques, but the approach is a little different and a little simpler.

SAMPLE! You can open a sample file named: ***806 Scotia Profile.rfa***.

A scotia is made up of a circular arc and elliptical arc. (As we noted above, a circle is really just a special case of an ellipse, so we could argue that the scotia is two elliptical arcs, one circular in form, but this is a semantic distinction). The approach shown in the dataset file and figure here uses an overall fixed proportion of 3 to 2 ½. To avoid having lots of unnecessary parameters, a grid of reference planes is used with equality dimensions to flex them. A parameter called **Grid Size** is used to size one bay of the gird, which in turn sizes the entire gird. While this family does not use the Base Diameter parameter, it does have a **Scale** parameter which is multiplied by Grid Size to give us **G**. G drives the size of the grid and family overall. The arc and ellipse are simply aligned and locked to the reference planes using techniques covered above.

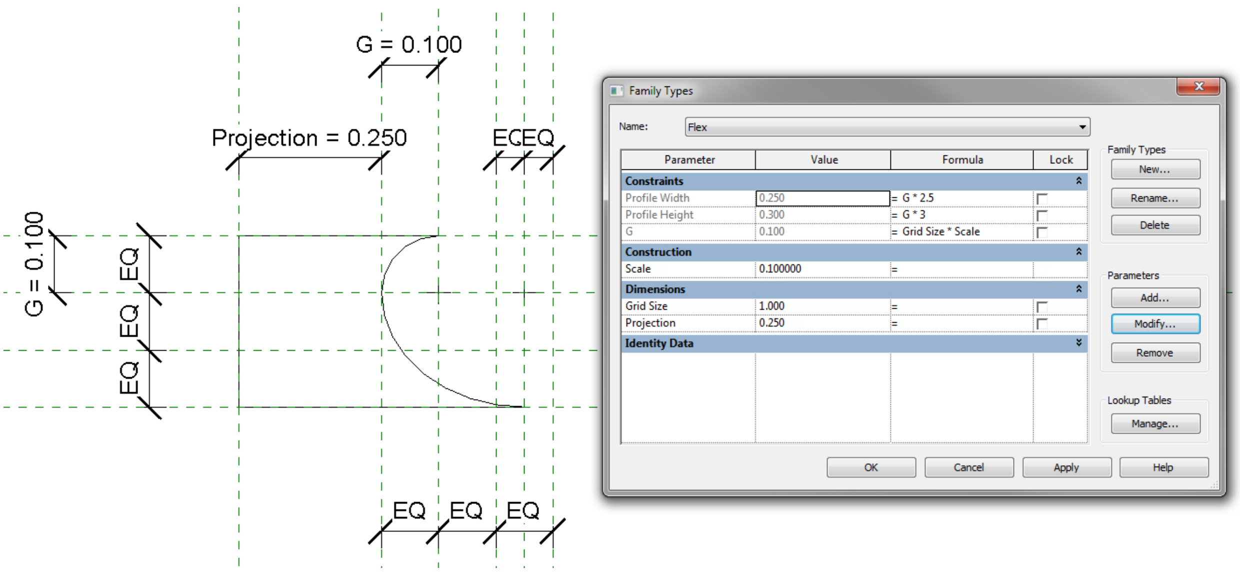


Figure 46—Construction of a Scotia Profile

No rigs or trigonometry are necessary in this family. If you keep the goals of the family fairly limited you can often avoid the more complex approaches. This makes the families easier to construct, maintain and troubleshoot. The downside is that this family only scales in the proportion built into it. If you want it to scale disproportionally, you would need to plan for Grid X and Grid Y. This might require more formulas, trigonometry or rigs. All are possible of course, but sometimes it is easier to just save the family as a new name and build two or more, each with a different proportion.

807 Controlling a Spline

All of the examples so far have used some combination of arcs, circles and ellipses. To wrap up our inventory of curves and techniques to parametrically control curves, we'll take a brief look at splines. In the traditional family editor, the spline is the last type of curve that we have. The spline in the traditional family editor is a Bezier spline.

According to Wikipedia, "A Bézier curve is a parametric curve frequently used in computer graphics and related fields… In vector graphics, Bézier curves are used to model smooth curves that can be scaled indefinitely."

SAMPLE! You can open a sample file named: ***807 Traditional Spline.rfa***.

In Revit, a spline is drawn as a series two or more control points. Splines are open curves in Revit; there is no "close" option. You can have as many intermediate points between the start and end point as required to shape the curve. With a little practice, you can create fairly complex curves from splines with little effort. When creating 3D forms from splines, the surfaces will remain smooth; no facets or edges. This can be a big advantage for certain types of forms. If you need a hard edge, consider other types of lines or create more than one spline (see the top portion of Figure 47).

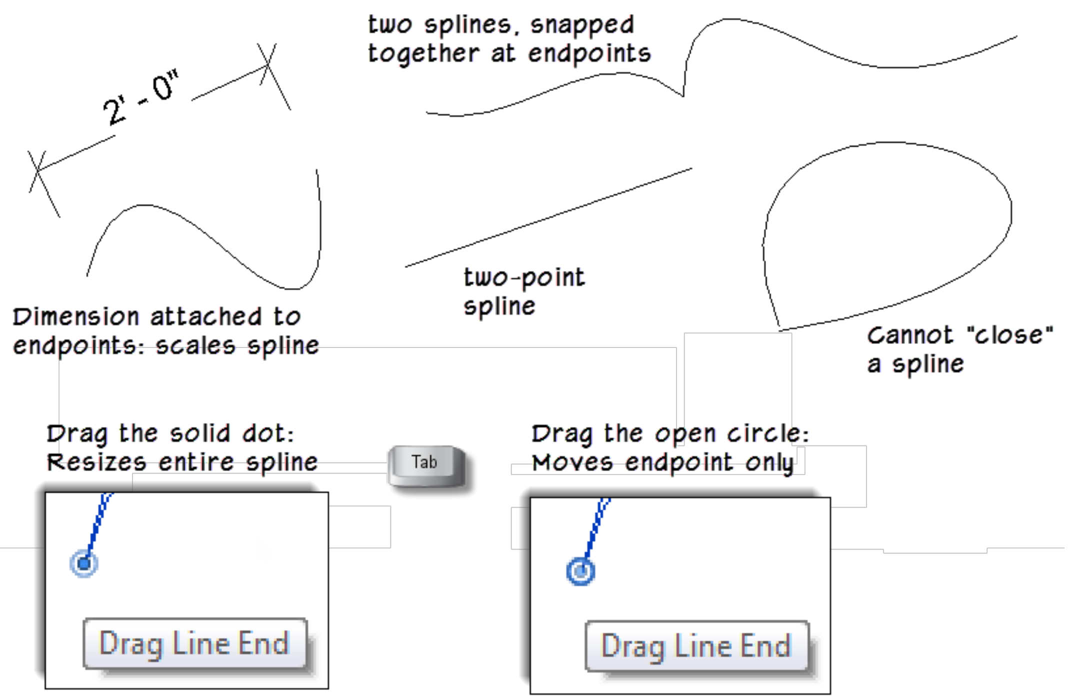


Figure 47—Working with Splines

Another interesting and useful characteristic of splines is that if you drag either endpoint, the entire spline will stretch and scale proportionally at the same time. This means that as you stretch the implied line that connects the start and end points, your spline will maintain its shape and scale proportionally as it grows larger or smaller. You do not need to do anything special to achieve this behavior. This is the built-in behavior of splines (and as the Wikipedia definition above noted, of Bezier curves in general).

If you wish to actually reshape your spline at one of its ends, make sure you press TAB to cycle the selection into the open circle at the grip point. The open circle is the control handle, while the solid dot is the endpoint. Endpoints will scale the spline. The open circles reshape it (see the bottom of Figure 47).

Note also in the figure that you can attach a dimension to the endpoints. This allows you to scale your spline using parameters and labeled dimensions. You can attach the dimension directly to the endpoints (TAB as necessary) or you can align and lock the endpoints to reference planes and flex them that way instead.

Combining Strategies

By now you should be feeling pretty comfortable with the various techniques and procedures needed to get curved forms to flex reliably in parametric Revit families. In this topic, we will perform one more exercise and use this as an opportunity to combine a few of the techniques we have learned together into a single family.

Let's create an arched doorway opening. This will be a simple example to illustrate how the pieces might fit together. We could approach this family in a few different ways, so naturally the first step should always be to do some initial planning. You can do this on a sketchpad, or directly in Revit.

What we would like here is a door family that has an arched shape. We can use any of the shapes discussed above in the "Arches" topic. In this example we will look at a new shape not covered above. This one will be a three-center arch. It combines three arc together into a form that closely approximates an ellipse. (Feel free to use an elliptical arc like shown above instead if you prefer).

For this exercise, we will create the opening and a molding that surrounds it only. Ultimately however, we would want a door panel, moldings on both sides and possibly even an adjustable swing. In other words, we can incorporate almost everything previously discussed in this single family. You are welcome to take it further following the completion of the tutorial that follows.

807 Three Center Arch

Let's start with the three center arch. A diagram of the shape is shown in Figure 48. The geometry is pretty simple. The two arcs on the left and right are 60° arc with centers along the spring line. The middle arc is similar to our segmental arch above. We could use either rigs or formulas to construct this one. We'll go with a formula since the angles are fixed at 60° which makes the formula very simple.

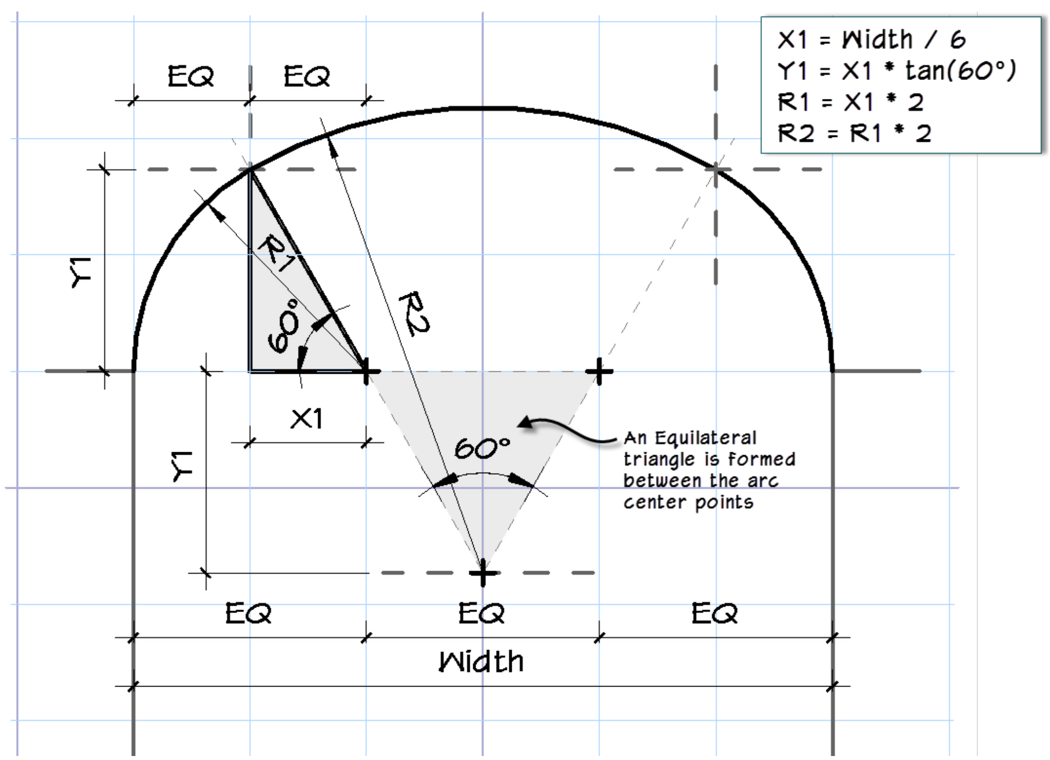


Figure 48—Construction of a Three-Center Arch

We can create a new door family and build the sketch of this form directly in the door family. To do so, select the Opening Cut object that appears in the default *Door.rft* template and edit its sketch. However, let's build a profile family instead. You cannot use a profile family to shape the Opening Cut, so we will delete it. In its place, we'll use a Void Sweep that uses our profile. The reason for this approach, is we can reuse the same profile to create and arched shaped door panel. In this way, you will be able to edit one sweep profile and change the shape of both the opening and the door itself.

1. From the Application menu, choose New > Family.
2. Choose the template: ***Profile.rft***.
3. Save the file as: **Three Center Arch Profile**.
4. Add a series of reference planes: four horizontal and six vertical.
    a. Create the four horizontal ones above the Center (Front/Back) reference plane.
    b. For the vertical ones, create three on each side.
    c. Add dimensions as shown in Figure 49.
    d. On the Properties palette, name the reference planes indicated.

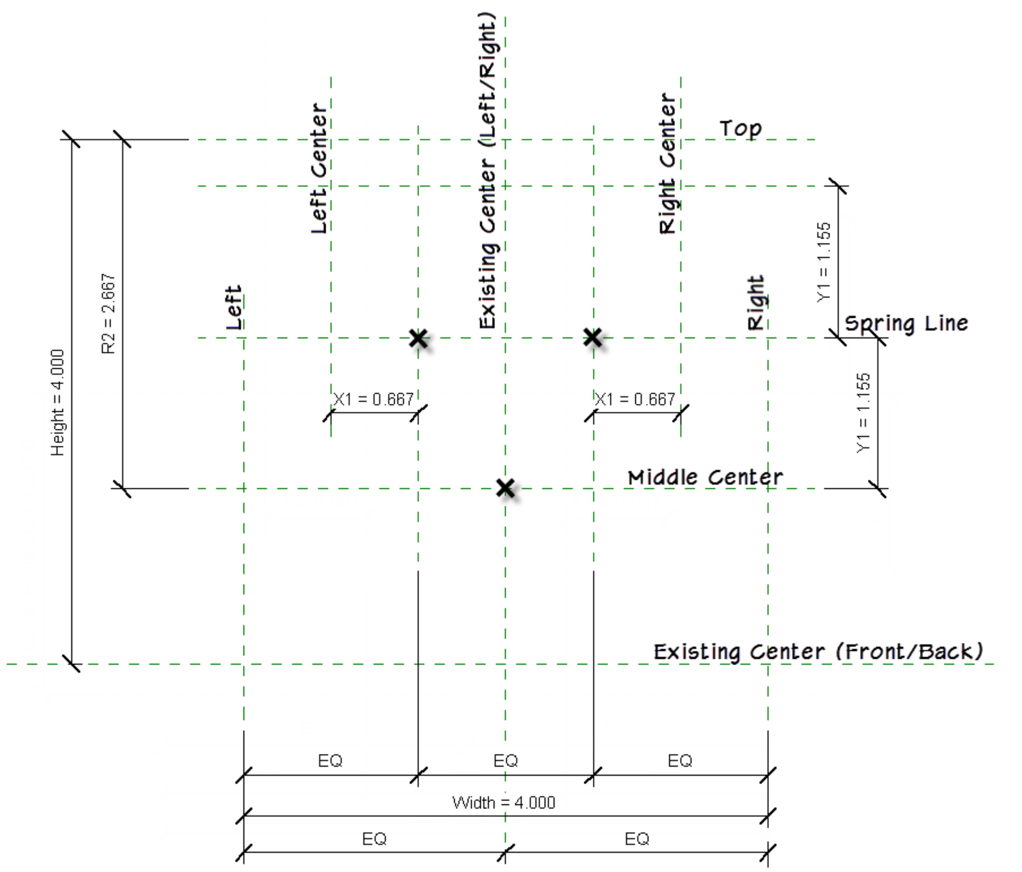


Figure 49—Create the three center arch profile family and set up reference planes and dimensions

CATCH UP! You can open a file completed to this point named: ***808 Three Center Arch Profile (Ref).rfa***.

5. Create the following parameters and assign them to the dimensions as shown.

Parameter	Type	Group Under	Formula
Width	Length	Dimensions	
Height	Length	Dimensions	
X1	Length	Constraints	Width / 6
Y1	Length	Constraints	X1 * tan(60)
R1	Length	Constraints	X1 * 2
R2	Length	Constraints	R1 * 2

6. Flex everything to ensure it is working properly.
7. Using Figure 48 above as a guide, on the Create tab, click the Line tool and then the Center-Ends Arc icon. Draw the three arcs required.
    a. Draw the two arcs on the sides first. Align and lock the endpoints in both directions. (Eight total: two arcs, each with two endpoints, both X and Y).
    b. Select both arc and on the Properties palette, check Center Mark Visible.
    c. Align and lock the centers in both directions.
8. Select both arcs. On the View Control Bar, click the sunglasses icon and choose Hide Element.
9. Draw the remaining arc. Turn on its center mark, align and lock the endpoints and center mark.

If an error appears about over constraining the sketch, simply click Cancel and ignore that point.

10. Reset the Temporary Hide/Isolate and then open the "Family Types" dialog.
    a. Flex the Width parameter to test the family.
    b. Set it back to 4'-0" when you are sure it is flexing properly.

You should get in the habit of creating a default family type for every family you create. The reason is that if you do not create one, Revit will create one for you and its name will be the same name as the family. This is not ideal. You can name your default type anything you like. If the family is intended to nest into other families and will have its parameters driven by associated family parameters, I like to name the default one: "**Flex**." Feel free to use a different name if you prefer.

11. On the right, click the New button (under Family Types) and name it: **Flex**. Close the "Family Types" dialog.
12. Draw the remaining three straight lines on the Left, Right and Center (Front/Back) reference planes. Align and lock them.
13. Save the family.

CATCH UP! You can open a file completed to this point named: ***808 Three Center Arch Profile.rfa***.

807 Compound molding profile

The next step is to look at the molding profile. To save some time, the family has been provided already. The molding uses both a Cyma Reversa and Ovolo as well as some straight fillet portions. Given the complexity of this shape it uses the nested detail item rigs that we have already built. This will avoid having lots of parameters and complex formulas (see Figure 50).

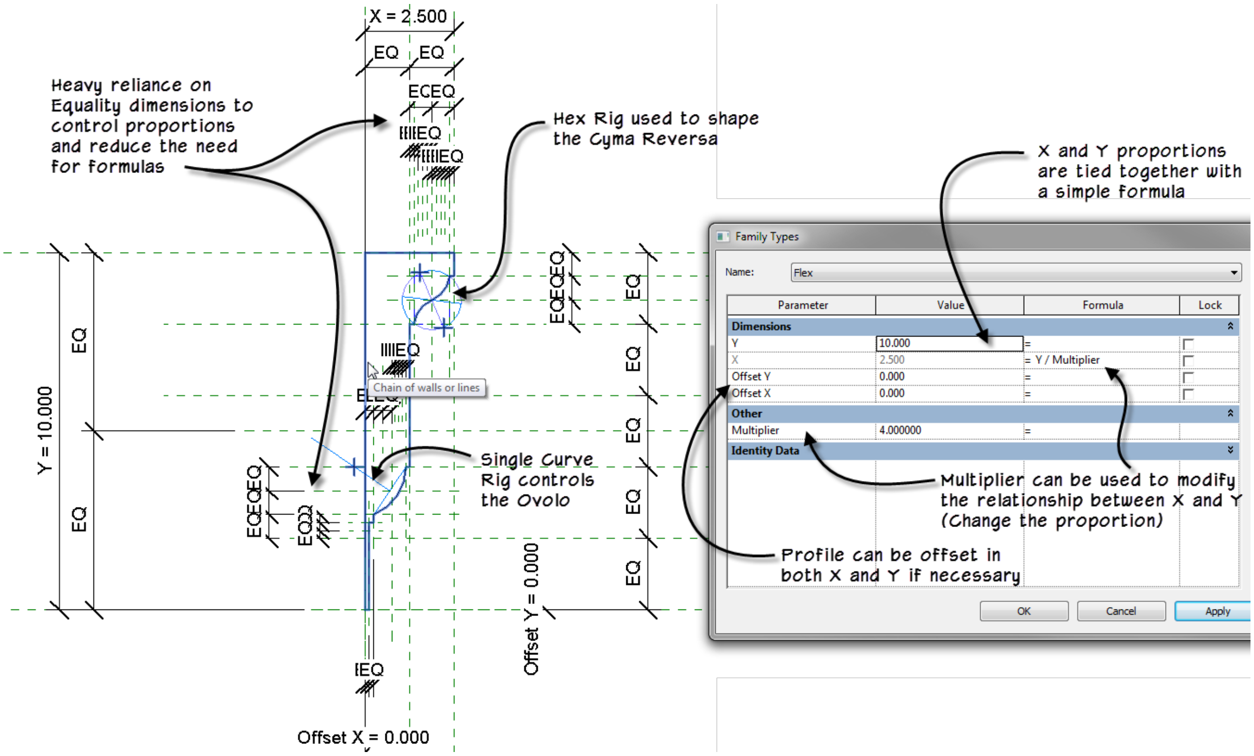


Figure 50—Understanding the Door Molding Profile Family

File Provided! Please open a sample file named: ***808 Door Molding Profile (Rig).rfa***.

As you can see, this family contains MANY reference planes. When building such a family, it is recommended to approach it systematically. Have a good sketch handy and build the reference planes in small groups. Notice that that they are built to varying lengths that provide visual hierarchy. This is critical to helping you keep everything straight both when building and later when editing the family. Naming reference planes is also important, but you may notice that this family has few named reference planes. The reality is that coming up with meaningful names in an example like this provides a diminishing return when compared to the time it would take to actually select and name them. Your results may vary and you are welcome to name them if you wish.

Notice the heavy reliance on equality dimensions. Many of the reference planes in this family are used simply to leverage equality dimensions rather than parameters and formulas. For example, let's say you have a distance that should be one fifth some other distance. You can create a parameter and add a formula that calculates the correct value for you, or you can place a series of reference planes and then put an equality dimension to control them. Either approach will flex properly, but the equality approach avoids many extra parameters.

Notice the two previously discussed rigs used to shape the curved portions of this molding. The rigs were inserted, aligned and locked to the appropriate reference planes.

If you open “Family Types” notice that there is only one formula! This ties X and Y together to maintain the desired proportion. There are two additional features to note here. One is the presence of two “Offset” parameters. All of the dimensions in this family are actually associated to two reference planes that are directly on top of the default Center (Left/Right) and Center (Front/Back) ones. These two parameters are set to zero, but can be flexed to move the entire profile away from the insertion point. The reason to do this has to do with a limitation in swept forms. You can shift the profile of a sweep when inserting it, however, you cannot do so parametrically. So whatever shift you apply is fixed in the sweep. If you want to vary the offset value from one type to another, you can use these two offset parameters instead.

Finally, there is a Multiplier parameter that allows this profile to scale disproportionately. It applies to the X value only. So it controls the relationship between X and Y. For example, the default Multiplier is set to 4. This makes the proportion between X and Y 4 to 1. Try different values if you would like to experiment.

807 Arched Door Family

In the final step, we will combine the two profile families in a new door family. Since we built a door family previously, we can start with that file instead of building from scratch. If you prefer, you can repeat the steps covered above in the “Creating a Door Family with Variable Swing” topic instead of starting with the provided file.

1. Open the file: *801 Door w Variable Swing.rfa*.
2. Save the file as: **Door w Three Center Arch**.

The standard door family template includes an Opening Cut (which makes the hole in the wall) and some trim. We will delete both of these.

3. Delete both trim elements and the Opening Cut.
4. Load both profile families into the door family. (**808 Door Molding Profile (Rig)** and **808 Three Center Arch Profile)**.

For the Three Center Arch Profile family, you can use your own version created above or the one provided.

CATCH UP! You can open a file completed to this point named: ***808 Door w Three Center Arch (01).rfa***.

Since we removed the Opening Cut, we need to create a new opening in the host wall. We will use a void form for this. Specifically a Void Sweep so we can use our profile family to shape it.

5. On the Create tab, click the Void Forms tool and choose Void Sweep.

6. Click the Sketch Path button and draw a single line segment across the thickness of the wall (draw along the Center (Left/Right) reference plane and snapping to the face of wall on each side).
7. Align and lock the endpoints of the line to the faces of the wall. Use the TAB key as required. Align and lock the sketch line to the Center (Left/Right) reference plane.
8. Finish the sketch and then on the Modify | Sweep tab, click the Select Profile button. From the Profile dropdown, choose **Three Center Arch Profile:Flex**.
9. Open the *Interior* elevation view.

Notice that the arch is down near the floor. Also, the shape of the profile does not have the correct height or width either. We will address those issues after we complete the sweep.

10. On the ribbon, click the Finish Edit Mode button.
11. Open the 3D view. Notice that the void is unattached.
    a. On the Modify tab, click the Cut tool.
    b. Pick the wall, then the void.
    c. Click the Modify tool to complete the command.
12. On the Project Browser, Beneath the *Families* branch, expand *Profiles*, then the *Three Center Arch Profile*.
    a. Right-click on Flex and then choose **Type Properties**.
    b. Next to the Width parameter, click the small Associate Family Parameter button. In the "Associate Family Parameter" dialog, choose Width and then click OK.
    c. Repeat for Height and then click OK again (See Figure 51).

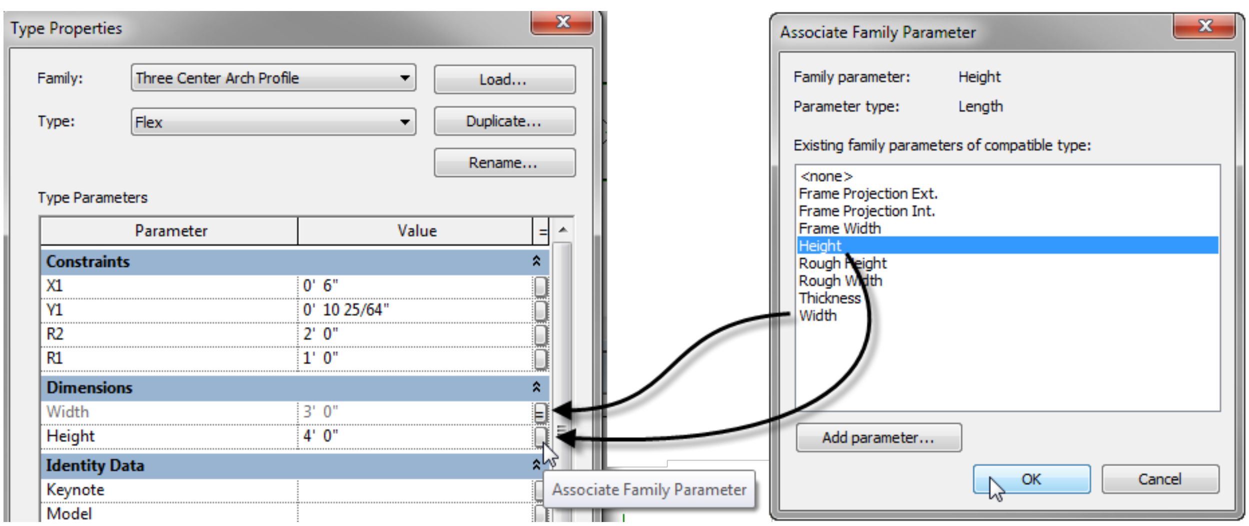


Figure 51—Associate Family Parameters to make the Profile match the door size

CATCH UP! You can open a file completed to this point named: ***808 Door w Three Center Arch (02).rfa***.

You should now have a hole in your wall that matches the shape of our custom profile and the dimensions of the door family. If you flex the Width and Height, the shape of the arch will flex accordingly. Now let's build a 3D door panel from the same profile.

13. On the Create panel, on the Work Plane panel, click the Set button.
    a. In the "Work Plane" dialog, click the Pick a plane option and then click OK.
    b. Click the diagonal Reference Line to make it the active Work Plane.
14. On the Create panel, click the Sweep button.
15. Click Sketch Path and then draw a small straight path perpendicular to and from the midpoint of the Reference Line. (Draw towards the doorway at a 45°).
    a. Add a dimension and label it with the Thickness parameter.
    b. You can also add another dimension in the other direction from the endpoints of the Reference Line and toggle the equality (see Figure 52).

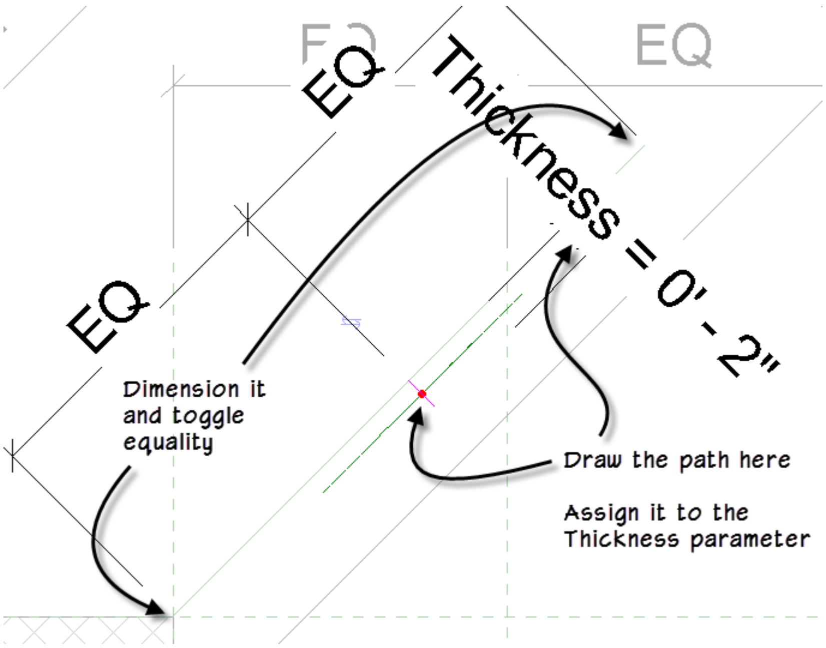


Figure 52—Sketch the path of the panel sweep, constrain and parameterize it

16. Finish the path and assign the **Three Center Arch Profile:Flex** profile to it. Finish the Sweep.
17. Open the 3D view called *View 1* and flex.

CATCH UP! You can open a file completed to this point named: ***808 Door w Three Center Arch (03).rfa***.

The final step is to add the moldings around the door opening. These will also be a sweep, but this time we will use the Pick Path option to pick the edges of the 3D door opening. Stay in the 3D view for this step.

18. Create a new Sweep. For the path, click the Pick Path button.
    a. Carefully click the edges around the opening on one side of the door. There will be five edges total.
    b. Click Finish and then select the Profile: **Door Molding Profile (Rig):Flex**.
    c. If necessary, rotate and flip the profile using the controls on the Options Bar.
19. Click Finish when done.
20. Repeat the entire process on the other side.

You will need to actually repeat the steps on the other side. If you mirror it, the sweep will lose its association to the 3D edges. So create a new sweep and pick new edges for the path. When you are finished, you can flex it to make sure everything works. While you are in the "Family Types" dialog, add a few family types and assign some materials to the geometry if you like. Your final result should look something like Figure 53.

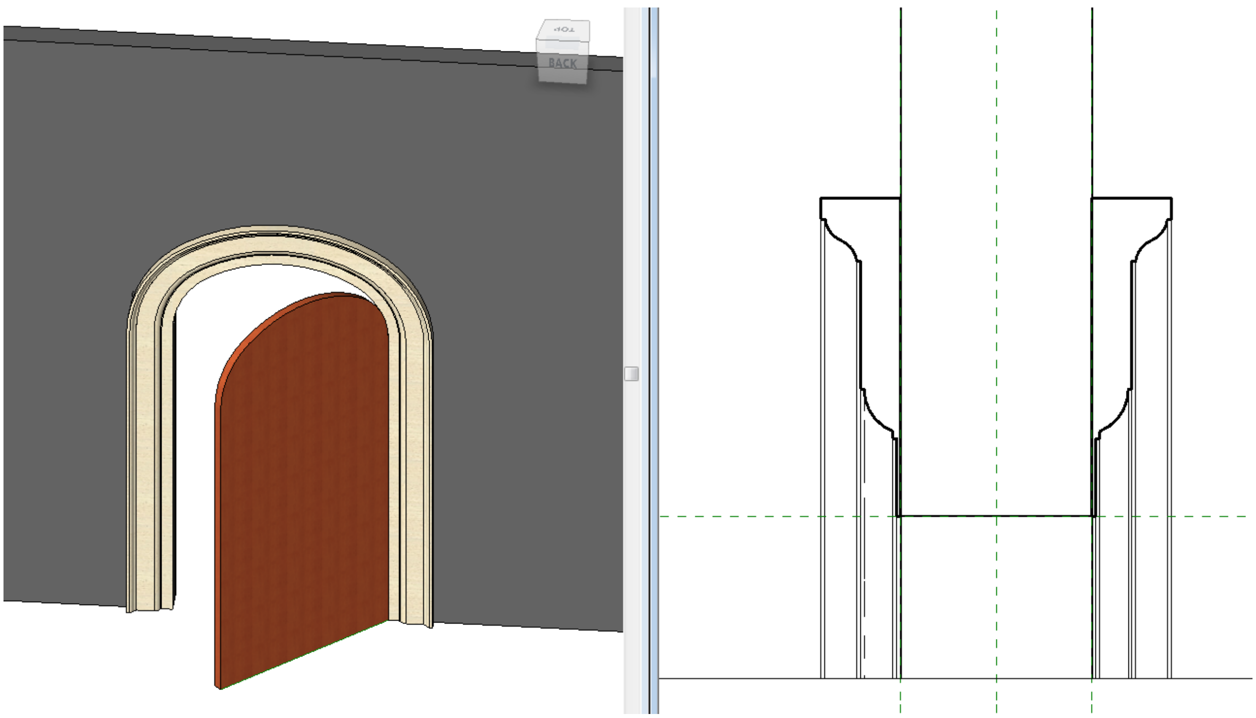


Figure 53—The finished arched door family

CATCH UP! You can open a file completed to this point named: ***808 Door w Three Center Arch.rfa***.

Naturally there is much more we could do with this door family. We could add a low detail version of the molding for medium detail and turn it off completely in course. We could add a vision panel to the door panel. We could add 2D graphics to the elevations and plan view. We could create a closed 3D version or simply rely on the swing parameter. There are transoms, pilasters, other moldings and any number of other enhancements you could consider. We will leave it to you as an additional exercise.

Massing Family Editor Curves

This paper has gone into great detail on the various tools techniques and issues that you may encounter when creating parametrically controlled curves in the traditional family editor. We could easily do another paper of equal size on curves in the massing environment. Time and space will not permit such coverage. Instead, I would like to mention just a few tips that you may find useful if your family editor work takes you out of the traditional editor and into the massing environment.

Working in 3D

The most obvious difference in working in the massing environment is the ability to work and snap to elements in 3D. Even seasoned family editor experts need time to get used to the massing environment the first time they open it. Reference planes and levels show in 3D and to set an active work plane, you simply select the plane. This includes the surfaces of other objects. So you have to be careful where and how you select things.

Selection is also different. Chain selection is the default in the massing environment. If you want to select a single edge, use the TAB.

Traditional Techniques

While the interface is different and everything from working with reference planes to creating forms is different, all of the techniques covered so far can be applied in the massing environment. However, not all of them will be directly applicable.

For example, you will rely heavily on rigs when building complex flexible forms in the massing environment, but you will not be using Detail items for those rigs. In fact, Detail items cannot be inserted in the massing environment.

The massing environment does not support any 2D families in fact. This means that you cannot use Profile families either. However, you can build your shapes inside of Generic Model families instead. When you load a Generic Model family into a massing family or adaptive component family, any enclosed model lines in that nested Generic Model will behave in much the same way as profile families. This technique can also be used to build rigs. Rigs can be both 2D and 3D.

Other than their displaying in 3D, Reference Planes behave virtually the same in the massing environment. You can add dimensions and parameters in exactly the same way. You can use equality dimensions, align and lock things and add family types and flex. Automatic Sketch Dimensions are also part of the massing environment and work the same way.

Masses vs. Adaptive Components

Families built from the *Mass.rft* template use the massing environment toolset, but cannot have their category changed to anything other than Mass. Adaptive Component families are a special kind of family that is built in the massing environment but can have a category other than Mass. They are built from the *Generic Model Adaptive.rft* template. Families with the category Mass are only able to serve as "clay models" and massing studies. They are not permanent objects in a project and typically do not display unless masses are turned on. Adaptive Components can use many standard categories, so they are actual objects in your project environment. Furthermore, adaptive components are so named because of their ability to "adapt" to the shape of other geometry. They can have multiple "placement points" which means that they placed by making several clicks during insertion. Each click places a placement point and the family will flex to the shape of the placement points. When created carefully, this feature is very powerful indeed.

Reference Lines and Points

Reference Lines were discussed above in the "Add a Swing Parameter" topic under "Controlling Rotation." Like Reference Points, Reference Lines also contain several integral work planes and can be used to host geometry. In the Massing Environment, all 2D shapes can be created from either Model Lines or Reference Lines. When you create a form from Model Lines, the Model Lines get absorbed into the form. To edit the form later, you can use direct manipulation, X-Ray or Dissolve. When you create a form from Reference Lines instead, the lines are not absorbed into the form and continue to drive the shape of the form. Manipulating the Reference Line's shape directly changes the shape of the 3D form as well. While, reference planes are a part of the massing environment, Reference Lines and tend to play a much larger role. Reference Lines are used in many of the ways that reference planes are used in the traditional environment. When you create forms from Reference Lines, they remain associated to the Reference Lines so that you can continue to manipulate them and thereby edit the forms.

Furthermore, the massing environment also contain Reference Points. Reference Points are useful in all massing families and are an essential building block of nearly any Adaptive Component Family. They are so useful and powerful, it is a shame that they are not available in the traditional family editor or the project environment for that matter. Reference Points are point elements that you can place in the canvas. They can be moved in three-dimensional space using the integrated gizmo control. The control allows movement along each of the X, Y and Z axes (red, green and blue respectively) and also along the plane of any two of these axes by dragging the small "L" shaped portion instead of the arrow itself.

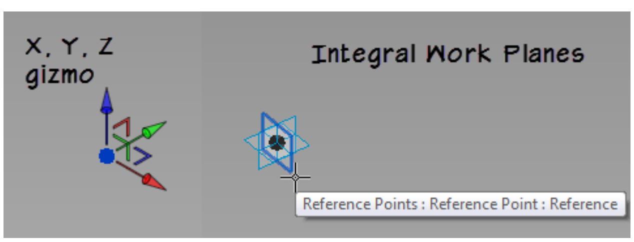


Figure 54—Point element with its gizmo visible

More importantly, Reference Points define Work Planes and consequently can host geometry. This feature gives tremendous power and flexibility to the use of Reference Points. Reference Points can also be turned into "Shape Handle Points" and "Adaptive Points." Adaptive Points are like insertion points when the family is placed in a project or other massing family. Adaptive Points are considered hosts, so when you place a family with adaptive points, the geometry can actually conform to the shape of the points as you click to place them. A Shape handle point is a special kind of adaptive point that can be manipulated after initial placement. This can be used to flex the family.

Spline Through Points

When you combine both Reference Lines and Reference Points, you gain some very useful advantages. There are two ways that you can host your lines (either Model or Reference) to Reference Points: 3D Snapping and Spline Through Points. The real key to leveraging these tools is realizing how they can work together. Using either method, we will have a construct whereby the Reference Points serve as the host for the Reference Lines, which in-turn will be used to generate the 3D forms.

Find the Spline Through Points icon on the Draw panel. You can use the tool two ways: click it first and then place several points. As you click points, a spline will appear passing through each point you click. The other method is to create several points using the point tool first. Then select the points and click the Spline Through Points icon. It will pass a spline through all of the selected points.

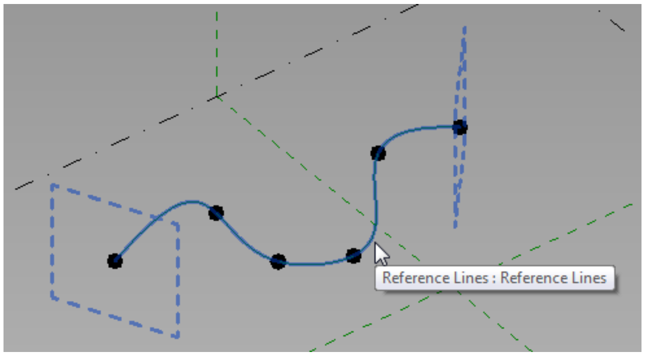


Figure 55—Spine Through Points

Hosted Points

In both of the methods noted for creating a Spline Through Points, the points will “drive” the shape of the spline. If you move a point, the spline will reshape. However, if you place a point on an existing line (any line, straight, curved or spline) it will become hosted to the line. The line will then “drive” the point. If you use that hosted point as the host for something else, like geometry or other lines and points, you can build a complex set of relationships. This is the essence of building rigs in the massing environment.

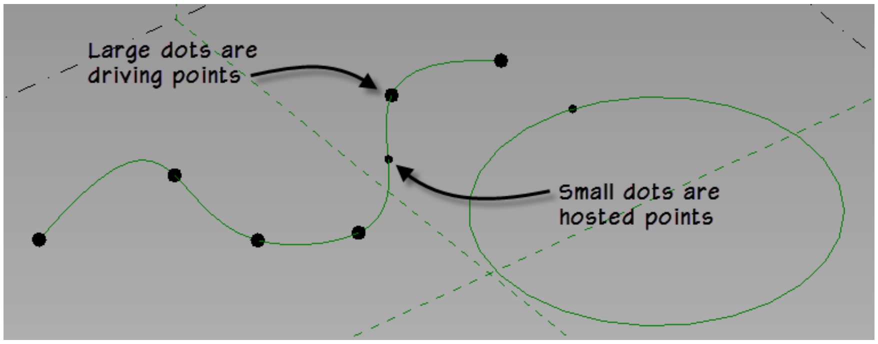


Figure 56—Points can drive the shape of geometry or be hosted by it

Building Rigs

The secret to building rigs is the "Normalized Curve Parameter". This parameter is a numerical value that determines the precise location of a hosted point along its host line. The host can be any shape as we noted above, but is illustrated on a straight line here for simplicity. Rather than being an absolute measurement, Normalized Curve Parameter is a numerical value between 0 and 1: basically a percentage. This number does *not* change if the length of the line changes. So, if you start with a 10 unit long line and a normalized curve parameter of .8, your point will be 8 units from the end. Stretch the line to only 5 units long and because the normalized curve parameter remains .8, the point is now 4 units from the end. In other words, the point's location (and anything hosted to it) scales proportionally!

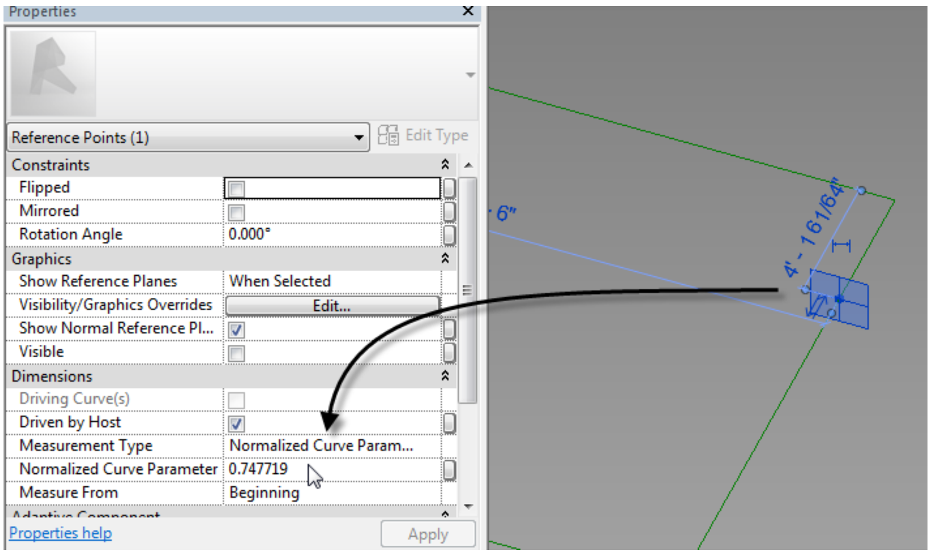


Figure 57—Normalized Curve Parameter

If proportional scaling is important to what you are building, then Reference Line rigs with hosted Reference Points can be a very powerful way to approach the task.

New Three-Point Arc

New in 2014, the massing environment includes Arc Through Points. This behaves much like the Spline Through Points. If any of the points is moved, the shape of the arc will adjust accordingly. However, this is a true arc (segment of a circle). This is a very exciting new development in the 2014 version of Revit.

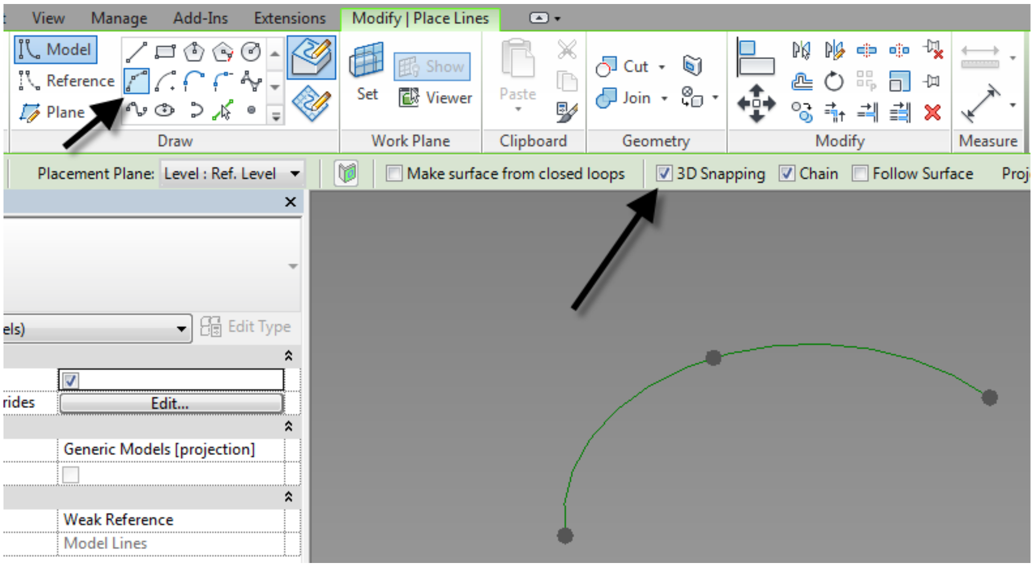


Figure 58—Three point arc through points

To create an Arc Through Points, first click the Start-End-Radius Arc icon. Before clicking, on the Options Bar, check the 3D Snapping checkbox. This will create points as you click and pass the arc through the host points. When you are done, click Modify and then try moving one of the points. The arc will reshape!

Conclusion

We have covered a lot of ground in this session and even more in this paper. Hopefully you have found some useful tips for your content creation tasks. I encourage you to try these techniques in your own content. It takes some time to digest everything. There are many additional resources online particularly for the massing environment which was only just given an introduction here. An appendix listing several sources follows. Please feel free to check it out for further reading.

That's all I have for now. Thank you for attending!

Sources and Further Reading

I have noted a few of my sources in the text, but I would like to present this list for suggestions on further reading and generally to give credit to my sources of information, research and inspiration.

Books:

The Classical Orders of Architecture Second Edition by Robert Chitham

The Greek and roman Orders (Architectural Reprint Edition) by J.M. Mauch

Canon of the Five Orders of Architecture (Dover edition) by Giacomo Barozzi Da Vignola

The American Vignola – A Guide to the Making of Classical Architecture (Dover edition) by William R. Ware

Gibbs' Book of Architecture – An Eighteenth-Century Classic (Dover edition) by James Gibbs

A Treatise on the Decorative Part of Civil Architecture (Dover edition) by William Chambers

The Four Books of Architecture (Dover edition) by Andrea Palladio

The Ten Books on Architecture (Dover edition) by Vitruvius

The Penguin Dictionary of Architecture by John Fleming, Hugh Honour, Nikolaus Pevsner

Web Sites

http://www.doric-column.com/index.html

http://www.doric-column.com/glossary_classical_architecture.html

http://www.realtor.org/rmoprint.nsf/pages/arch36

http://theclassicalorders.com/theclassicalorders.html

Must read post for anyone interested in formulas:
http://www.revitforum.org/tutorials-tips-tricks/1046-revit-formulas-everyday-usage.html

Blogs and Blog Posts

Not a comprehensive blog list. These are just a few that dive deep into the building of form, mostly in the massing environment. The posts on these sites will make up for the brevity included here.

My Blog: http://paulaubin.com/blog/

http://buildz.blogspot.com/

http://grevity.blogspot.com/

http://grevity.blogspot.com/2013/06/making-glass-onions.html http://revitswat.wordpress.com/

http://autodesk-revit.blogspot.com/

Some other blogs that I read regularly (not necessarily directly related to this class content)
http://revitoped.blogspot.com/

http://whatrevitwants.blogspot.com/

http://bdmackeyconsulting.com/blog/

http://malleristicrevitation.blogspot.com/

PDFs

https://docs.google.com/viewer?url=http%3A%2F%2Faucache.autodesk.com%2Fau2008%2Fsessions%2F3758%2FAB400-1-Handout.pdf

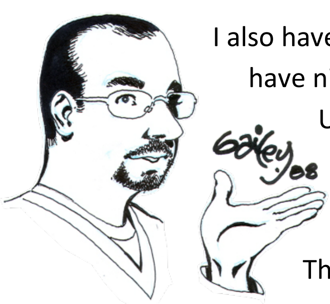
http://ebookbrowse.com/ab327-4-fuzzy-math-essentials-for-revit-family-builders-pdf-d139312736

Further Study

You can find more information and tutorials in *The Aubin Academy Master Series: Revit Architecture*.

Past Autodesk University Classes:

"Autodesk® Revit® Families: A Step-by-Step Introduction"
"Autodesk® Revit® Families: Step-by-Step Advanced Concepts"



I also have Revit video training available at: www.lynda.com/paulaubin. I have nine courses at lynda.com: *Revit Essentials (2014, 2013 and 2011)*, Up and Running with Revit, ***Revit Family Editor***, *Revit Architecture Rendering, Migrating from AutoCAD to Revit, Phasing and Design Options* and ***Advanced Modeling in Revit Architecture***.

The Revit Family Editor course is devoted entirely to the Family Editor and content creation. The Advanced Modeling course covers the Massing Environment as well as many other related topics.

If you have any questions about this session or Revit in general, you can use the contact form at **www.paulaubin.com** to send me an email.

Follow me on titter: **@paulfaubin**

Thank you!