AUTODESK **UNIVERSITY** 2015

CS9597

3D, 4D, and 5D—Not Your Ordinary Storage Tank

Quoc Pham
Autodesk Consulting

Learning Objectives

- Discuss client requirements
- Learn how to measure BIM success
- Discover best practices using Reo Tools
- Learn how to look at adaptive components differently

This class will demonstrate the workflow between Revit software, Navisworks software, and Primavera software, referring to a project **ADG Engineers** delivered (the LNG tank located in Gladstone, Australia). In successfully delivering our work, we developed a structural model with scheduled 3D reinforcement utilizing the rebar extension tools and developing adaptive component families to represent as post tension. We will go through the tips and tricks that the company has picked up along the way, and explain further the reason why we used adaptive components. Furthermore, you will see that within Navisworks software we used the simulate functionality of the product to integrate the client's native construction program utilizing certain rules and tricks. Once the Building Information Modeling (BIM) was developed, we validated the design and constructability utilizing 3D, 4D, and 5D workflows.

Your AU Experts

With years of involvement with BIM technology and experience working for a reseller to working in a design consulting firm (ADG Engineers Pty Ltd). Supporting them with BIM implementation, training matrix, co-ordination, Revit multi-disciplinary family creation, Multi-disciplinary Revit project management, coordination and facility management projects. Consulting to clients and contractors on the utilization of BIM. Some of the projects to name are 1200 man mining housing facilities in remote locations, Construction 4D implementation and Virtual design construction and more recently the BIM Management of 1 William Street located in Brisbane. Now being at Autodesk Consulting team, Quoc looks further to expand on the technology and utilizing it throughout the life cycle of a project to gauge tangible value and efficiencies to the project.

Contents

System Requirements

Revit Concrete Structural Modelling

Foundation

It was important to model the foundation of the concrete structure in accordance with the stages in which they would construct the LNG tank. In modelling the base of the tank it was broken up in different pours. For the base of the foundation, we used the system base family Floors and slab edge to incorporate the thickening around the edge of the tank. At later stage of the development of the BIM we would be able to use area reinforcement and also any other specialised reinforcement modelling.

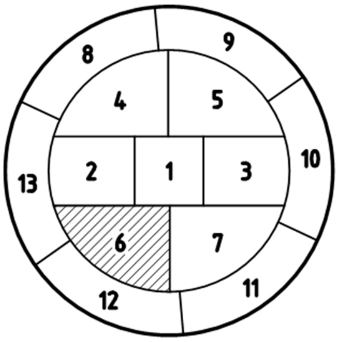


FIGURE 1: FOUNDATION KEY PLAN

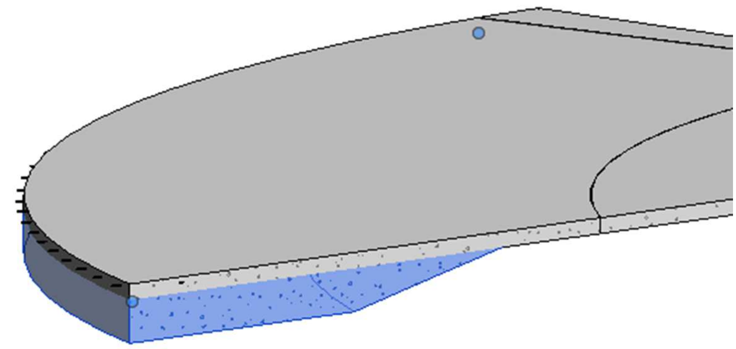


FIGURE 2: FOUNDATION PERSPECTIVE SECTION

Lift Walls

The walls are usually the easiest part of the project, however, a slight issue arose. There was a thickening at the base of the walls due to the post tensioning design. In order for us to combine this into our structural concrete model we incorporated sweeps into the wall.

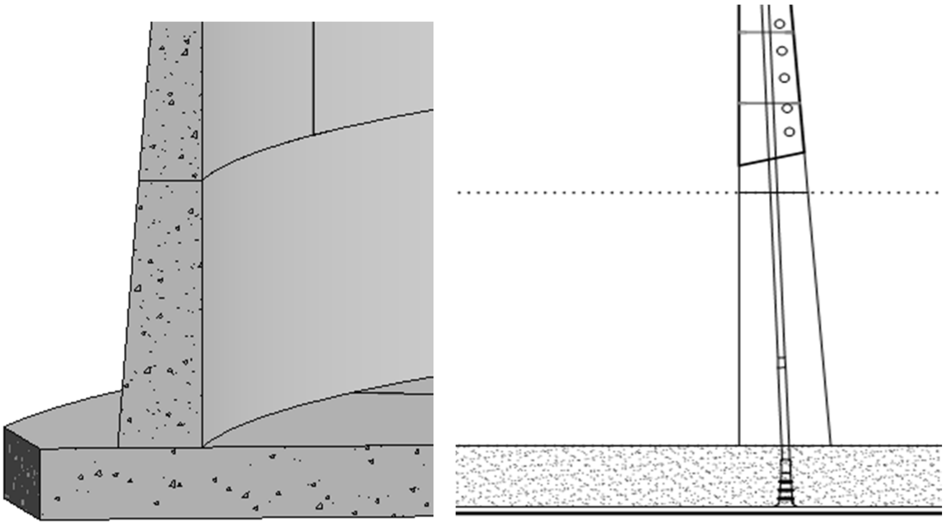


FIGURE 3: LIFT WALL SECTION

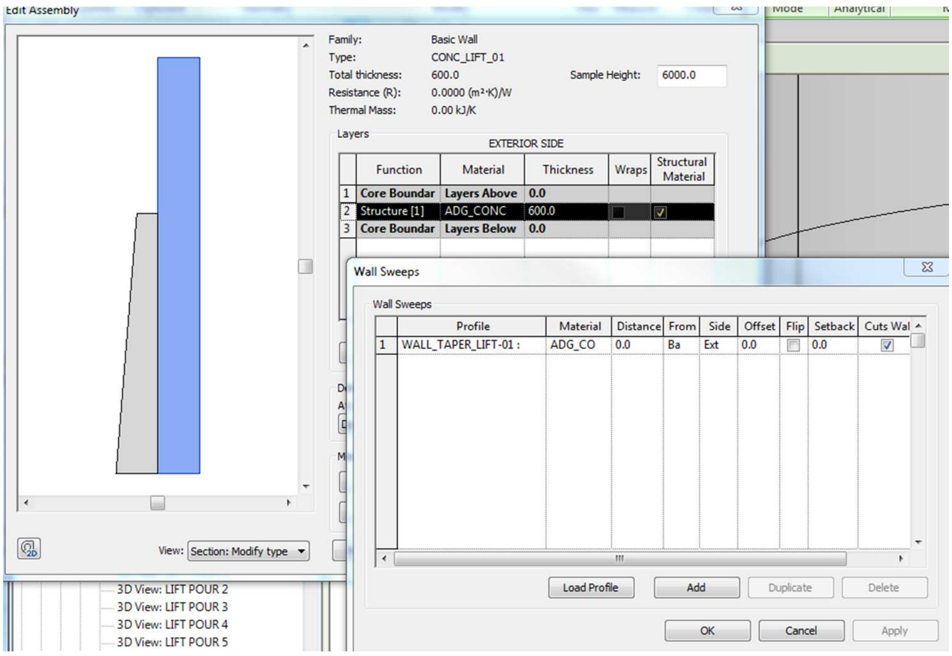


FIGURE 4: LIFT WALL PROPERTIES

Buttress

There are 4 locations around the tank where there is a thickening called the buttress. These are where the post tension anchors are eventually located in order for tensioning. To minimise families, we developed a structural column family that would be capable of being parametrically adjusted. Referring to the diagrams below, the column needs to be able to flex for the first two lifts, then maintain its shape for the remainder of the lifts to the roof. Note that the column itself is flat on one side of the face and curved on the other.

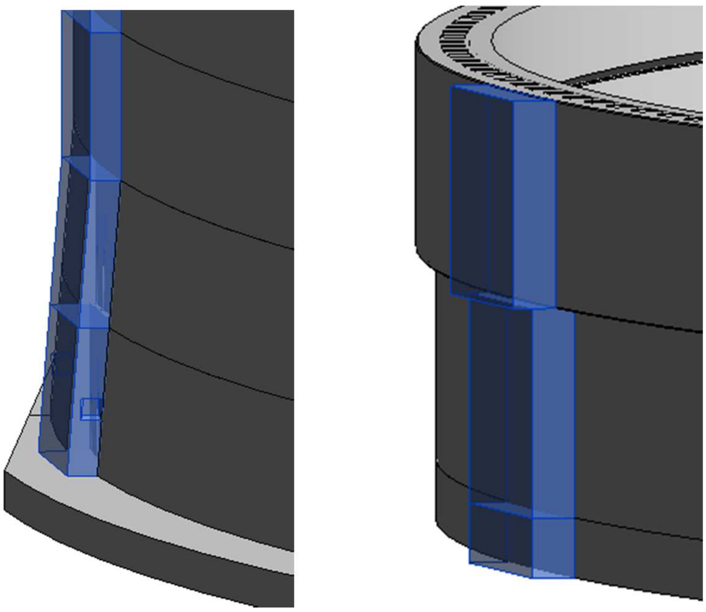


FIGURE 5: BUTTRESS RUNNING FROM BASE TO ROOF

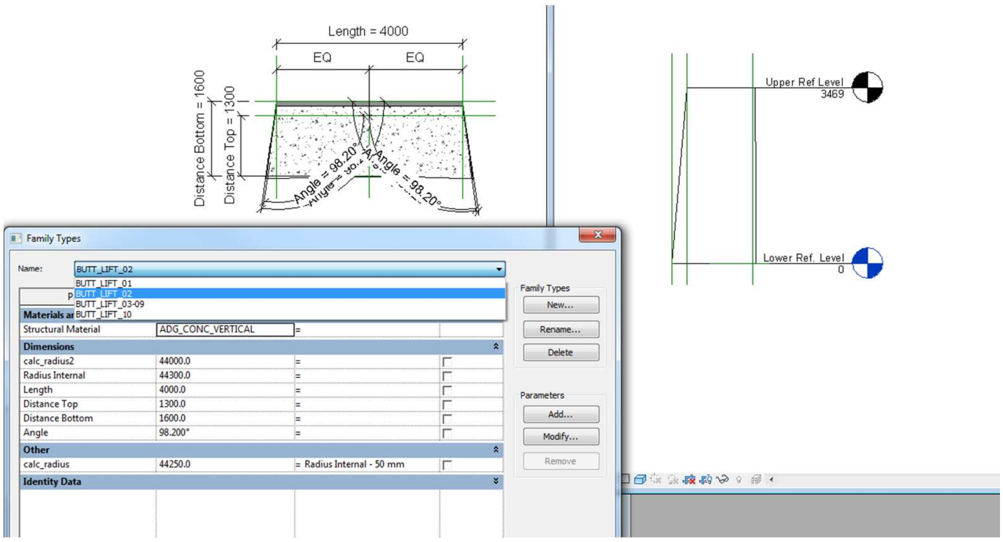


FIGURE 6: STRUCTURAL COLUMN REVIT SETUP

Roof

Similarly to the foundation, the roof consisted of multiple pour sequences. In addition, the roof was curved. As we could not use any of the system based families to create this particular roof, instead, we modelled in placed families using sweeps and sweep blends where required. The category structural framing allowed us to do the following:

1. Quantity take offs;
2. Allow hosting of reinforcement; and
3. Control the visibility and its material behaviour.

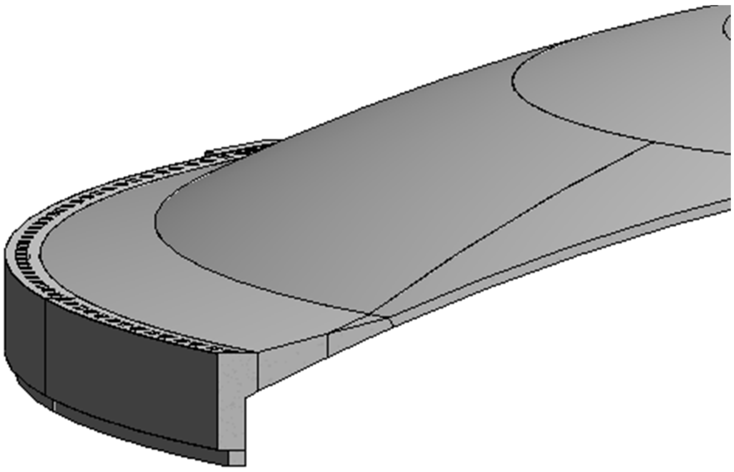


FIGURE 7: PERSPECTIVE VIEW OF ROOF

Included in the roof construction are pedestals. The pedestal's position varies depending on the curve of the roof. There are very limited areas where there are duplications. For the concrete representation, we used structural columns which suited perfectly for the purpose of the element and also for scheduling.

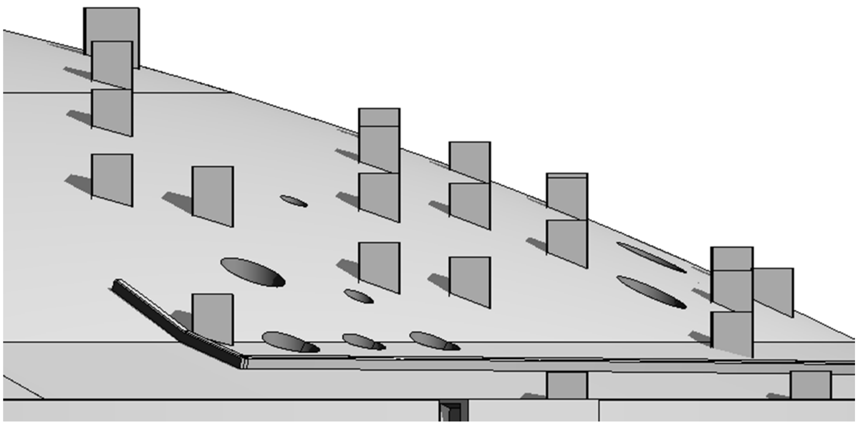


FIGURE 8: PEDESTAL LOCATIONS

Revit Structural Reinforcement Modelling

Reinforcement modelling has been included in Revit for a number of years. This handout won't go through in detail of how to use this but you could download Nathan Love's handout - Reinforcing your skills in Revit.

Foundation Reinforcement

To reinforce Revit floor is quite a simple task. The slab edge acted like a beam where it required certain ties and vertical bars. This required more time to model, once a certain vertical section was done. We then determine the repetition and created groups to suit.

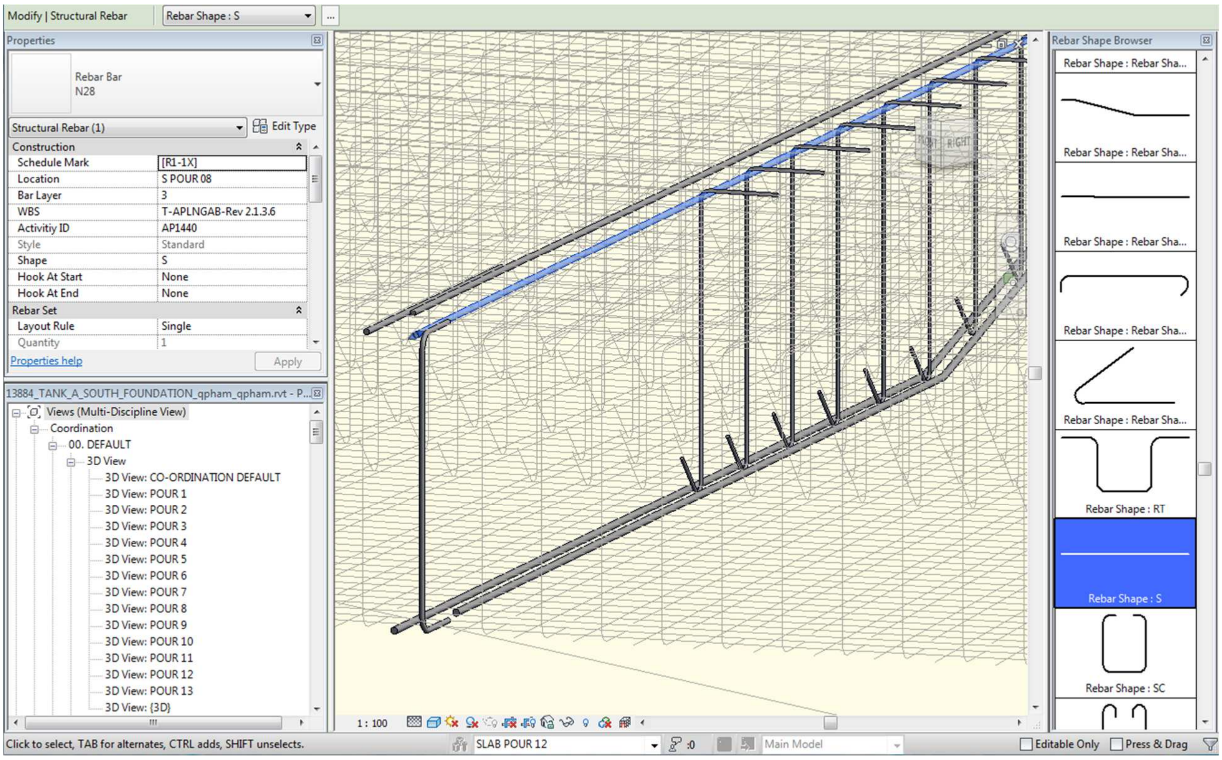


FIGURE 9: REVIT REINFORCEMENT INTERFACE

Some of the issues we had with the reinforcement are due to the nature of the project. Each type of reinforcement bar had its own mark for scheduling purposes. This became more problematic as all reinforcement within Revit would look the same. Thus, from a modelling or drafting perspective it was hard to distinguish the difference, especially in a course view.

The benefits of the Revit reinforcement tool is that it allowed you to have rebar bending in 3 to 4 directions. This suited us perfectly because again due to the nature of this particular project, reinforcement bars had to be bent in a particular way.

Wall Reinforcement

For the wall reinforcement, we found at that point in time that using groups was the easiest way to model. During the installation process the bars would be staggered going vertically and also horizontally. This required different types of groups to help enable us to model as they would build on site, keeping in mind we needed to call up each different type of bar.

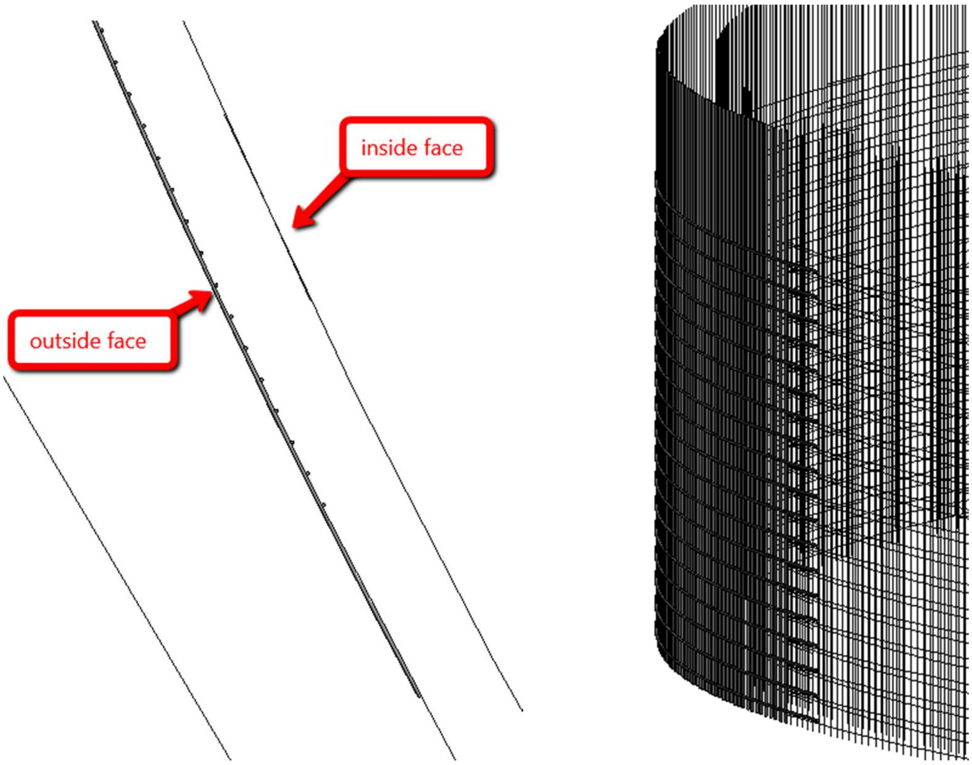


FIGURE 9: WALL HORIZONTAL & VERTICAL REINFORCEMENT

Note that the reinforcement bars all looks the same. Again, this was one of the biggest issues for our design teams. Using work sets and filters, you can control the level of information.

Buttress reinforcement

With the buttress reinforcement, this became very problematic due to the number of ties. With all the types of ties and sizes, we had to create filters to help as a validation system for the design team to know what they have modelled and also determine what areas could become a problem during construction.

The thought process for our design team was not only to think about the position of the bars but also the practicality of the installation. Questions such as, would a steel fixer be able to fit his hand in the space? Would a vibrator be able to fit in the space and does the reinforcement bars have enough development length?

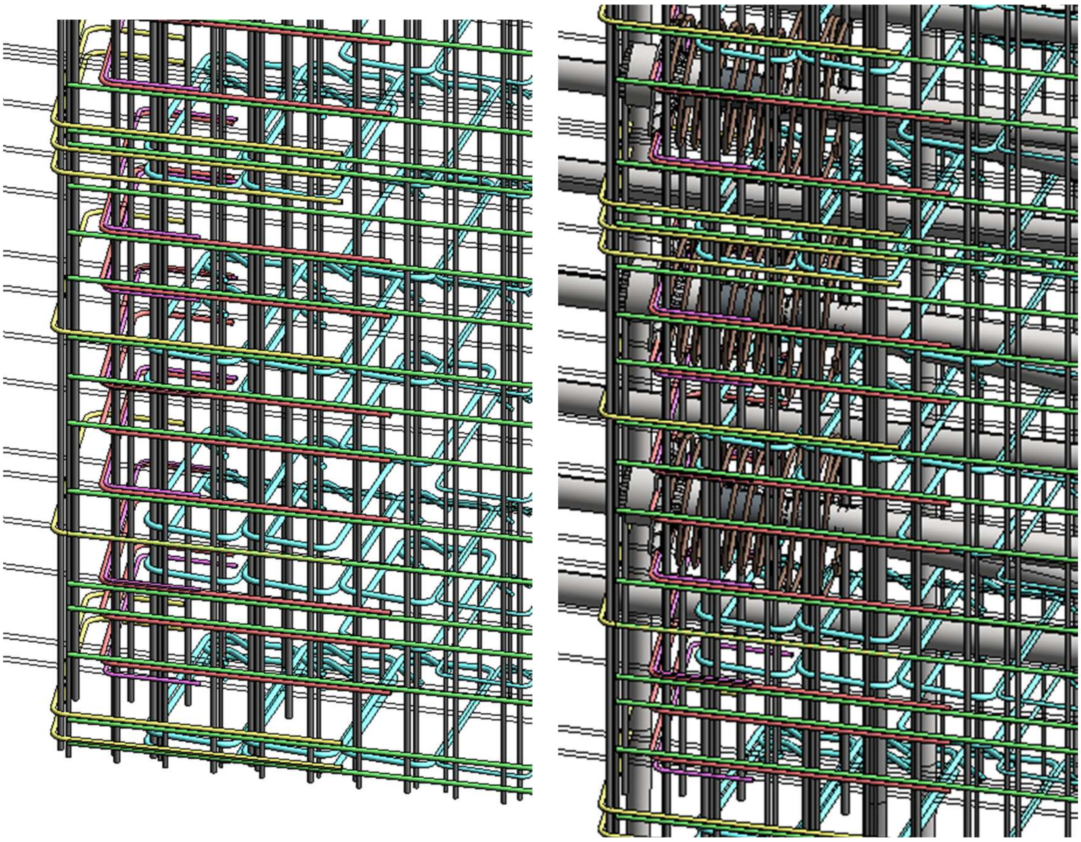


FIGURE 10: LEVEL OF DETAIL FOR BUTTRESS REINFORCEMENT

Horizontal & Vertical Post Tension (PT)

For coordination purposes, in our scope of works we're required to model the post tension. For this particular project there where specific vertical and horizontal PT.

For the following, there are multiple offsets from the inside of the tank. There were two options for developing such a component. Firstly, to create either a dummy component and save out each family to the correct arrangement to suit. Secondly, to create a super family that would accommodate for all the situations.

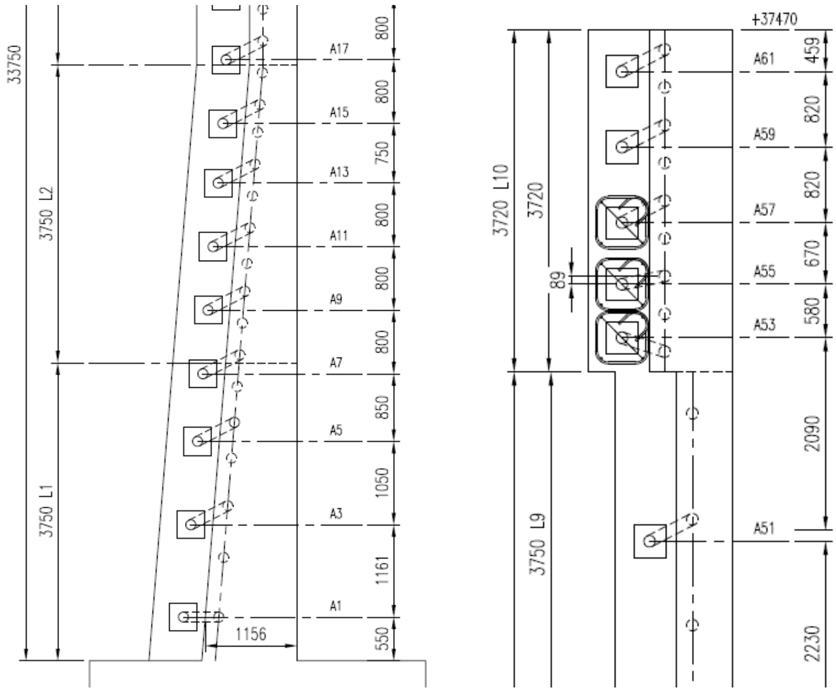


FIGURE 11: POST TENSION HORIZONTAL ARRANGEMENT

So looking at the details of the design intent, we figured out it was no different to a road design. By that, we mean that there was a cross section and a long section with tangent curves that represented the position of the tendons.

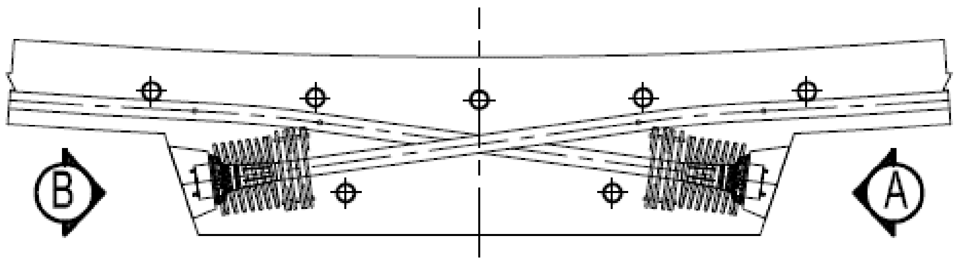


FIGURE 12: BUTTRESS PLAN ARRANGEMENT

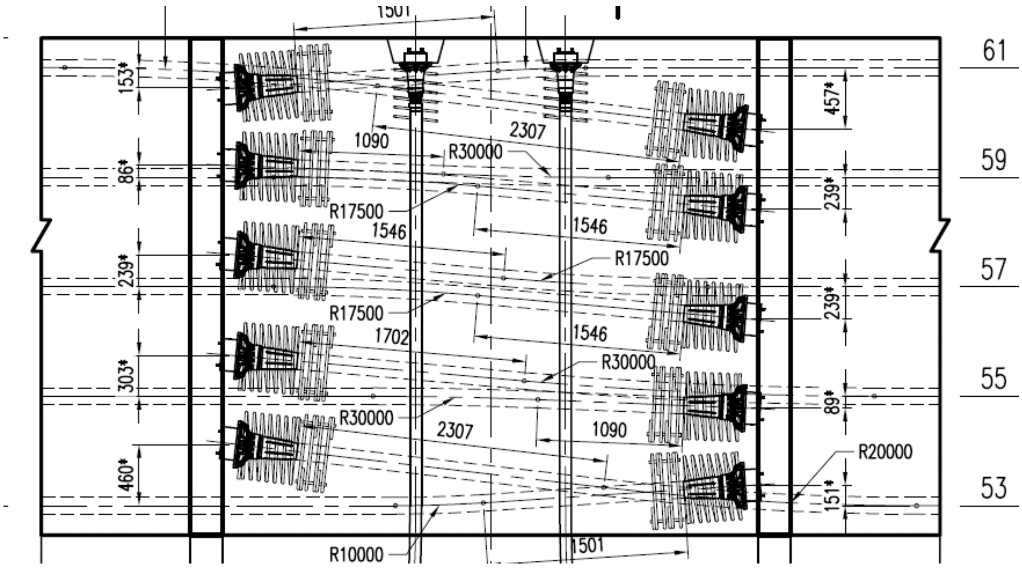


FIGURE 13: ELEVATION VIEW OF ELEVATION

The elevation in the diagram shows arc radius, similar to road designs. Using civil design formulas to figure out the cord lengths, arc lengths and various other information we were able to build a parametric family that could accommodate for all the scenarios. Again saving us from spending heaps of time tweaking and jigging the component to suit. The following is a simple formula table used to determine each point along a curve.

Arc Definition...

$$R\ (ft) = \frac{5729.58}{D\ (degrees)}$$

$$T = R \tan \frac{\Delta}{2}$$

$$L = 100 \frac{\Delta}{D}$$

$$LC = 2 R \sin \frac{\Delta}{2}$$

$$E = R \left[\frac{1}{\cos \frac{\Delta}{2}} - 1 \right]$$

$$M = R \left(1 - \cos \frac{\Delta}{2} \right)$$

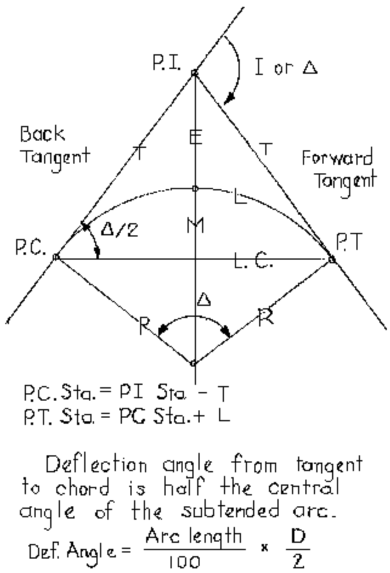


FIGURE 14: CIVIL DESIGN 101

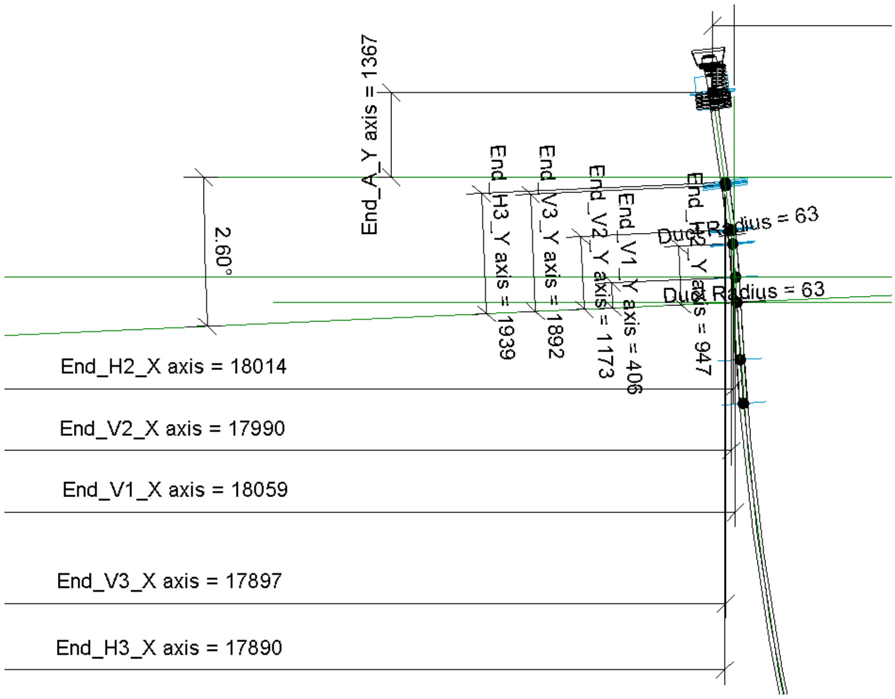


FIGURE 15: PT FAMILY PLAN VIEW

Each point would have a parameter controlling X, Y and Z distances.

Overall Legend		
End_A_Z axis	201.3	= if(PT End UpDown, (Start Vertical PT Length + PT Vertical Bend t) * sin(PT Vertical Angle), ((Start Vertical P
End_A_Y axis	1367.5	= (End PT Length * cos(End Angle Horizontal))
End_A_X axis	45077.0	= (Post Tension Radius + (End PT Length * sin(End Angle Horizontal))) + (PT Horizontal Bend - Start_V3_X a
End_V3_Z axis	66.6	= if(PT End UpDown, PT Vertical Bend t * sin(PT Vertical Angle), (PT Vertical Bend t * sin(PT Vertical Angle) *
End_V3_Y axis	1892.0	= if(PT Horizontal Bend = 18800 mm, (PT Horizontal Bend * sin(PT_Horizontal V Ref Angle)) + Start_V1_Y axi
End_V3_X axis	17896.7	= if(PT Horizontal Bend = 18800 mm, PT Horizontal Bend * cos(PT_H Ref Angle + PT_Horizontal V Ref Angl
End_V2_Z axis	16.7	= if(PT End UpDown, (PT Vertical Bend t / 2) * sin(VV_angle), ((PT Vertical Bend t / 2) * sin(VV_angle) * -1))
End_V2_Y axis	1173.2	= (PT Horizontal Bend * sin(HV_angle2)) + Start_V1_Y axis
End_V2_X axis	17990.4	= PT Horizontal Bend * cos(PT_H Ref Angle + HV_angle2 + HV_angle1)
End_V1_Z axis	0.0	=
End_V1_Y axis	406.0	= PT Horizontal Bend * sin(HV_angle1)
End_V1_X axis	18058.5	= PT Horizontal Bend * cos(PT_H Ref Angle + HV_angle1)
End_H3_Z axis	70.7	= if(PT End UpDown, ((Start_H3_Y axis - Start_V3_Y axis) + PT Vertical Bend t) * sin(PT Vertical Angle), (((Star
End_H3_Y axis	1939.1	= if(PT Horizontal Bend = 18800 mm, PT Horizontal Bend * sin(PT Horizontal Angle), (PT Horizontal Bend *
End_H3_X axis	17889.9	= if(PT Horizontal Bend = 18800 mm, PT Horizontal Bend * cos(PT_H Ref Angle + PT Horizontal Angle), PT
End_H2_Z axis	6.8	= if(PT End UpDown, ((PT Vertical Bend t / 2) - (Start_V2_Y axis - Start_H2_Y axis)) * sin(VV_angle), (((PT Verti
End_H2_Y axis	947.3	= PT Horizontal Bend * sin(HH_angle1)
End_H2_X axis	18013.8	= PT Horizontal Bend * cos(PT_H Ref Angle + HH_angle1)
Other		
Start_A_Z axis	-201.3	= if(PT Start UpDown, (Start Vertical PT Length + PT Vertical Bend t) * sin(PT Vertical Angle), ((Start Vertical
Start_A_Y axis	1367.5	= (Start PT Length * cos(PT Horizontal Angle))
Start_A_X axis	45077.0	= (Post Tension Radius + (Start PT Length * sin(PT Horizontal Angle))) + (PT Horizontal Bend - Start_V3_X ax
Start_V3_Z axis	-66.6	= if(PT Start UpDown, PT Vertical Bend t * sin(PT Vertical Angle), (PT Vertical Bend t * sin(PT Vertical Angle)
Start_V3_Y axis	1892.0	= if(PT Horizontal Bend = 18800 mm, (PT Horizontal Bend * sin(PT_Horizontal V Ref Angle)) + Start_V1_Y axi
Start_V3_X axis	17896.7	= if(PT Horizontal Bend = 18800 mm, PT Horizontal Bend * cos(PT_H Ref Angle + PT_Horizontal V Ref Angl
Start_V2_Z axis	-16.7	= if(PT Start UpDown, (PT Vertical Bend t / 2) * sin(VV_angle), ((PT Vertical Bend t / 2) * sin(VV_angle) * -1))
Start_V2_Y axis	1173.2	= (PT Horizontal Bend * sin(HV_angle2)) + Start_V1_Y axis
Start_V2_X axis	17990.4	= PT Horizontal Bend * cos(PT_H Ref Angle + HV_angle2 + HV_angle1)
Start_V1_Z axis	0.0	=
Start_V1_Y axis	406.0	= PT Horizontal Bend * sin(HV_angle1)
Start_V1_X axis	18058.5	= PT Horizontal Bend * cos(PT_H Ref Angle + HV_angle1)
Start_H3_Z axis	-70.7	= if(PT Start UpDown, ((Start_H3_Y axis - Start_V3_Y axis) + PT Vertical Bend t) * sin(PT Vertical Angle), (((Sta
Start_H3_Y axis	1939.1	= if(PT Horizontal Bend = 18800 mm, PT Horizontal Bend * sin(PT Horizontal Angle), (PT Horizontal Bend *
Start_H3_X axis	17889.9	= if(PT Horizontal Bend = 18800 mm, PT Horizontal Bend * cos(PT_H Ref Angle + PT Horizontal Angle), PT
Start_H2_Z axis	-6.8	= if(PT Start UpDown, ((PT Vertical Bend t / 2) - (Start_V2_Y axis - Start_H2_Y axis)) * sin(VV_angle), (((PT Vert
Start_H2_Y axis	947.3	= PT Horizontal Bend * sin(HH_angle1)
Start_H2_X axis	18013.8	= PT Horizontal Bend * cos(PT_H Ref Angle + HH_angle1)

FIGURE 16: FORMULAS TO CONTROL EACH POINT

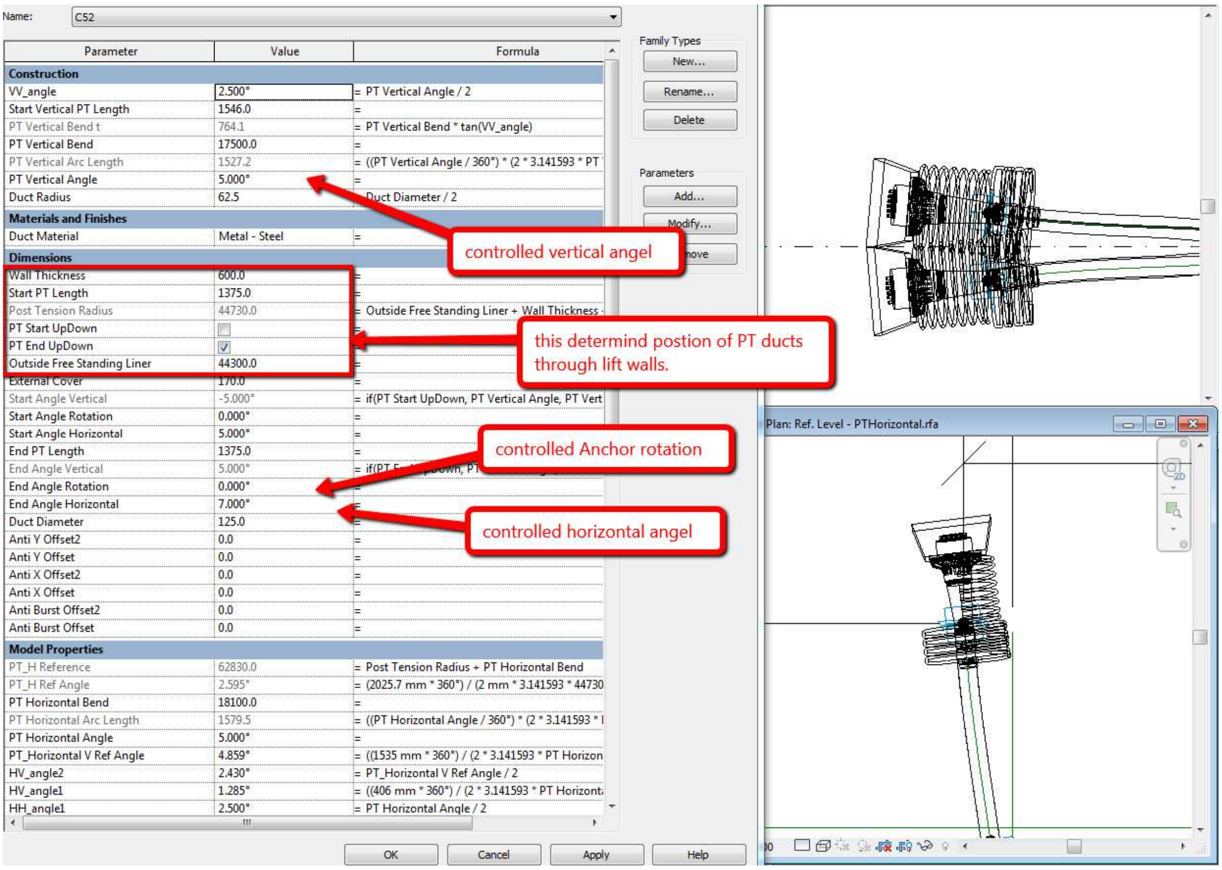


FIGURE 17: SIMPLE USER IMPUTE INTERFACE

As per the image above there was basic information the user had to modify in order to have the correct PT type. The 3 key areas of input are:

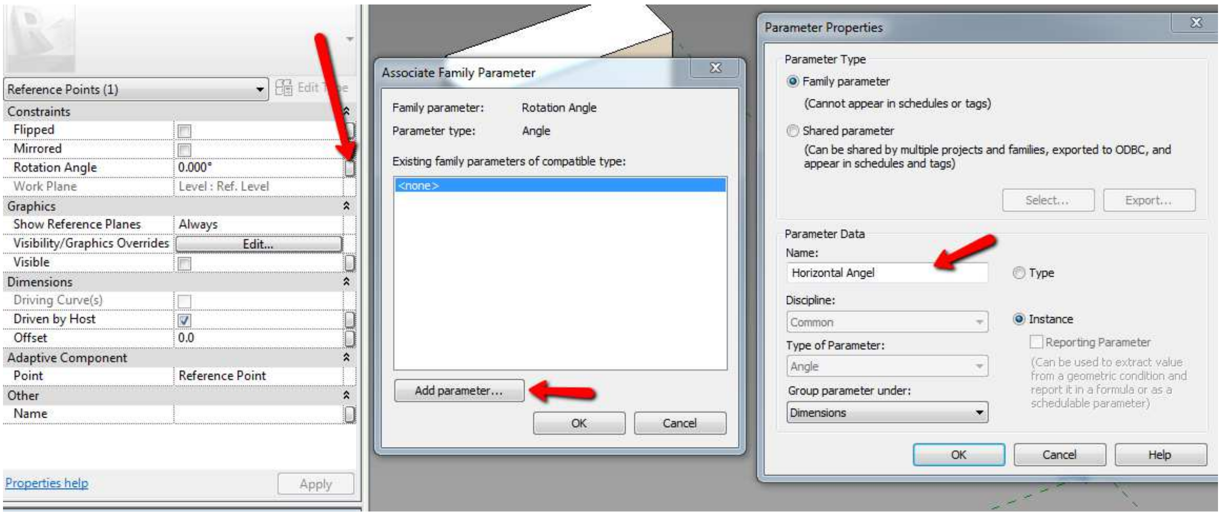
1. The Vertical angle which determine clearances as per the design intent;
2. Outside free standing Liner that gave the family a starting point;
3. Wall thickness which automatically determines the correct cover.

The other advantages of adaptive components is not only being able to control geometry by points, but you can have multiple points aligned to each other in order to create a 3 plane rotation system. As you can imagine, the anchor would need to be positioned with the ability to be rotated not only vertically or horizontally but it would need to be able to rotate along its axis.

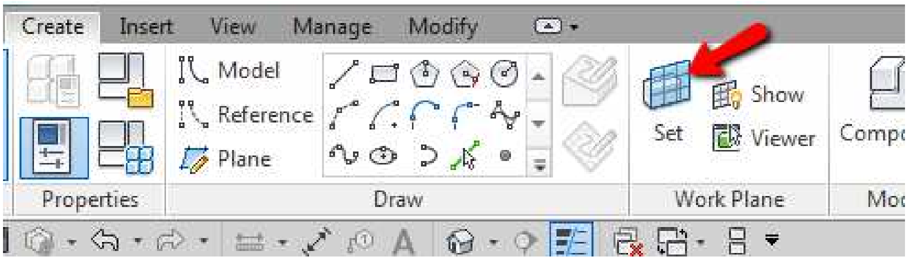
Creating Parametric Multiplane Point

This part of the article will go through in steps of how to create a parametric multiplane point. As per the presentation and the handout, the where this was applied was during the connection of the PT Anchor. For this example I will use a Generic Adaptive component to demonstrate.

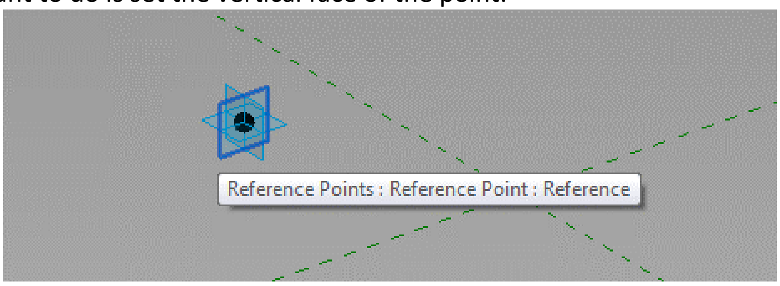
1. To start you will need 1 point.
2. Point one is going to be our Horizontal rotational axis. By selecting the point, go ahead and create a parameter and associate to the element.



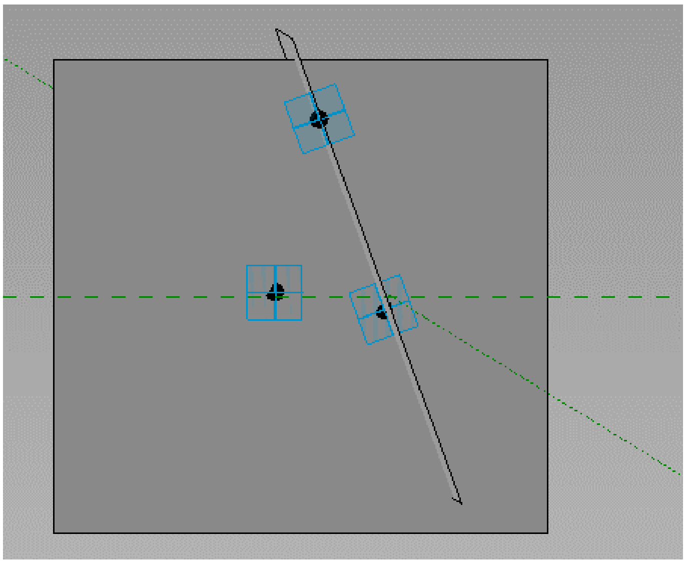
3. After that you will be required to select the create tab and click on the set work plane command.



4. What you want to do is set the vertical face of the point.



5. I would recommend occasionally adjusting the angle of the points so that you can get an idea where the angle is rotating.
6. Repeat step 2 and create a parameter for the angle.
7. From here onwards you can start aligning the points but I would leave them separately just so you can keep testing the parameters and if anything went wrong you can always go back a few steps and do it again.
8. For our rotation around the axis, you would need to again set the work plane to the vertical face of your second point.



9. Remember, keep testing the angles. This will help you keep track of what point was doing what.

Your final product would perform the way you want it to a component that has the ability to rotate along 3 planes.