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SolidWorks® Skeleton Sketch Part Method

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Contents

List of Figures

List of Tables

Introduction

Abstract

The following is documentation of the development of a Solidworks modeling technique based off the Skeletal Sketch Part Method (SSP), with the goal of modeling movable bridges in a dynamic environment. This method is based on the method described in John Stoltzfus's documents, originally pioneered by Neil Sardinas from Prism Engineering. The purpose of pursuing this method is to reduce the number of mates in the final assembly, and allow for changes on the fly that don't break the assembly. The SSP method in general, uses only sketches and planes to define key characteristics of the parts that make up the assembly. This differs from the traditional bottom-up design in that almost all mates are discarded and sketch relations are used in their place.

This manual is a thorough guide on how to produce robust Skeleton Sketch Part assemblies.

Chapter 1

Preliminary Work

1.1 Overview

Before any modeling can be done a significant amount of time must be devoted to defining the project scope, flow, and organization. The first and most important step is to define the scope of the project. What do you want to accomplish with the model? What features of your model are subjected to change at any moment? What parts and sub-assemblies interact with each other? What is the hierarchical dependency of each subassembly and each part that constitutes each assembly? Answering these questions will put the model on the track to success before a single line is drawn.

1.2 Scope

In general the purposes of modeling a movable bridge are to check for appropriate space limitations, correct operation, give a strong visual model for engineers and contractors, and to aid in the development of engineering drawings. A few features that can change on a whim are the footprint and elevation of the main pier, distance to the centerline of the channel, structural members, machinery components and locations, wall thicknesses, and conduit/piping paths. Designing sketches to be able to handle these changes without causing failures down the line is crucial to the effectiveness of this method. The last two questions will be answered more in depth during the organization and flow design, but as a broad example electrical components depend on mechanical components, and both depend on the structural components.

1.3 Flow

After the scope is defined the organization and flow of the model can be determined. Every part must first be identified, and sorted into different sub-assemblies. A considerable amount of work and planning must be put into recognizing the relationships between different parts and sub-assemblies. A hierarchy must be developed based off these relationships, and this will help drive the whole design process. In general, the hierarchy begins with the master SSP, and then is broken down into the main sub-assemblies.

For movable bridges the sub-assemblies are usually broken down based off of location. Typical top-level sub-assemblies are Pier, Tower, and Span. Each of these sub-assemblies will have their own SSPs, parts, and multiple sub-assemblies. Every sub-assembly, and even parts, will have its own SSP derived from its parent sub-assembly. Each skeleton sketch part should only derive information from the next level up. For instance, if we have Master SSP - Sub SSP - Subsub SSP, the Subsub SSP should only be driven from Sub SSP, and not the Master SSP. The basic idea is to keep it simple. Assemblies should not have too many parts and skeleton sketches should have only the basic information needed to drive the parts associated with them.

While it may seem labor intensive to create these parts and assemblies, it puts the work up front, and makes downstream changes easier to make without the need to fix what can be a very complicated mess of mates in the feature tree. An example is given in Figure 1.1. The hierarchy follows dominance from the top left to bottom right. Placement interactions are shown as arrows between parts. Placement of parts in the same groups are contingent upon each other already.

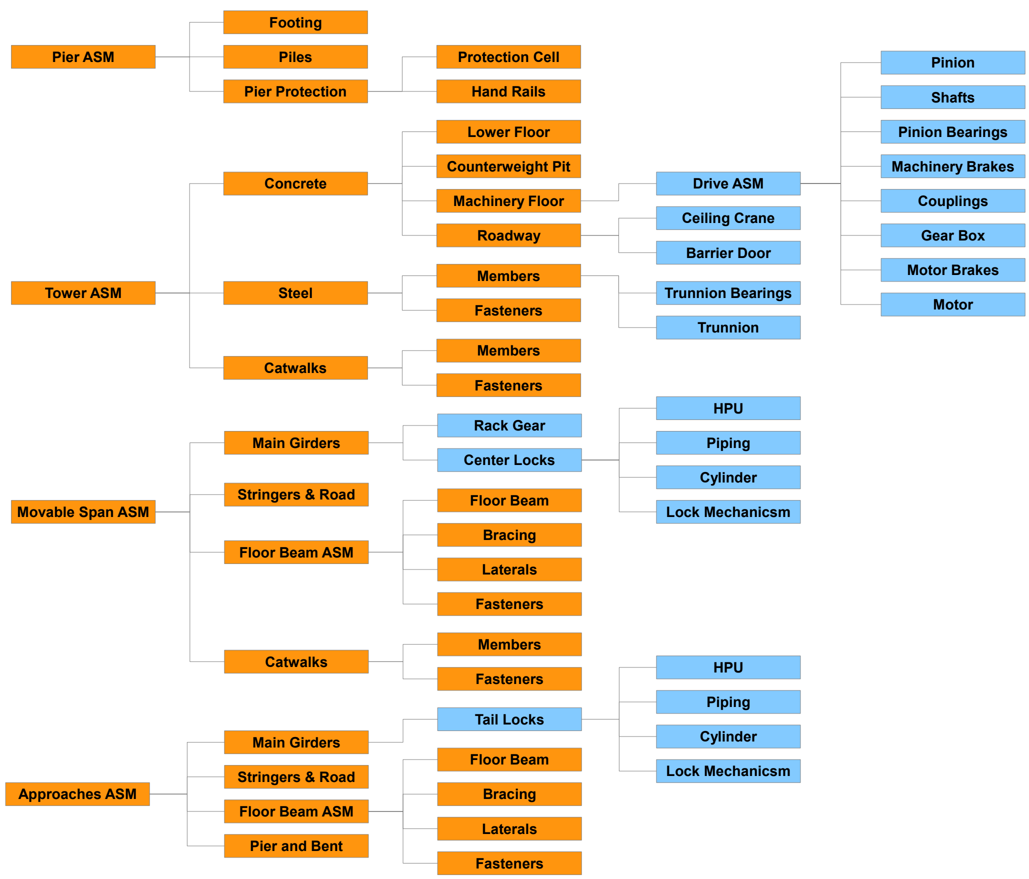

Figure 1.1: Example Flow

Chapter 2

Setting Up Solidworks

2.1 Overview

To speed up the development of a project from the start of the modeling process to the production of engineering drawings some upfront work is required. Most of this work will be creating templates and file naming conventions that allow project information to flow into every part without having to do too much manually. When done properly this can save a lot of time that otherwise would've been spent editing properties in monotony. It also reduces the chances of clerical errors.

2.2 Templates

Templates are a great way to propagate information to all parts, and reduce monotonous tasks. They serve as the base when starting a new part, assembly, or drawing. To create a new template start by pressing New Document, as shown in Figure 2.1.

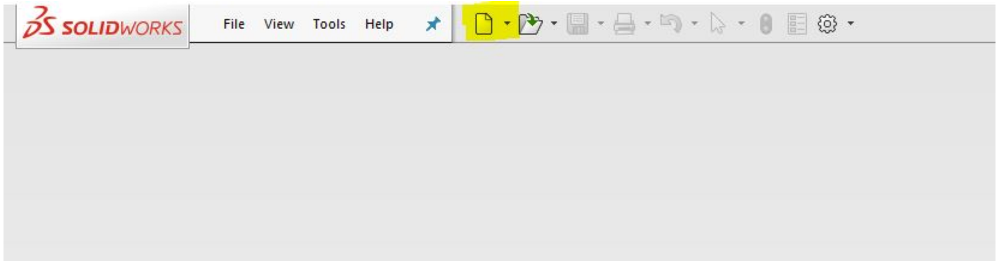

Figure 2.1: New Document Location

2.2.1 Part and Assembly Templates

Next select the "Template" tab (the "Advanced" options button must be pressed for this to show up), then select which type of template you wish to make. Figure 2.2 shows a part template being selected.

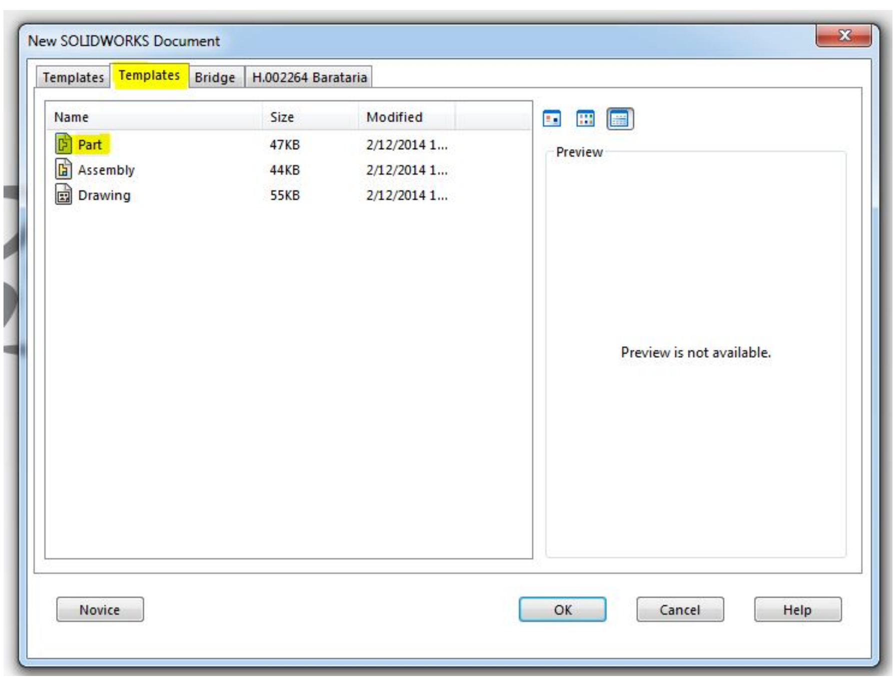

Figure 2.2: New Template Location

The screen appears the same as a standard new part, and anything done in this space can be permanently saved as part of the template. Anything saved to the template will appear in any part that you create with the template. Now there are three main things that are usually done with part and assembly templates. The first, and most obvious, is creating and renaming planes, axis, and origins. Figure 2.3 shows an example of a part template. Only the standard planes were renamed in the design tree (highlighted on the left side), and the planes were set to visible(which can be accessed by clicking on the eye highlighted at the top middle). New planes, sketches, and even surfaces or solid bodies could be added if it was universal to all parts.

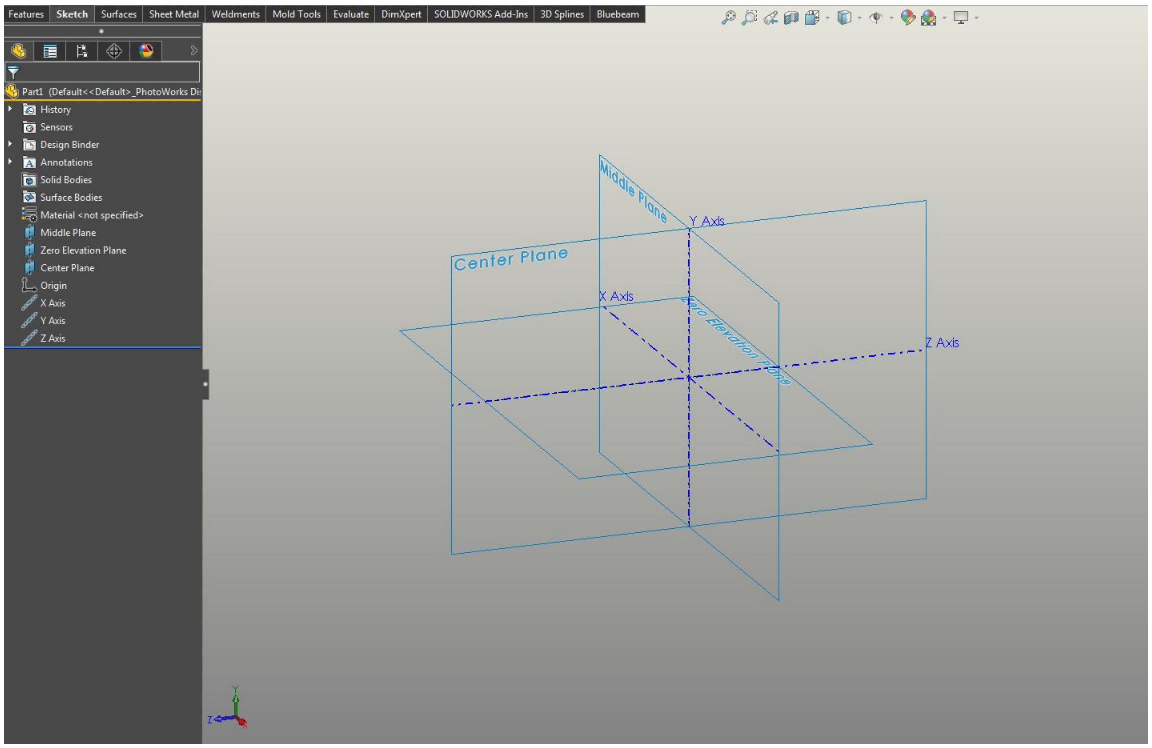

Figure 2.3: Example Part Template

The second feature of templates is the ability to add custom properties. These properties usually contain part number, description, cost, or revision, but just about anything can be attached to the file. To get to custom properties press the highlighted button shown in Figure 2.4.

Figure 2.4: Custom Properties Button

Next, click on the "Custom" tab shown in Figure 2.5. New properties can be added to the "Property Name" column. These can be chosen from a pull down menu or added by hand. You have the option to change the type and description.

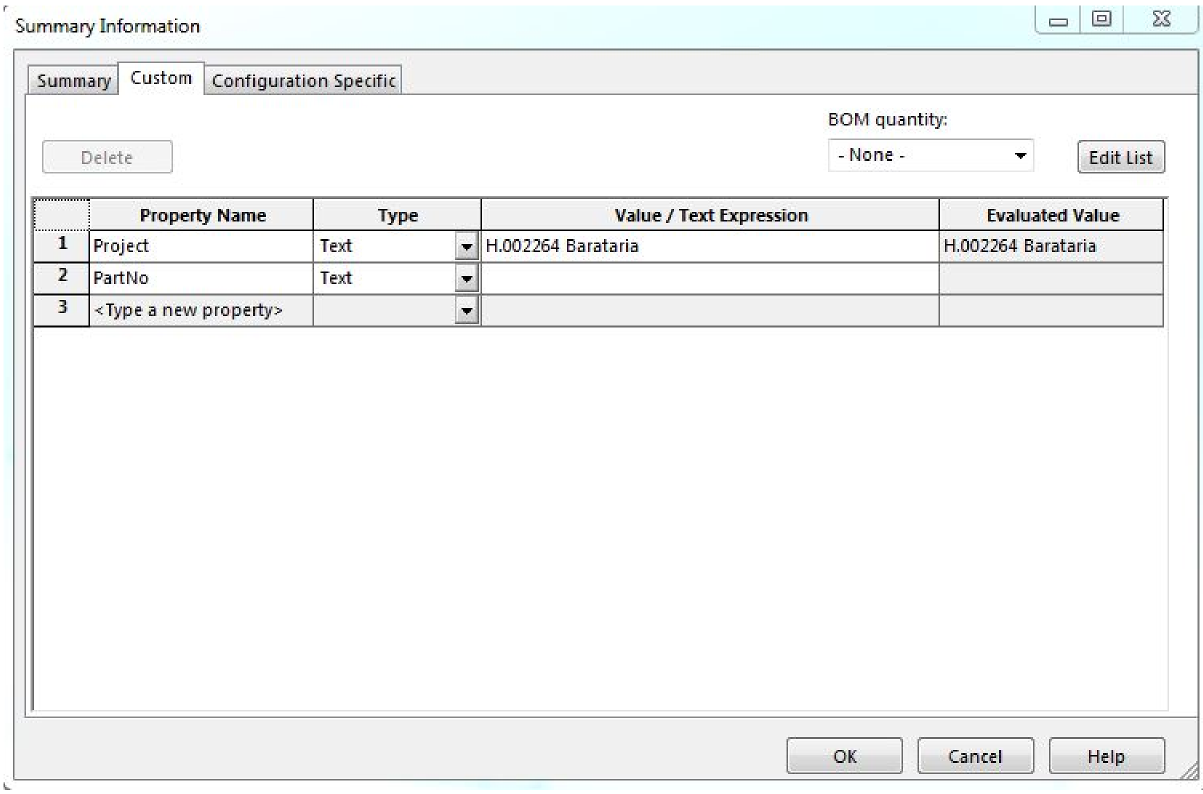

Figure 2.5: Custom Properties Tab

The final feature of templates, and possibly the most important, is the ability to edit the document options, and apply them to every part made with the template. This can be accessed by clicking the button highlighted in Figure 2.6.

Figure 2.6: Options Button

Once in the manager, either the system options or document properties can be edited. Any changes to the system options will affect the whole system regardless of template. Changes to document properties only affect documents made with the template. One of the most important system options that must be activated to properly use the SSP method is shown in Figure 2.7. If this feature is not checked, it won't be possible to derive sketches from an SSP to parts that are in separate assemblies. One of the most important document properties is the unit system, which can be accessed as shown in Figure 2.8. The system, precision, and rounding can be edited here.

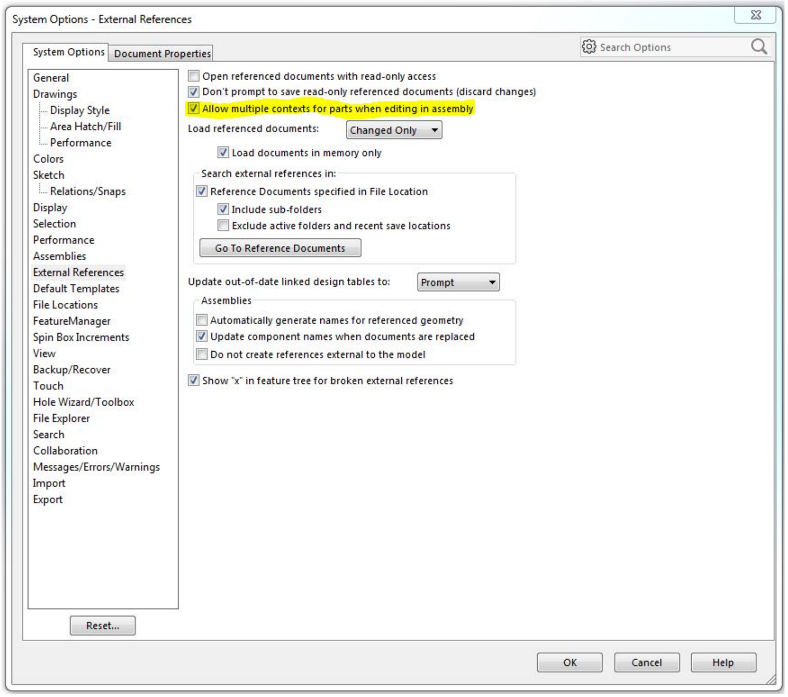

Figure 2.7: Multiple External References System Option

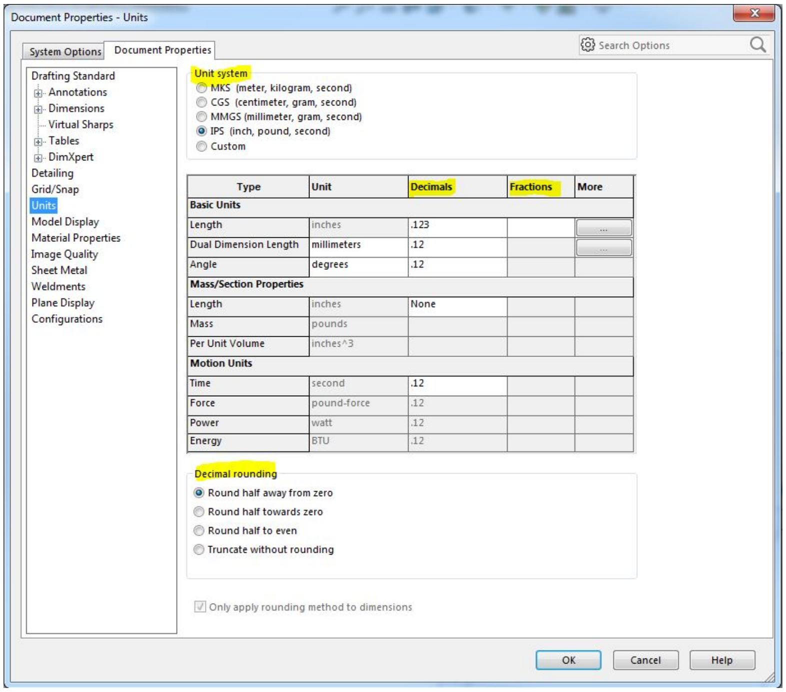

Figure 2.8: Unit System

It may be beneficial to also change the precision of dimensions. This can be done as shown in Figure 2.9. There are many more options in this field and the document properties as a whole. The user should go through and check out each tab to be sure everything is set up correctly before moving on to save the template. In particular "Image Quality" and "DimXpert" can be especially beneficial to set up to make the program look better or run smoother, and save time on the back end.

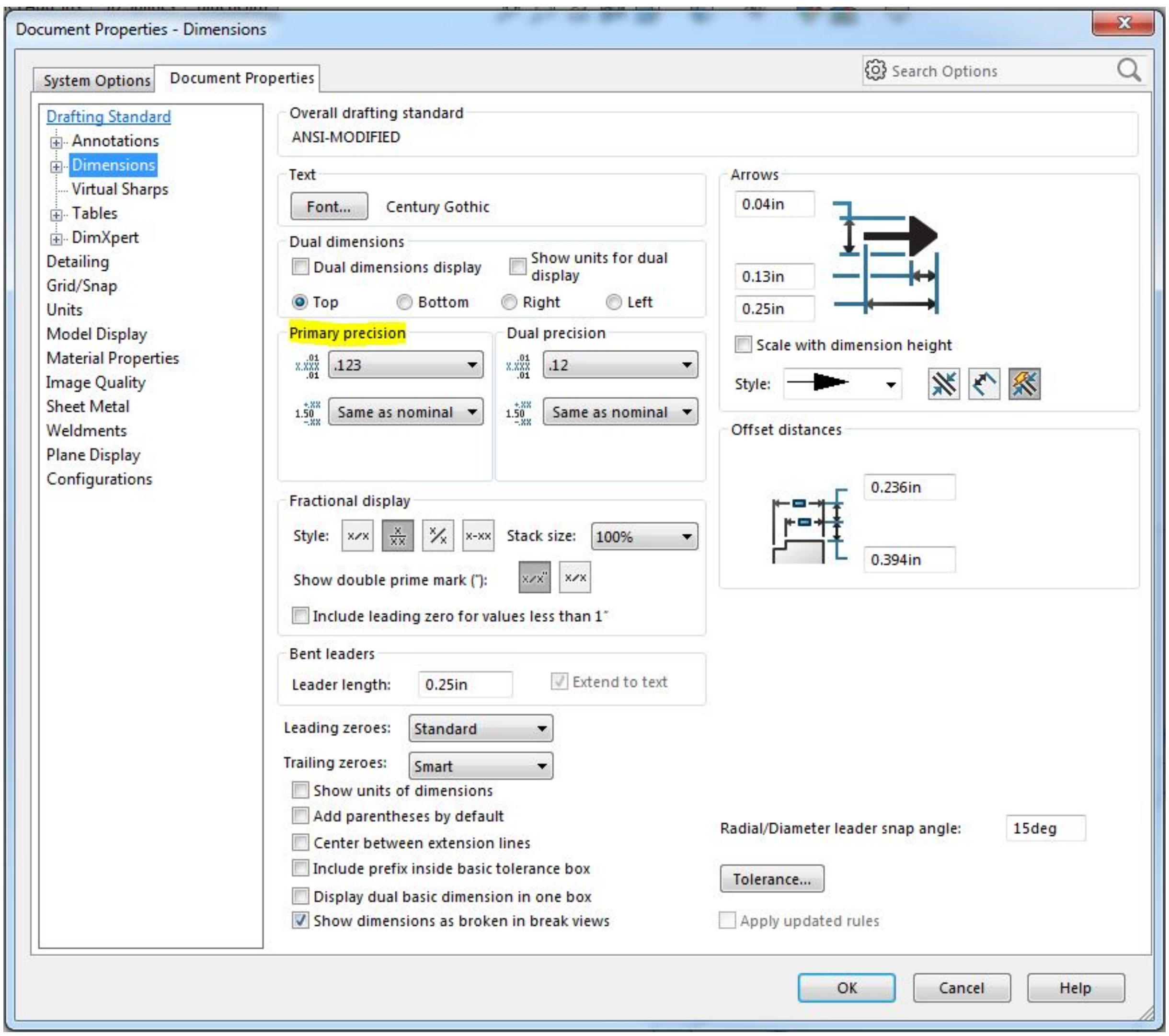

Figure 2.9: Smart Dimension Precision

Once the template is configured properly it must be saved correctly. It must be saved as a template to the file location shown in figure 2.10. Use **File>Save As** and select "Template". This will save the file with a .prtdot file extension (this is just for parts, assemblies will be .asmdot and drawings will be .drwdot). A new folder specific to the project can be created if needed.

Figure 2.10: Template File Location

It may be necessary to configure the system options to show a new templates folder when creating a new part. The location where this can be accomplished is shown in Figure 2.11. This process works the same for assemblies, and it is recommended that the assembly template is the same as the part template, although it is not necessary.

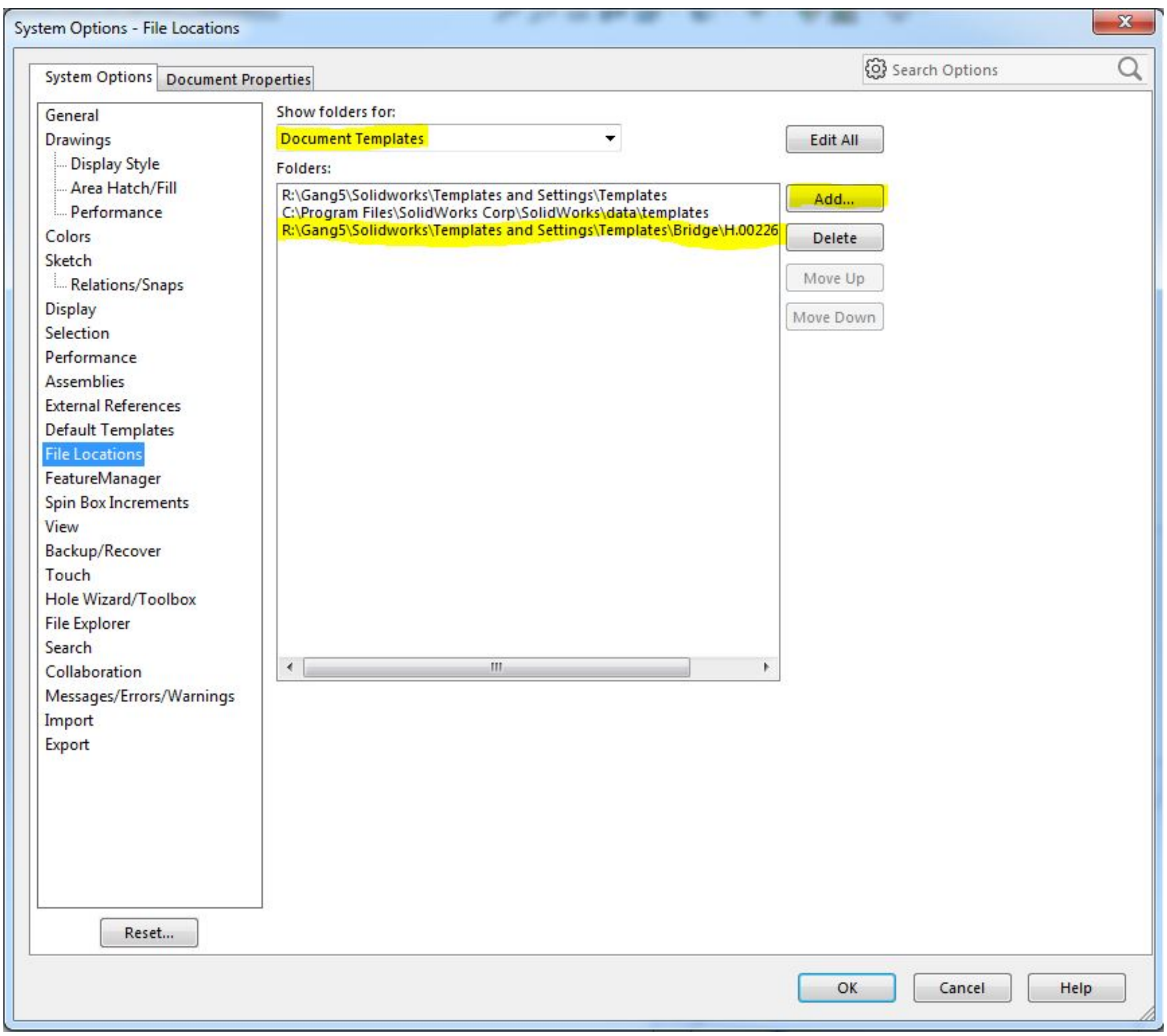

Figure 2.11: Adding Template File Location in System Options

2.2.2 Drawing Formats and Templates

Drawings are a little different from parts and assemblies, not only because they do not have the same overall layout (2D instead of 3D etc.), but because they also have sheet formats that can be edited. Drawing templates are the same as part templates, and follow all the same steps. The only difference is that there may be more information added in the "Custom Properties Tab" as shown in Figure 2.12. The user may also want to change some of the document properties, but the options are the same.

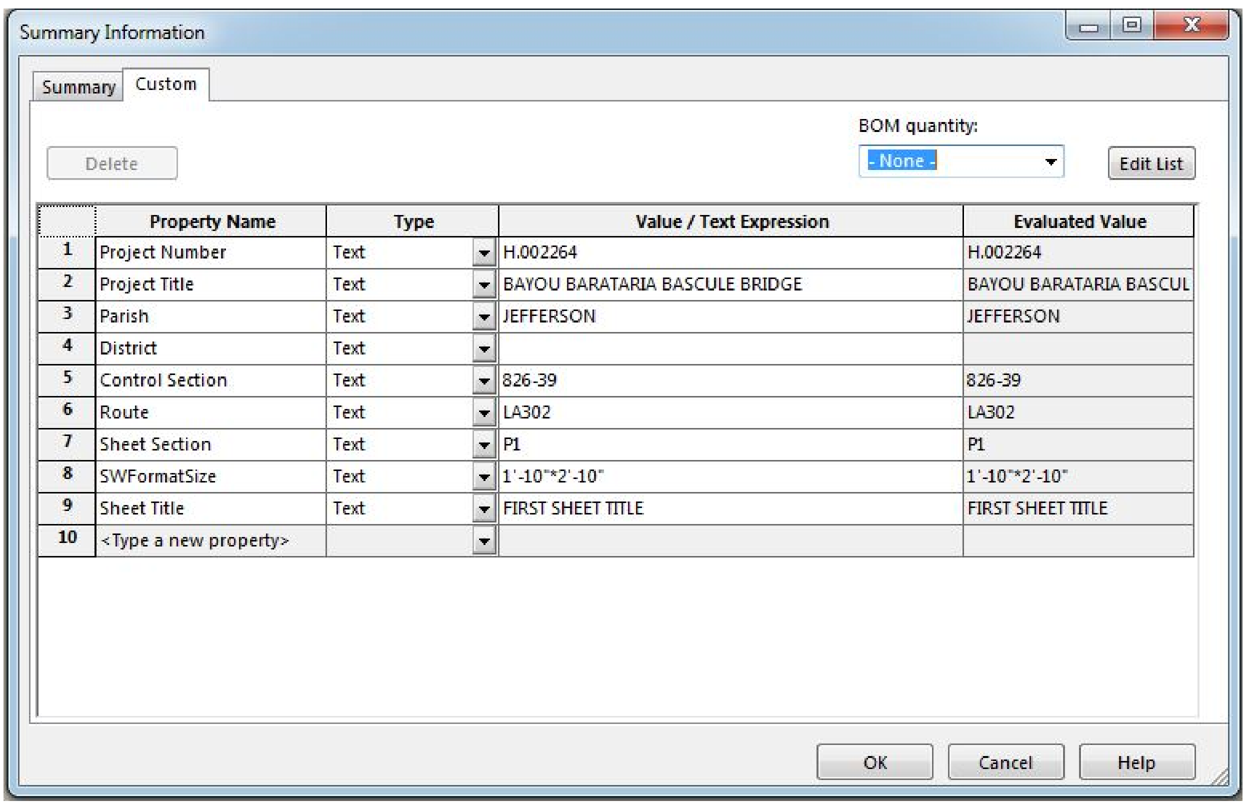

Figure 2.12: Custom Properties Tab For a Drawing

One of the most crucial components of a drawing is the sheet format. The sheet format contains all the general information about the project, such as the title block, borders, logos, and anchors for various tables (BOM, Cutlists, etc.). It would be extremely tedious and improbable to create a sheet format for each drawing, luckily formats can be created and linked to templates. The first step is to open a new blank drawing in the same way as described in Section 2.2.1 (this can be an actual drawing file or drawing template). Select the sheet size by clicking **Edit>Properties** (the sheet must be selected). Figure 2.13 shows what the dialog box should look like.

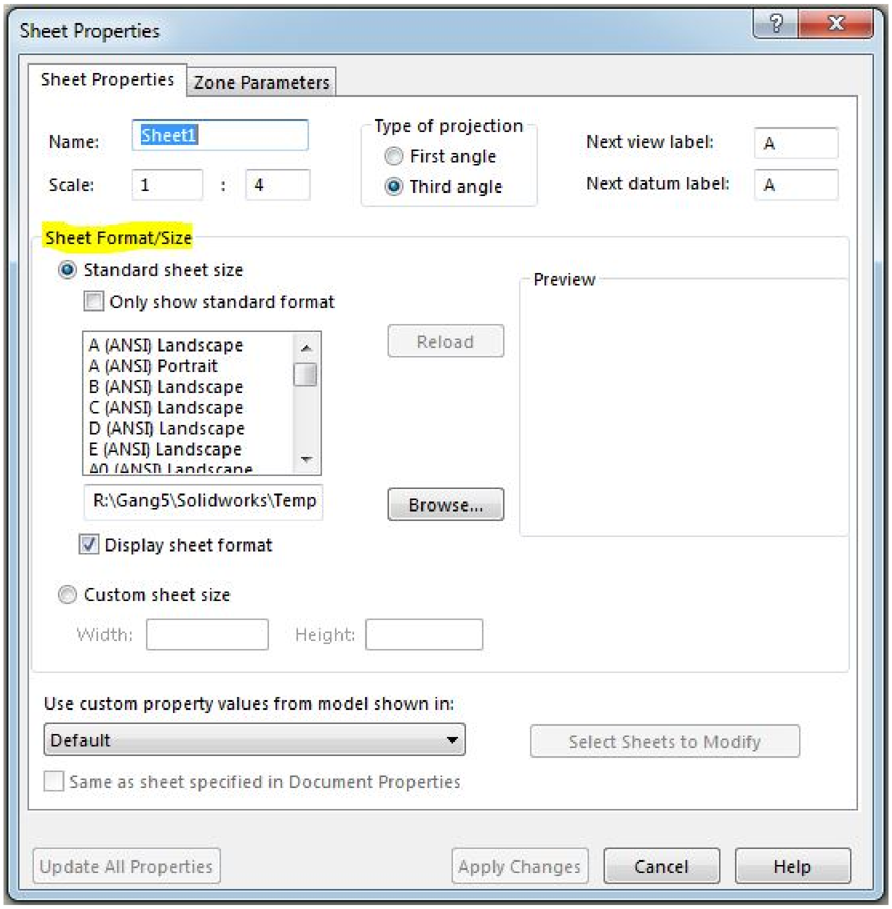

Figure 2.13: Sheet Properties Dialog Box

After choosing and accepting a sheet size the format can be edited. Click **Edit>Sheet Format**, and Solidworks will isolate the format. Now the title block, borders, and anchors can be customized. When finished click **Edit>Sheet** to get back to the drawing. Once the format is satisfactory click **File>Save Sheet Format...**. This will save the file with a .slddrt extension. Once again a file location must be selected, and it is recommended to have a dedicated folder to sheet formats in an easy to find location. Figure 2.14 shows an example location.

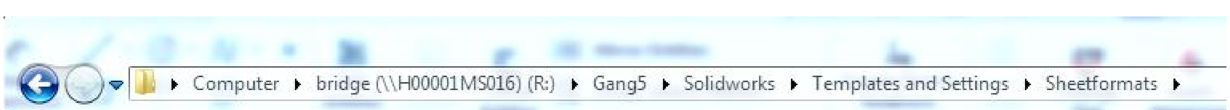

Figure 2.14: Sheet Format File Location

It may be necessary to specify the location in the same way the templates were done. This can be accessed under system options as shown in Figure 2.15.

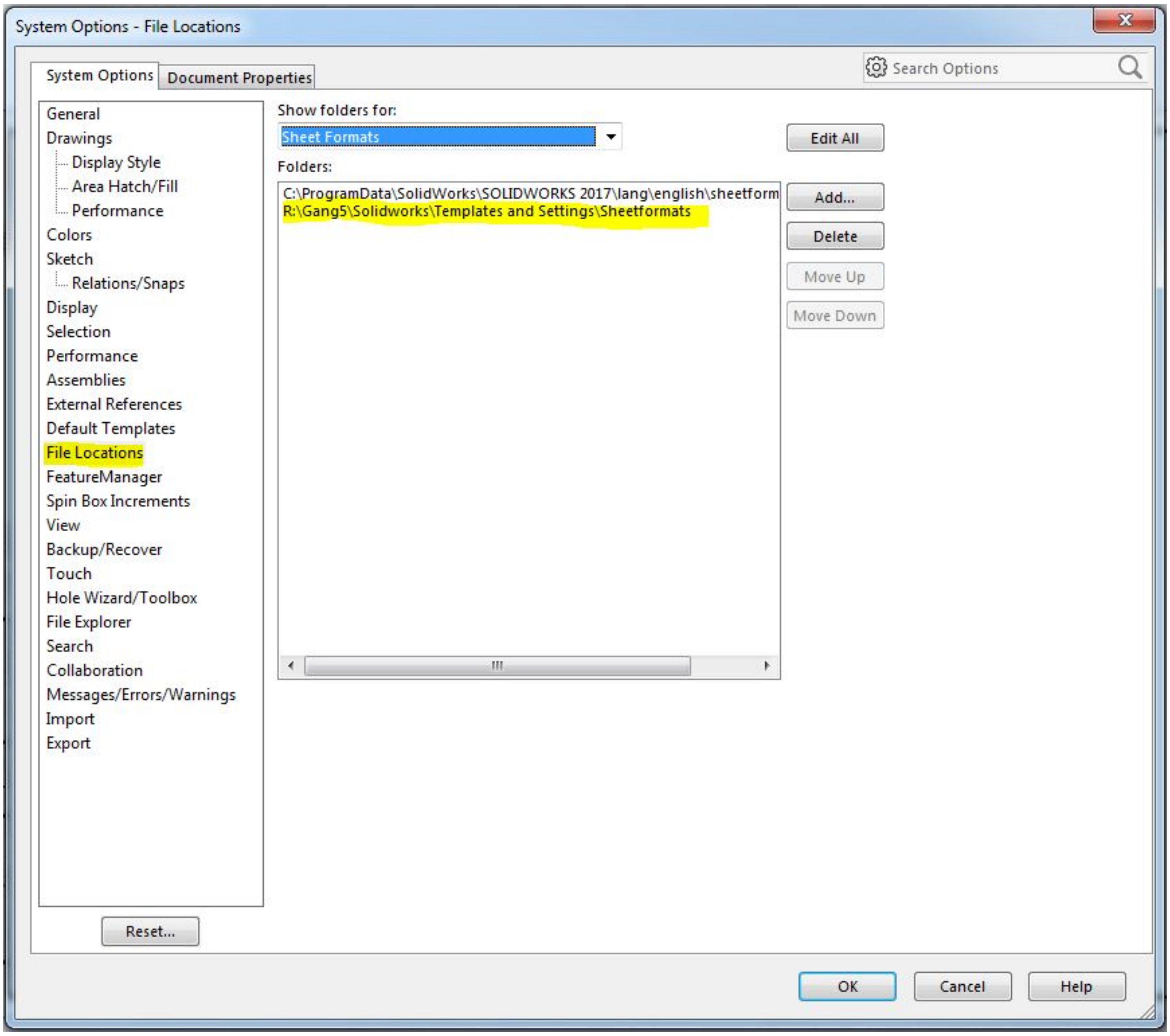

Figure 2.15: Adding Sheet Format File Location in System Options

The final step is to link the sheet format with the drawing template. Return to the sheet properties tab (Figure 2.13) and click the "Browse..." button under the "Sheet Format/Size" heading and select the desired format. Once finished editing all the properties save the file as a template in the same way as in Section 2.2.1.

2.3 Numbering Parts

Before proceeding, a file naming convention should be established to make it easier to find assemblies by discipline. We have 4 major disciplines that work on movable bridges, structural, mechanical, electrical and architectural. Therefore, it is broken down by disciplines in Table 2.1. This will also prevent parts with the same names from different projects from interfering, as well as enabling the reuse of parts. This list will change for each different type of bridge, and even different bridges of the same type that use different drive methods.

Filename Prefix	Section
H.XXXXXX-00-	Bridge Assembly
H.XXXXXX-S1-	Piers and Piles
H.XXXXXX-S2-	Towers
H.XXXXXX-S3-	Movable Span
H.XXXXXX-S4-	Approaches
H.XXXXXX-M1-	Turned Bolts
H.XXXXXX-M2-	Span Drive Machinery
H.XXXXXX-M3-	Rack and Pinion Assembly
H.XXXXXX-M4-	Trunnion Assembly
H.XXXXXX-M5-	Span Lock Assembly
H.XXXXXX-M6-	Buffer Assembly
H.XXXXXX-M7-	Limit Switch Assembly
H.XXXXXX-M8-	Movable Parking Barrier Assembly
H.XXXXXX-A1-	Operator's House Assembly
H.XXXXXX-A2-	Operator's House Structure
H.XXXXXX-A3-	Operator's House Openings
H.XXXXXX-A4-	Operator's House Storefront
H.XXXXXX-A5-	Operator's House Guardrails
H.XXXXXX-A6-	Operator's House Roofing System
H.XXXXXX-A7-	Operator's House Mechanical
H.XXXXXX-A8-	Operator's House Electrical
H.XXXXXX-E1-	Electrical Assembly
H.XXXXXX-E2-	Electrical Boxes
H.XXXXXX-E3-	Electrical Conduit

Table 2.1: File Naming Convention For Barataria Bascule

2.4 Organization

When modeling large assemblies using any method in Solidworks organization is key. The number of parts can easily reach into the thousands. Using the SSP method the number of parts won't really change, but there will be a much larger number of sketches and planes in one single SSP part. This means a user must be extremely organized from the beginning. The first steps are to design a hierarchy as described in Section 1.3, and a robust part numbering system as descried in Section 2.3. This section is dedicated to any other techniques that can be used to stay organized.

The most obvious way to organize a master assembly is to break it down into multiple sub-assemblies. In a way a lot of the legwork is done when developing the hierarchy, but there may be too many sub-assemblies to feasibly include them all in that hierarchy. It may be useful to compose a hierarchy for individual sub-assemblies listed at the bottom of the master hierarchy. At a certain point it may not be as practical to keep creating sub-assemblies, and folders should be used.

Creating a new folder in Solidwork's design tree is very easy and useful. They can be used to group anything together. For example a collection of sketches in SSP can be grouped together, or a group of parts in an assembly, or even features in a part. This could save the time of having to name all the features of a part, and instead just name the folder. To create a folder just right-click the part or parts you want to go in the folder and click "New Folder" as shown in Figure 2.16.

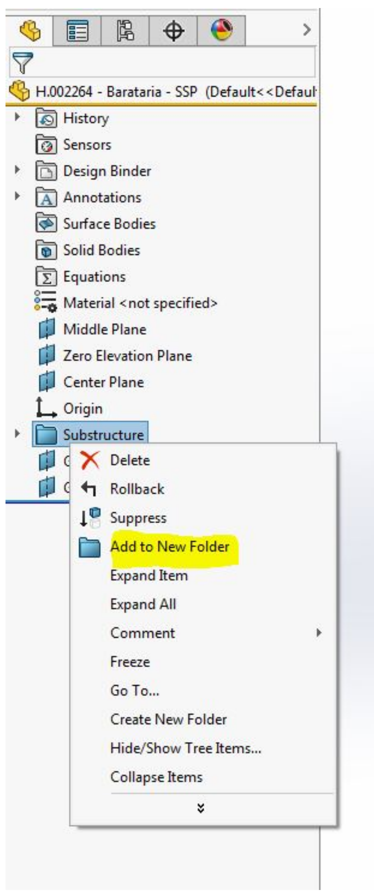

Figure 2.16: Adding a New Folder

Past organizing groups of entities into folders, it will become necessary to organize the information inside the folders. This can easily be accomplished by renaming the sketches. The names should relay the information about what the sketch is controlling and its purpose. This concept should also be applied to the dimensions, especially those that control information that propagates to other sketches, and those that may be subject to occasional changes. Another effective organizational tool at this level is to change sketch colors. This is a great visual tool when there are multiple sketches in one compact area. To change the color of a sketch right click the sketch in the design tree, and there should be a "Sketch Color" option. Note that this might not be available while the sketch is being edited, and must be done while editing the part that contains the sketch. It may not be possible to change the colors while editing the part in an assembly either. This is shown in Figure 2.17.

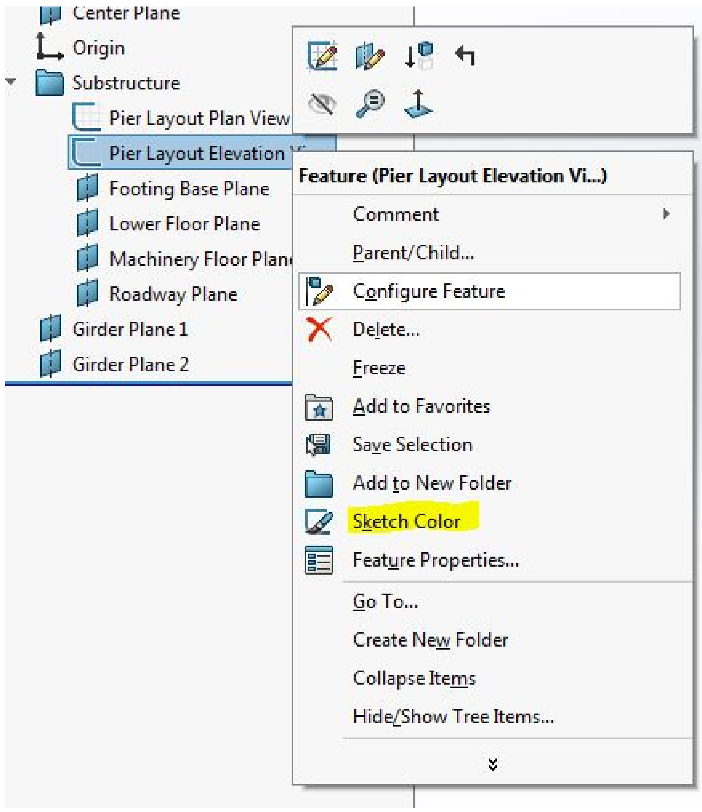

Figure 2.17: Changing Sketch Color

Some sketch colors should be avoided though. Blue is a poor choice because Solidworks uses blue by default to show under defined sketches. Dark or light blue should be fine, but in general it's best to stay away from any hue close to that recognizable Solidworks sketch blue. Gray and black should also be avoided as these colors represent a sketch being edited by default. These default colors can be changed in the system options referred to in Section 2.2.1.

Following these guidelines should make the drawing and assembling processes much easier and quicker.

Chapter 3

Modeling

3.1 Overview

Now that all the legwork is done, the actual drawing can begin! This chapter will walk through the process to develop a large assembly using an SSP. A precise process has been developed by the original pioneers of this method. This has cut down on most problems with SSP method, and has created very robust models. This process and the SSP itself will need to be discussed in detail, along with the concept of zones and their benefits. Finally all this upfront work will begin to pay off as the procedure for inserting parts is discussed. Just like with the rest of this method there is a finely honed series of steps that must be learned, but once it becomes second nature this method will become faster and more robust than bottom-up modeling methods.

3.2 The SSP

It has probably become pretty obvious that the Skeleton Sketch Part is the heart of this whole modeling technique. The main SSP will be at the top of the design tree for the main assembly with the next level sub-assembly SSPs within. It will drive at least one dimension in every subsequent sketch. Figure 3.1 shows where the highlighted SSP is located in the design tree of the main assembly.

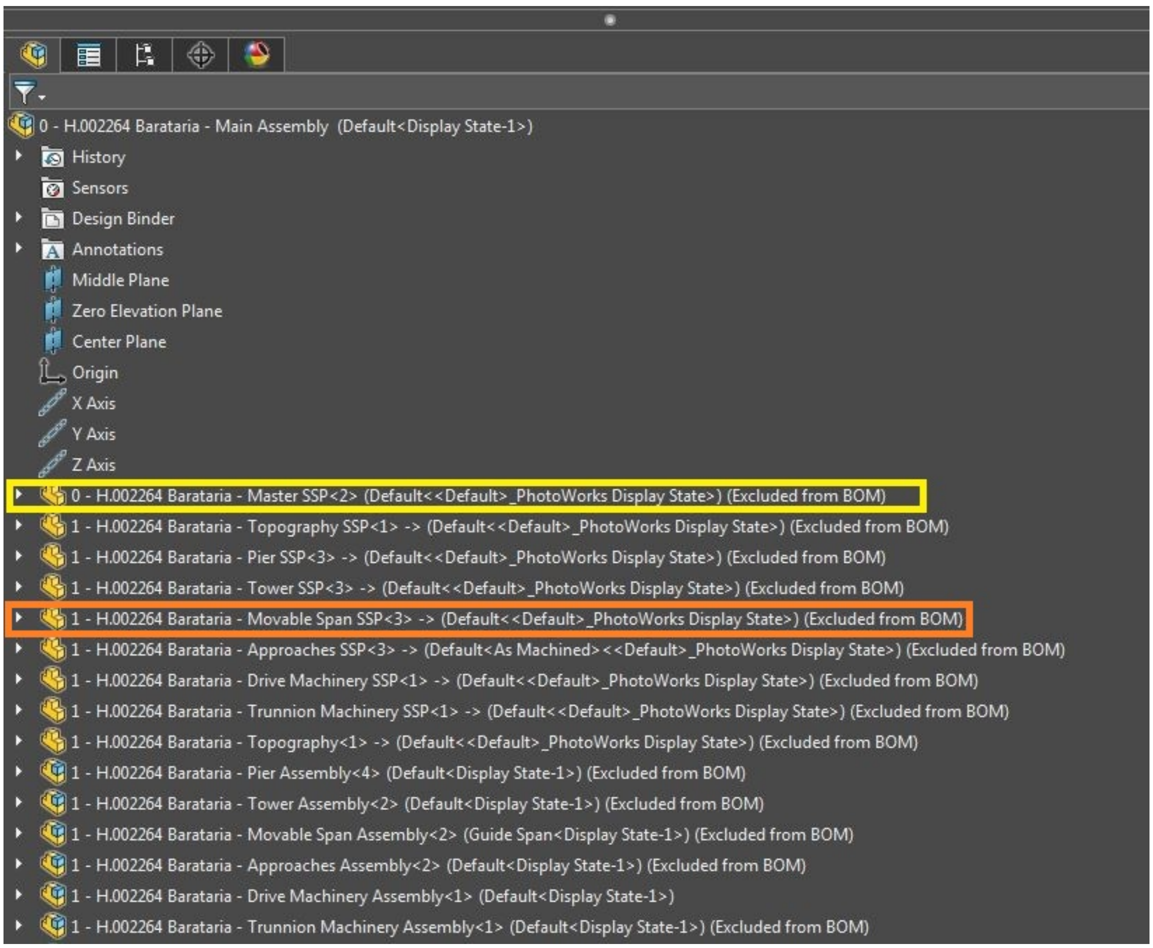

Figure 3.1: Design Tree

In the end there will be multiple SSPs at many different levels. Each SSP should only propagate information to the sub-assemblies' SSPs directly below it. This was briefly discussed in Section 1.3, and is an important concept to keep the sketches simple and flexible. When trying to plan what should go into an SSP the designer must figure out what information will need to be propagated to the next level. The key here is to keep the SSPs minimal with sketches and dimensions labeled and organized. It is also worth noting that no part should be referencing another non-SSP part if possible. Also an SSP is not necessary if there is only one part referencing it. Figure 3.2 shows an expanded design tree. Notice the numbers at the beginning of each part and assembly. The numbers help keep track of where each part belongs. There should never be a lower number part inside a higher number assembly except for the main SSP for that assembly (e.g. Movable Span SSP in the Movable Span Assembly).

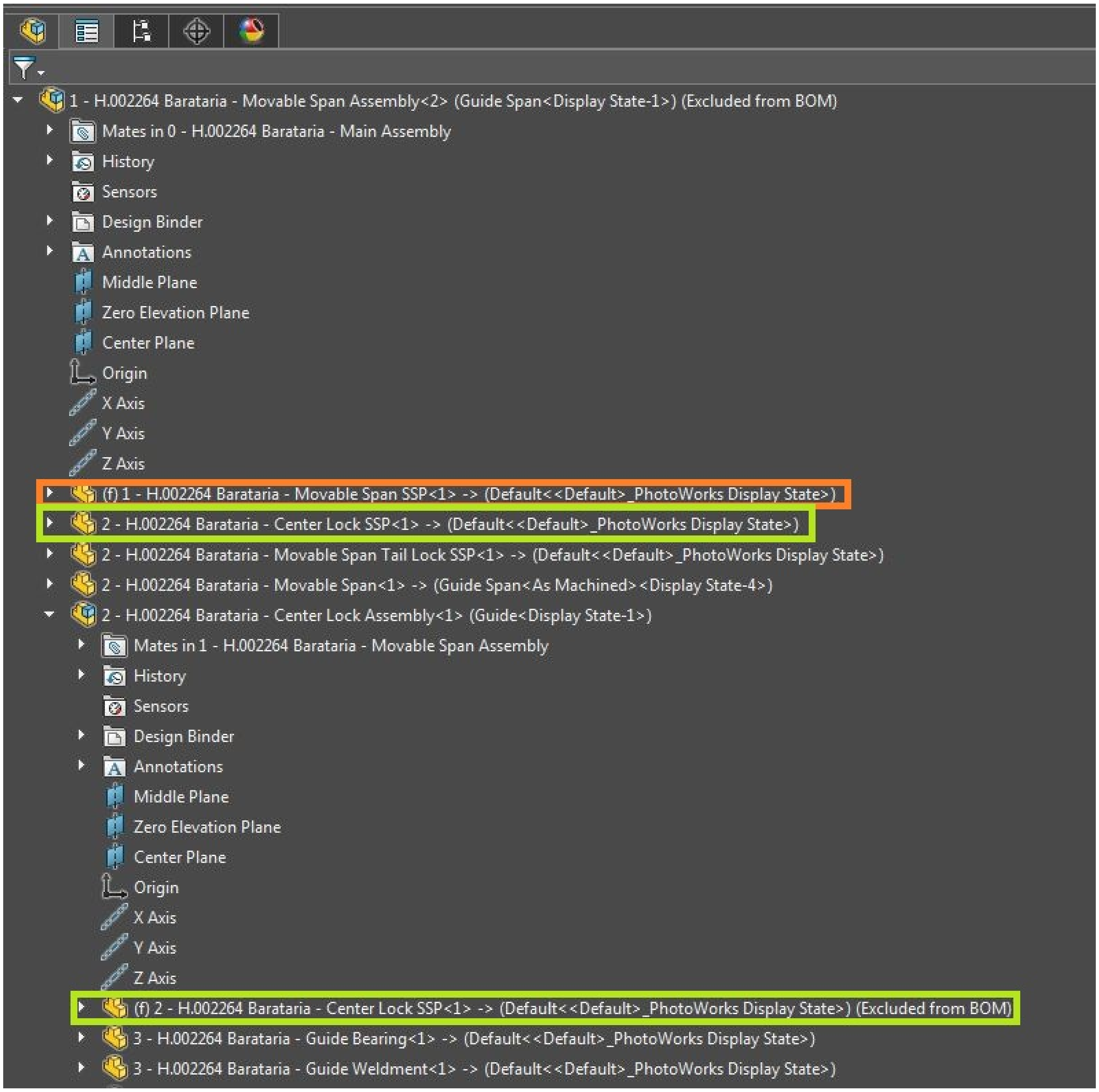

Figure 3.2: Expanded Design Tree

For a bascule bridge, the main SSP will be directly above the Pier, Tower, Movable Span, Drive Machinery, Trunnion Machinery, and Approaches SSPs. The most minimal amount of information that could be put in the main SSP would be just the center distance from the centerline of the channel to the centerline of the pier. There is almost no limit to the maximum amount of information you could put in, but to allow for effective control and simplicity at the top level a compromise must be made. This may lead to including the tower footprint, the tower height, floor/cross section change heights, and main girder separation. The end result is a very simple sketch with a high level of influence on the model.

When starting a new project it's always a good idea to create the top level sub-assemblies and SSP and combine them in the master assembly. Start by creating the master assembly, and then inserting a "New" part and save it as the SSP. Figure out how many sub-assemblies will be directly below the main assembly, and create these sub-assemblies with the SSP inserted using an origin coincident mate. Finally insert the sub-assemblies into the master assembly using the same origin coincident mate. Now the SSP can be opened and the sketches will propagate to all assemblies.

3.3 Zones

In large assemblies it may be very beneficial to create separate zones to work in. These zones can define a certain region of the design, such as different floors, or they can be equally partitioned from the main assembly into quadrants or grids. These zones can each have their own SSP, but each assembly must still contain all SSPs from each zone. Using zones can keep the sketches organized and allow work to be done in different regions at the same time. To reduce dependency of zones, they should only be connected to adjacent zones by their boundaries.

3.4 Inserting a Part and Deriving Sketches

Once the SSP has been developed significantly, the parts will need to start being created. It is important to follow the method laid out in this section for inserting new parts. It will insure that the proper relations are preserved, and the part is inserted how the user would expect. To begin open the sub-assembly that the part will be located in (for example the tower would be in the structural sub-assembly). Click **Insert>New Part** and save the part file (there is an option in the settings to make Solidworks prompt the user to save new parts when they're inserted into assemblies). Solidworks will then wait for the user to select a plane to begin sketching the new part, **always** choose the same plane of the assembly/sub-assembly for every part/SSP. I always choose the Middle Plane (or Front Plane) for my models. Then immediately close that sketch. Doing this keeps all the parts/SSPs origins, axes, and planes aligned with the main assembly. Now right click on the SSP in the design tree, and click "Isolate" as shown in Figure 3.3.

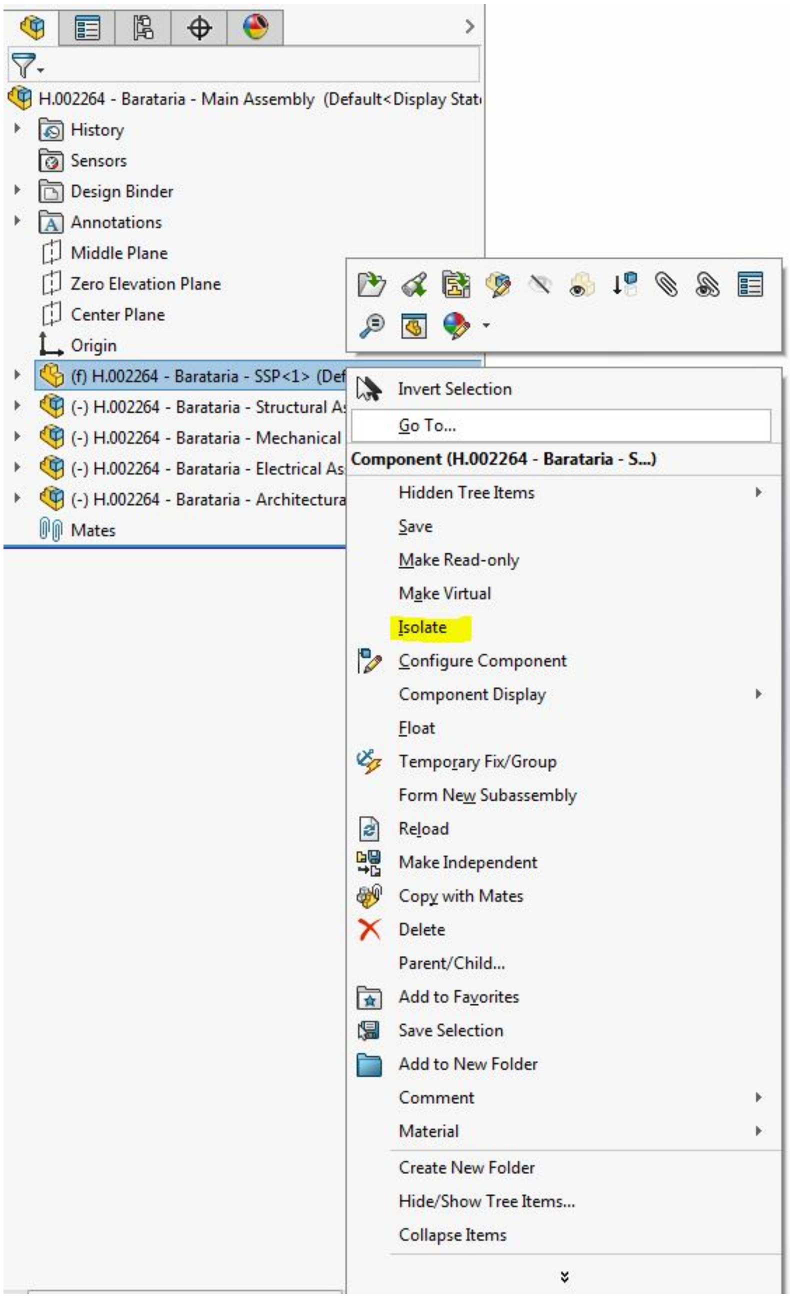

Figure 3.3: Isolating the SSP

Now select the plane the part will be made from, and holding the "Ctrl" key select the proper sketch from the SSP that will be used to make the part. Click **Insert>Derived Sketch** (shown in Figure 3.4) and a copy of the original sketch will be created on the selected plane. Any changes to the original sketch will be applied to the derived sketch. It is possible to use the "Convert Entities" command, but it doesn't create as strong of a relationship as the "Derive Sketch" command.

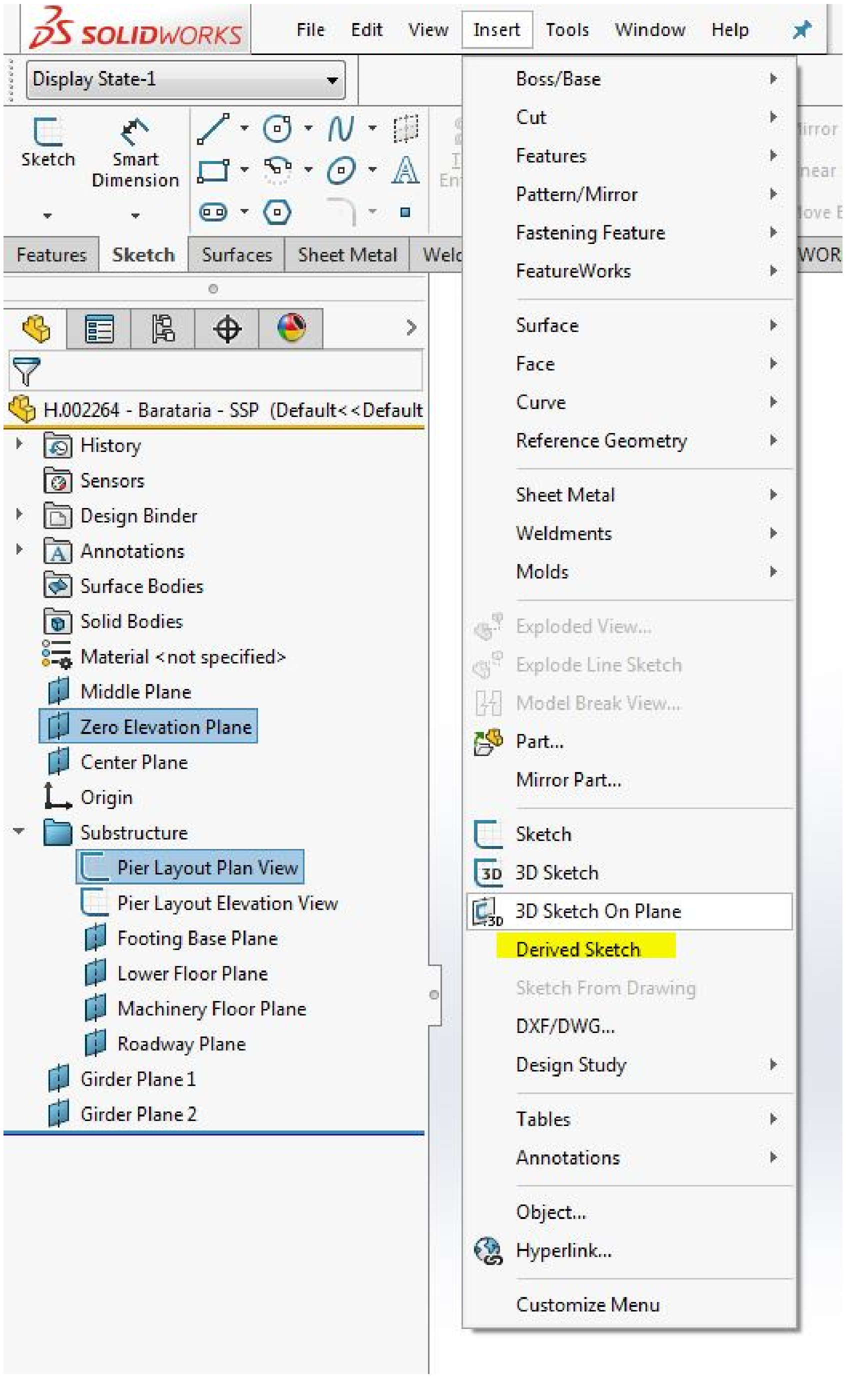

Figure 3.4: Deriving a Sketch

Once the sketch in the new part has been completed use various features to create the solid bodies of the part. The features should use parts of the sketch to define itself. For example, instead of extruding a set distance, there should be a vertex or plane at the beginning and end of the desired extrusion path. Use the from vertex/plane up to vertex/plane commands as shown in Figure 3.5. Using the sketches as controls for the features will allow the parts to change any time the SSP is modified. This means that almost all changes can be done from the SSP and will propagate to all other assemblies and parts.

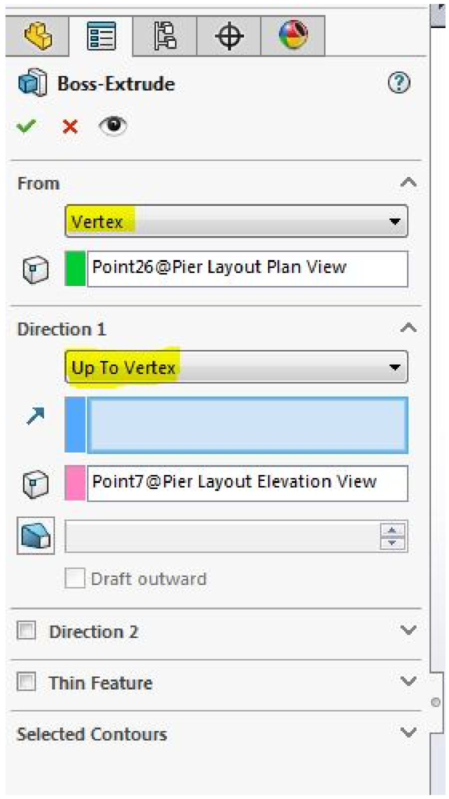

Figure 3.5: Extruding a Part

It is worth noting that when taking advantage of symmetry, use the "Mirror Features" command instead of "Mirror Sketch" command. Mirrored sketches aren't as robust as mirrored features. A mirrored sketch won't show up in the design tree, and it'll be harder to tell what entities were mirrored if the need to edit the sketch arises. Doing this will also reduce the overall amount of sketches that'll clutter the model.

3.5 Tips, Best Practices, and Warnings

To be developed...

Chapter 4

Barataria Walk-Through

4.1 Overview

In order to properly explain and document the SSP process, the design of the Bayou Barataria Double Leaf Bascule Bridge will be explained step by step. The process will be documented in the same way this document is laid out, starting with scope and flow and ending with the creation of the whole assembly. Much of this work has already been shown as examples in the preceding sections, but everything will be reiterated in this chapter.

4.2 Scope and Flow

The Barataria Bridge will be a double leaf, semi-high level, bascule bridge. The majority of the structural components haven't been designed at the writing of this document. Thus the model will have to have a large amount of flexibility. Luckily the bridge is being based off the previously designed Louisa Double Leaf Bascule Bridge, so we have a solid starting point. For the most part the bridge will be symmetrical about the centerlines of the channel and the tower, so we can get away with modeling a quarter section of the bridge.

The hierarchy will be the same as the example given in Section 1.3 (shown below in Figure 4.1). The structural components are at the beginning of the hierarchy (shown in orange) starting with the Pier Assembly. Below the pier are the rest of the structural components, and then the mechanical and electrical parts after. The different engineering domains are shown in different colors. The first parts to be made will be the piers then towers and all the components affiliated with them.

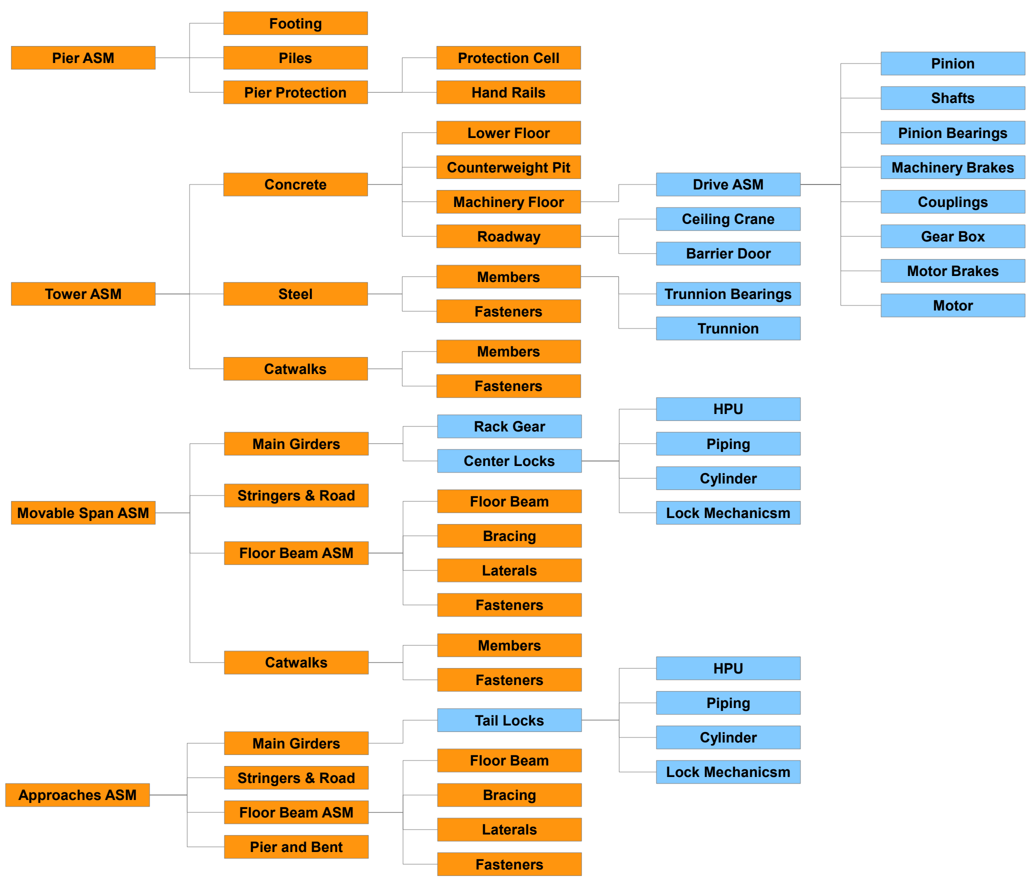

Figure 4.1: Barataria Hierarchy

4.3 Templates and Organization

Part, assembly, and drawing templates have been developed for Barataria. In the part and assembly templates the project information has been added, and the original planes were renamed as shown in Figure 4.2. This is really all that has been done to the templates, as there are not many other components that will be universal to the whole assembly.

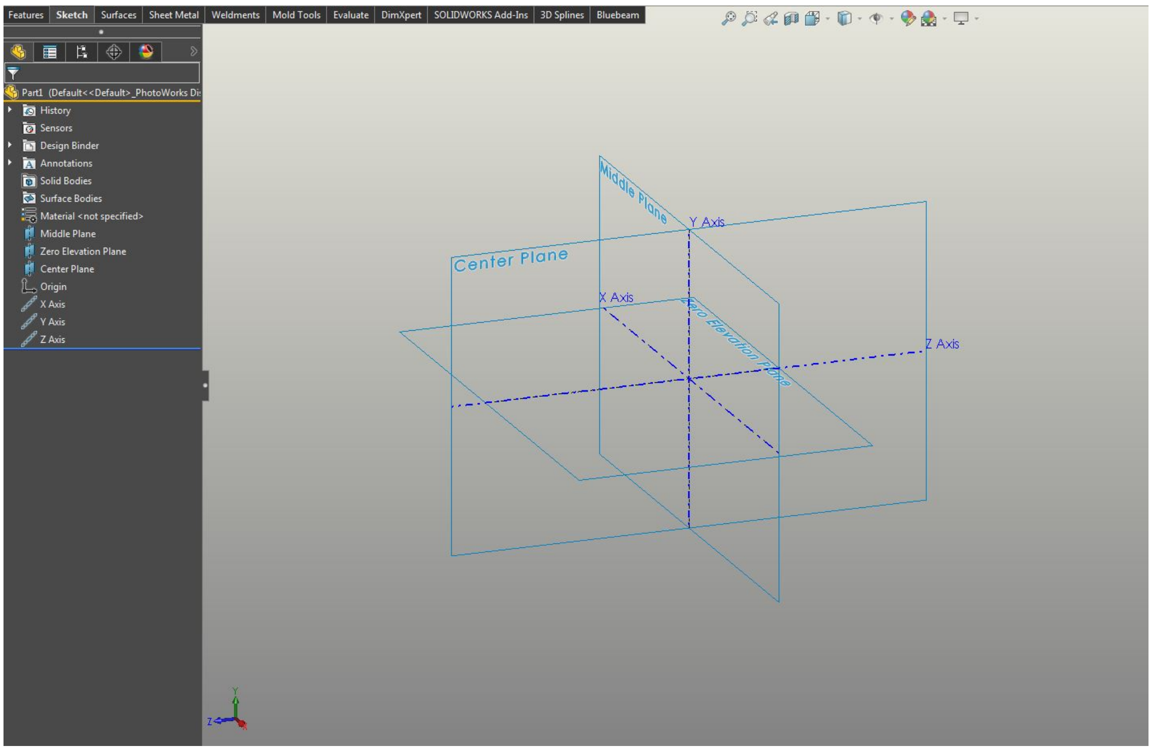

Figure 4.2: Barataria Part/Assembly Template

The drawing template contains the project information, as well as the standard title block we use. The information that will be universal to all drawings in the title block has also been filled out. The important info is shown in Figure 4.3. Note that this is only a part of the title block and doesn't include the revisions section.

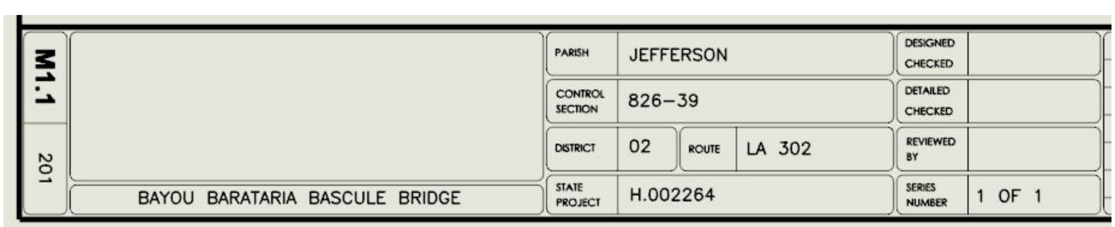

Figure 4.3: Barataria Drawing Template

The same naming convention from Section 2.3 will be used for this project. Table 4.1 shows the names of the parts. Special attention should be given to the structural and mechanical components. Notice the different prefix numbers. The higher numbers are nested in the lower numbered assembly above them.

Filename Prefix	File Name
0 - H.002264 Barataria -	Main Assembly
1 - H.002264 Barataria -	Pier Assembly
1 - H.002264 Barataria -	Tower Assembly
2 - H.002264 Barataria -	Movable Parking Barrier Assembly
1 - H.002264 Barataria -	Movable Span Assembly
2 - H.002264 Barataria -	Center Lock Assembly
2 - H.002264 Barataria -	Movable Span Tail Lock Assembly
1 - H.002264 Barataria -	Approaches Assembly
2 - H.002264 Barataria -	Approach Tail Lock Assembly
1 - H.002264 Barataria -	Drive Machinery Assembly
2 - H.002264 Barataria -	Drive Machinery Electrical Assembly
1 - H.002264 Barataria -	Trunnion Machinery Assembly
2 - H.002264 Barataria -	Span Limit Switch Assembly
1 - H.002264 Barataria -	Operator's House Assembly

Table 4.1: File Naming Convention For Barataria Bascule

4.4 Modeling

4.4.1 Master SSP

After creating the SSP, the main assembly, the first level sub-assemblies, and following the process laid out in Section 3.2, we can begin to draw. The first sketch will be on the "Zero Elevation Plane" and it will consist of the overall footprint of the tower, the distance from the center line of the channel, and the distance between main girders. The sketch is shown in Figure 4.4. There will be another tower opposite the channel centerline, but it is unnecessary to draw because we will take advantage of symmetry later.

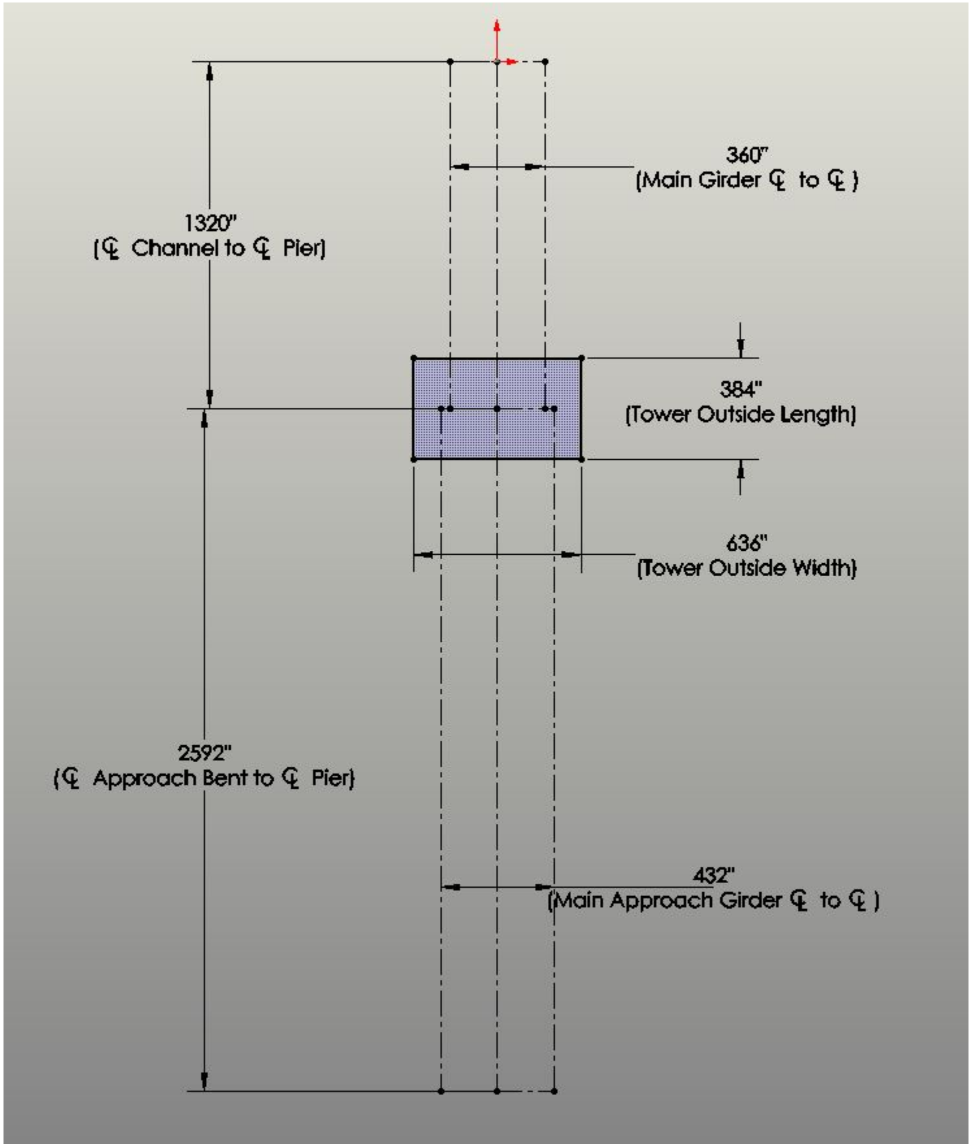

Figure 4.4: Tower Plan View

The next step will be to draw the elevation view for the tower on the "Center Plane". This will consist of a simple line extending above and below the "Zero Elevation Plane". Along the line are multiple key points that represent a different elevation or thickness of different parts of the tower. Shown in Figure 4.5, the elevation dimensions can be seen on the left hand side. These are taken from the "Zero Elevation Plane". On the right side of the image are the thickness dimensions taken between two points along the line. This may seem simple, but the sketch contains a lot of information.

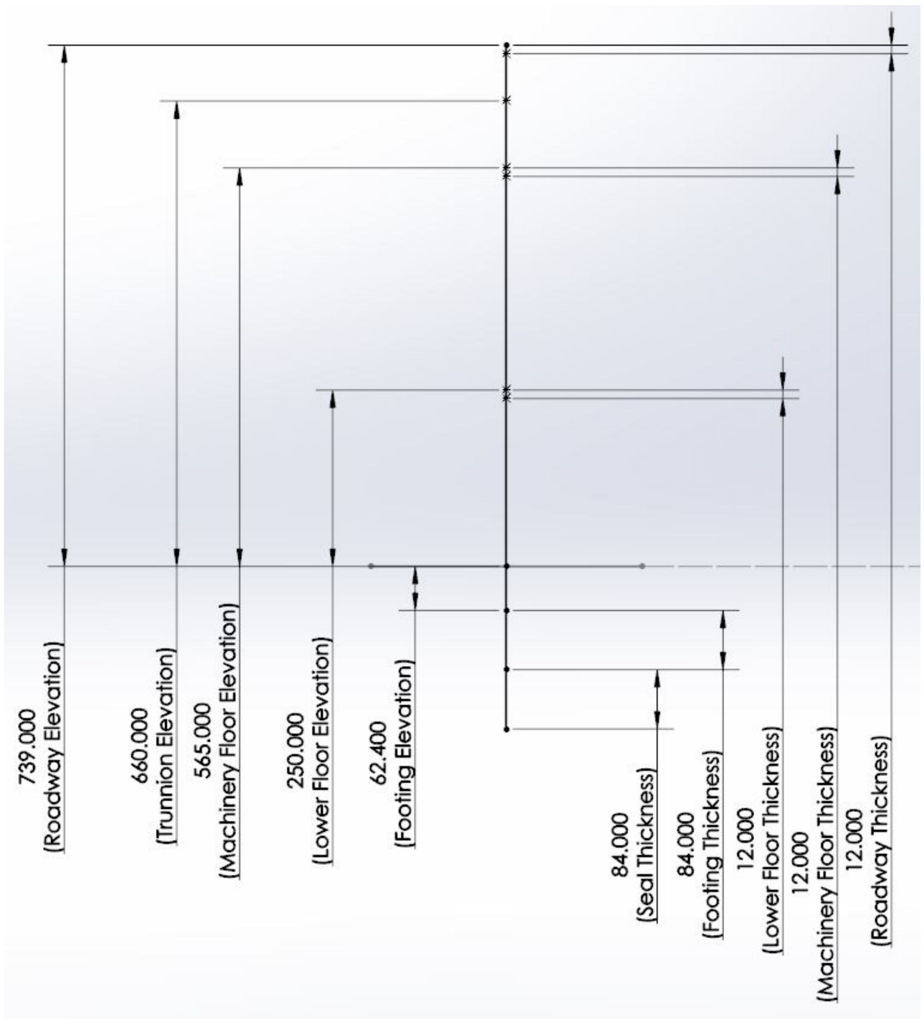

Figure 4.5: Tower Elevation View

This concludes all the information that will be included in the master SSP. Now we save everything and all of the sub-assemblies should include this information.

4.4.2 Structural Components

For the structural assembly we will have 4 main SSPs, the tower, the pier, the movable span, and the approaches. First we will go into the structural sub-assembly and insert the master SSP as described in Section 3.2. We will go ahead and add the 3 sub-assemblies and the 1 part according to Section 3.4. Don't forget that the main SSP should be in the structural assembly at the top of the design tree. The pier is the easiest to do, so we will start with this and leave the others blank for now.

Pier

To start we open the pier assembly that was created in the last step. We need to create a pier SSP part inside the pier assembly first. Now we must repeat the same process as before, and insert all the components that will be found in this assembly. This includes the footing, fenders, and the piles. For the next step it may be necessary to open the structural assembly. We select the "Zero Elevation Plane" and the Tower Plan View sketch to make a derived sketch. Now that the derived sketch is inside the part's design tree we can exit sketch and start a new one on the same plane. We then draw the footing and seal with reference to the derived sketch. This is shown in Figure 4.6, notice that it is only a sketch of half the footing because we plan to use symmetry later.

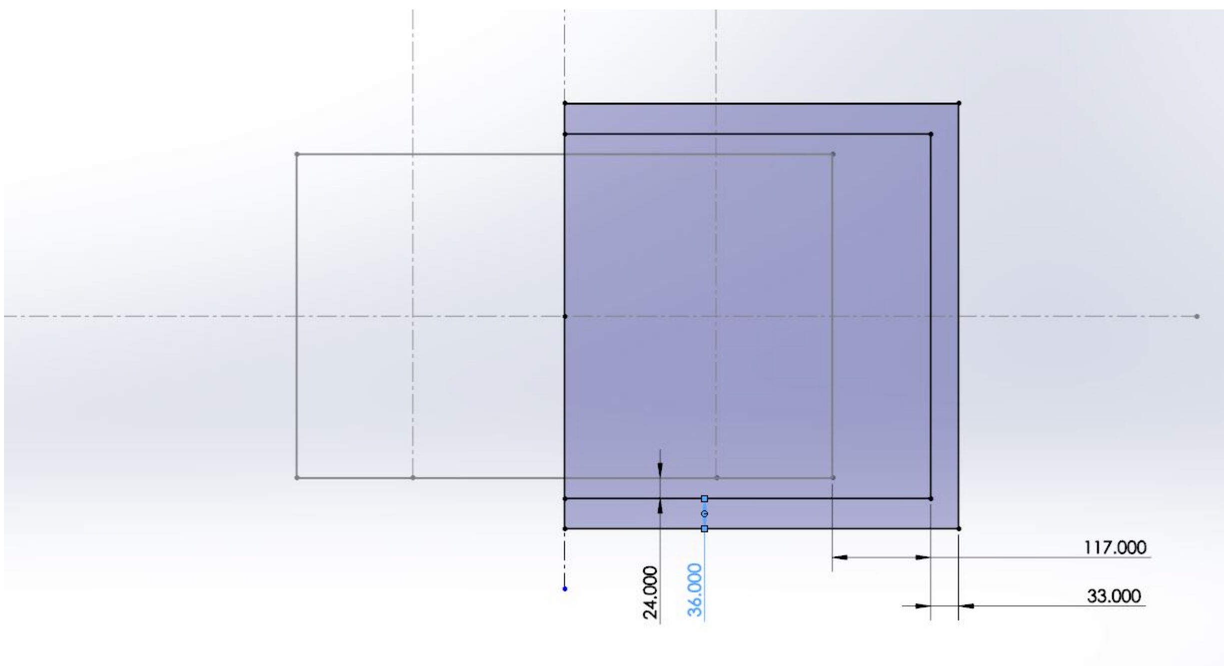

Figure 4.6: Seal and Footing Sketch

Now we will use this sketch and the Tower Elevation sketch to extrude the footing and seal. We select the entire enclosed region for the seal and extrude from the bottom vertex (seal elevation) to the next vertex (seal thickness). A similar action will be taken to create the footing. Both of these features can be seen in Figures 4.7 and 4.8. These two features will then be mirrored across the "Center Plane" to complete the footing. The final result is shown in Figure 4.9.

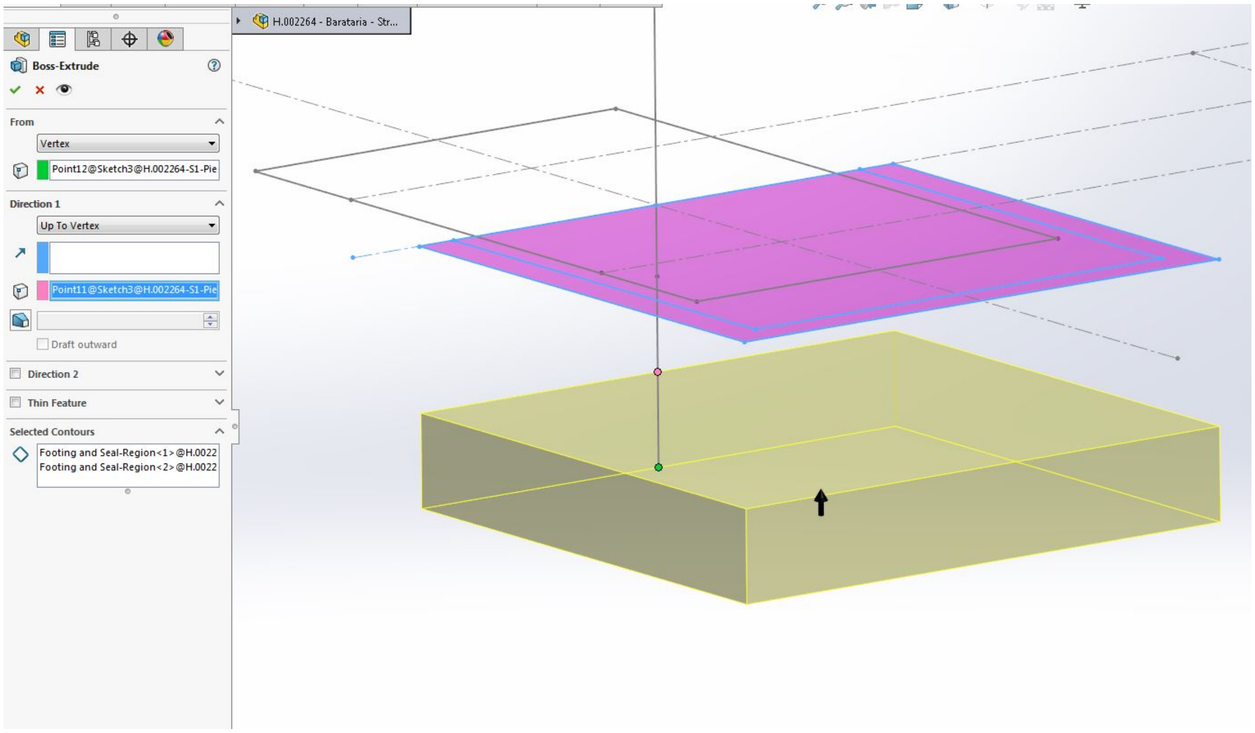

Figure 4.7: Seal Extrusion

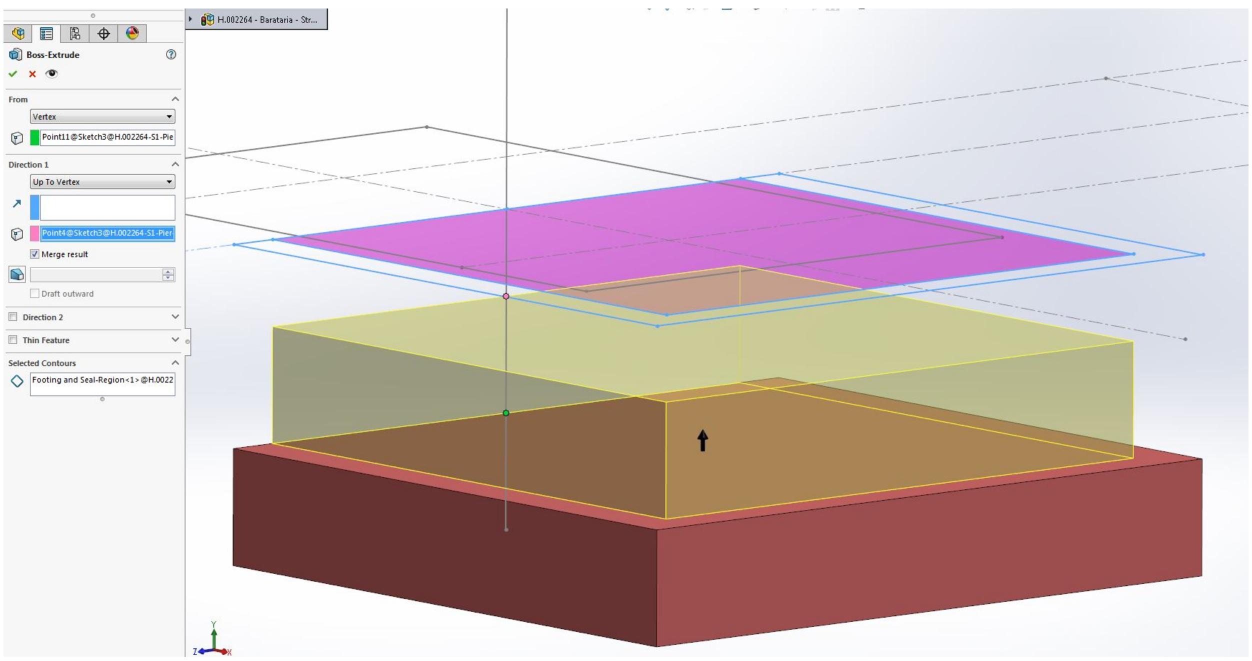

Figure 4.8: Footing Extrusion

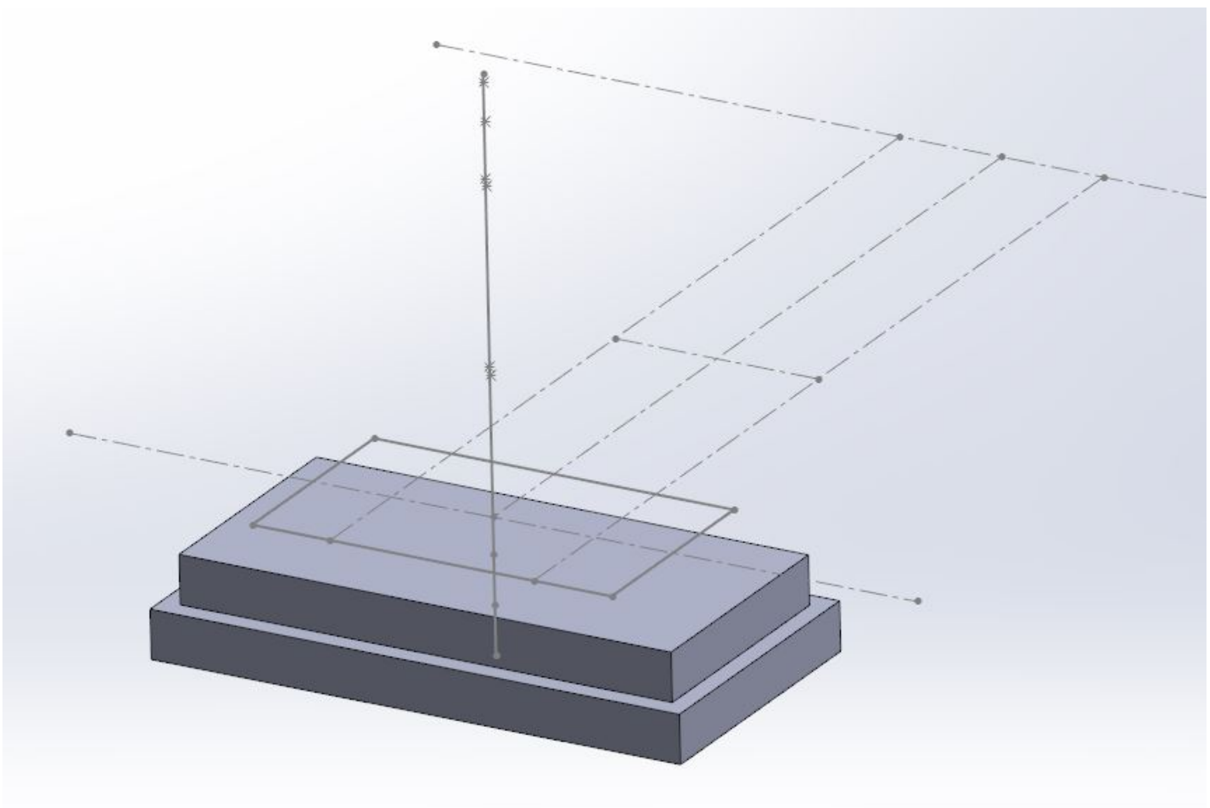

Figure 4.9: Seal and Footing Part

A similar approach will be taken for the pier protection (also called a fender). The plan view will be sketched out and be based off of the derived sketch from the master SSP. The sketch will be done in the pier SSP then a derived sketch will be created from the pier SSP to the fender part. Then the sketch is extruded and mirrored just as before. The results are shown in Figure 4.10 to Figure 4.12.

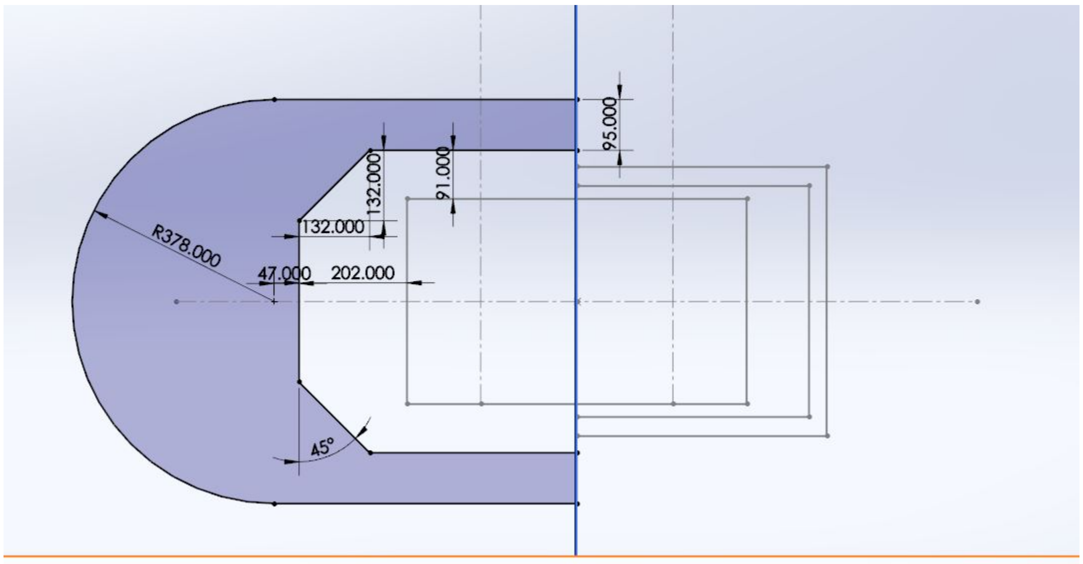

Figure 4.10: Pier Protection

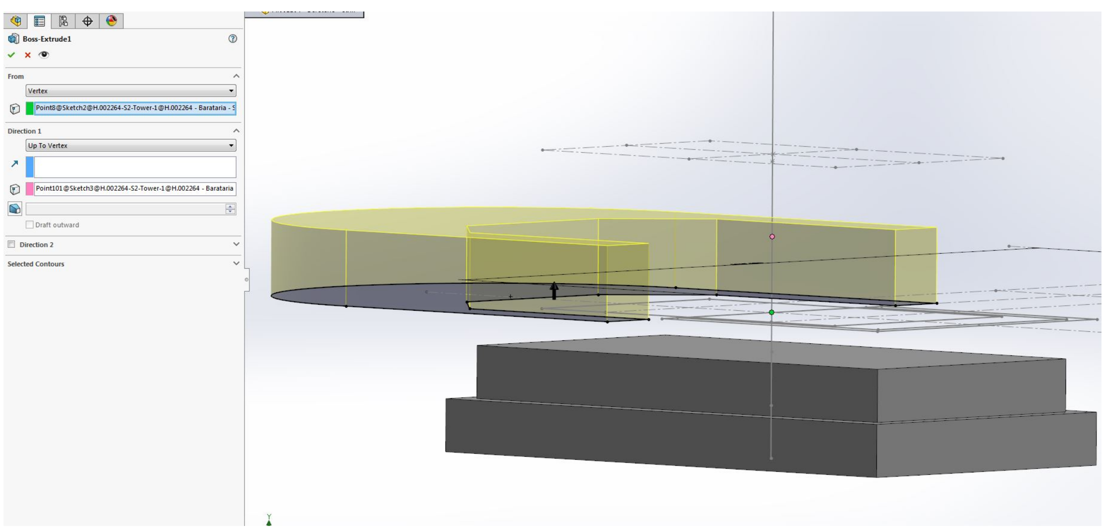

Figure 4.11: Fender Extrusion

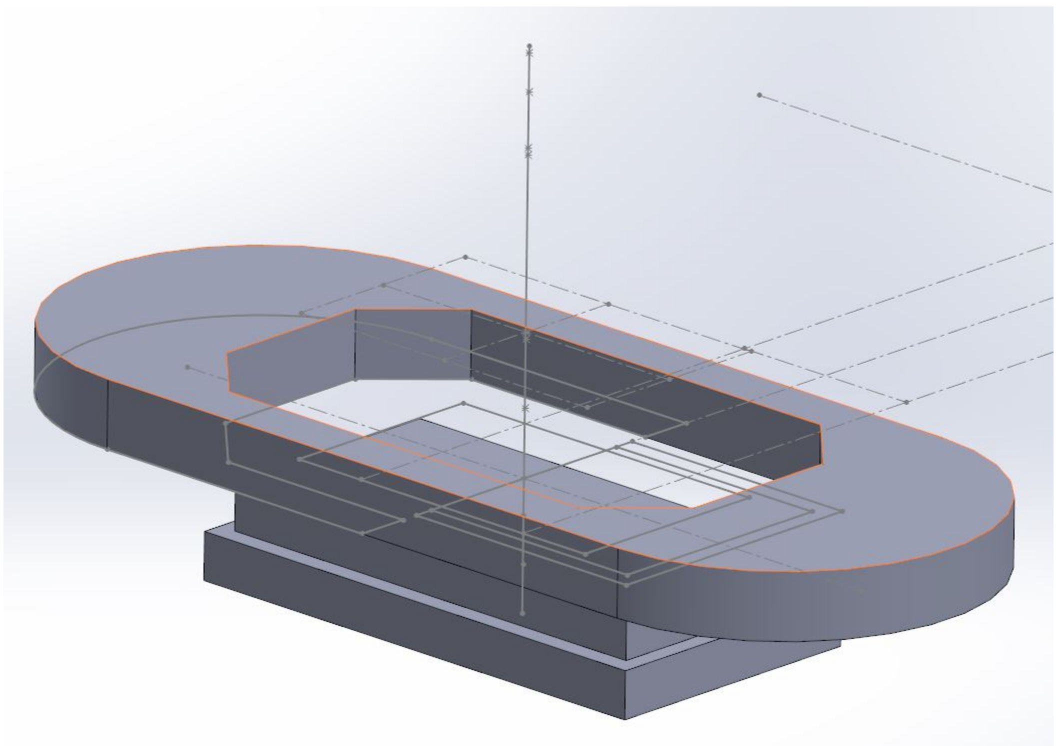

Figure 4.12: Fender Part

Tower

Now we will move on to the tower, which is a bit more complicated. The first step will be to create the tower SSP. I'll insert this part and the other parts (Concrete, steel, and walkways) into the structural assembly, and then start working on the SSP.

Next multiple planes were created to facilitate drawing in the future. A plane was created for each elevation shown in Figure 4.5, except the trunnion elevation. A plane was also created for each main girder. This can be seen in Figure 4.13. These planes will help later when drawing the tower cross sections and the main girders. Each plane is attached to one of the key points in the sketches. Thus if the sketch is edited the changes will propagate to the planes.

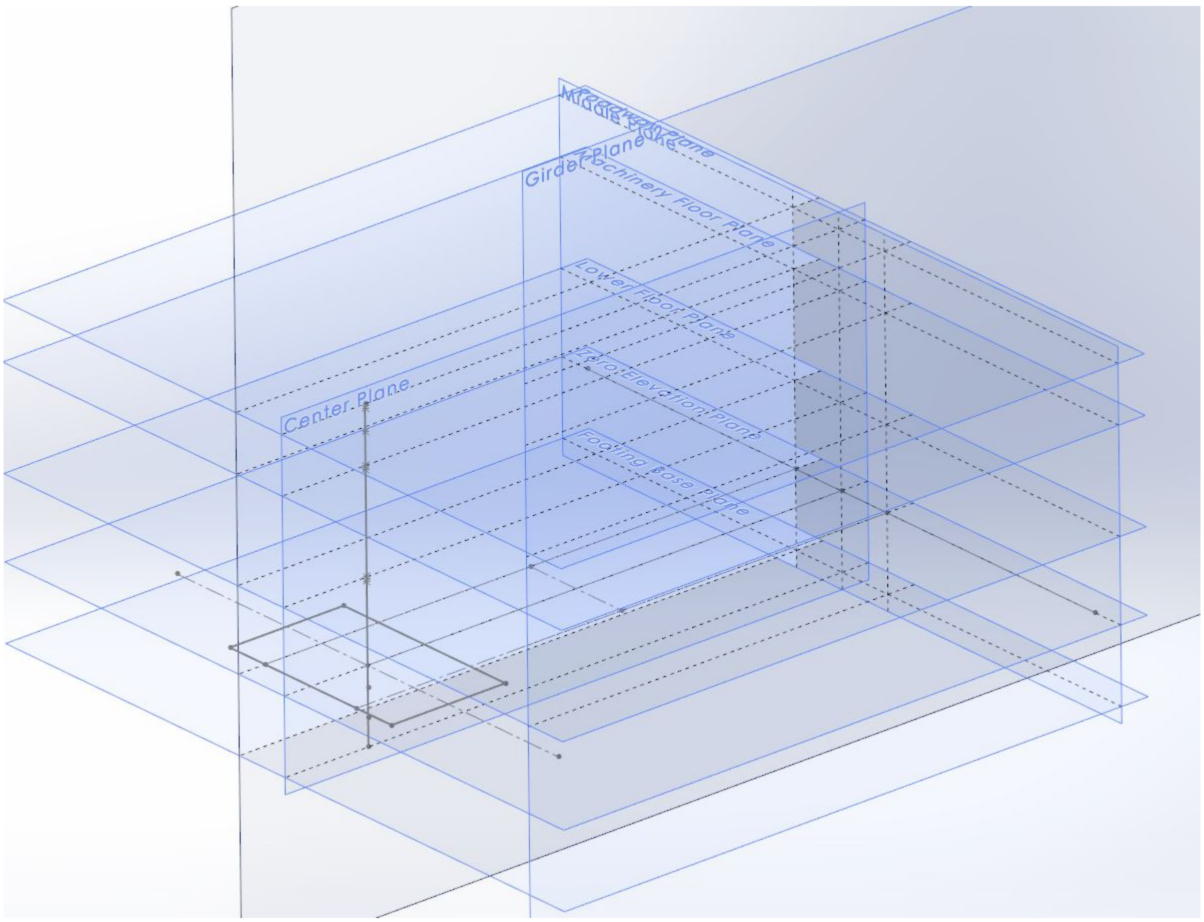

Figure 4.13: Tower SSP Planes and Derived Sketch

The plan for constructing the tower concrete will be to draw the various cross sections on the planes we created earlier. These cross sections will then be extruded along the elevation sketch. It may be necessary to create a separate top to the tower if it's not uniformly flat. To start a derived sketch was created from the sketch in Figure 4.4 onto the zero elevation plane in the tower SSP. Then a new sketch was created on the Lower Floor Plane and the convert entities command was used to pull in the outer tower wall boundaries from the derived sketch to our current sketch. The wall dimensions were then put in for half of the tower (we can mirror the features later). The final sketch is shown in Figure 4.14.

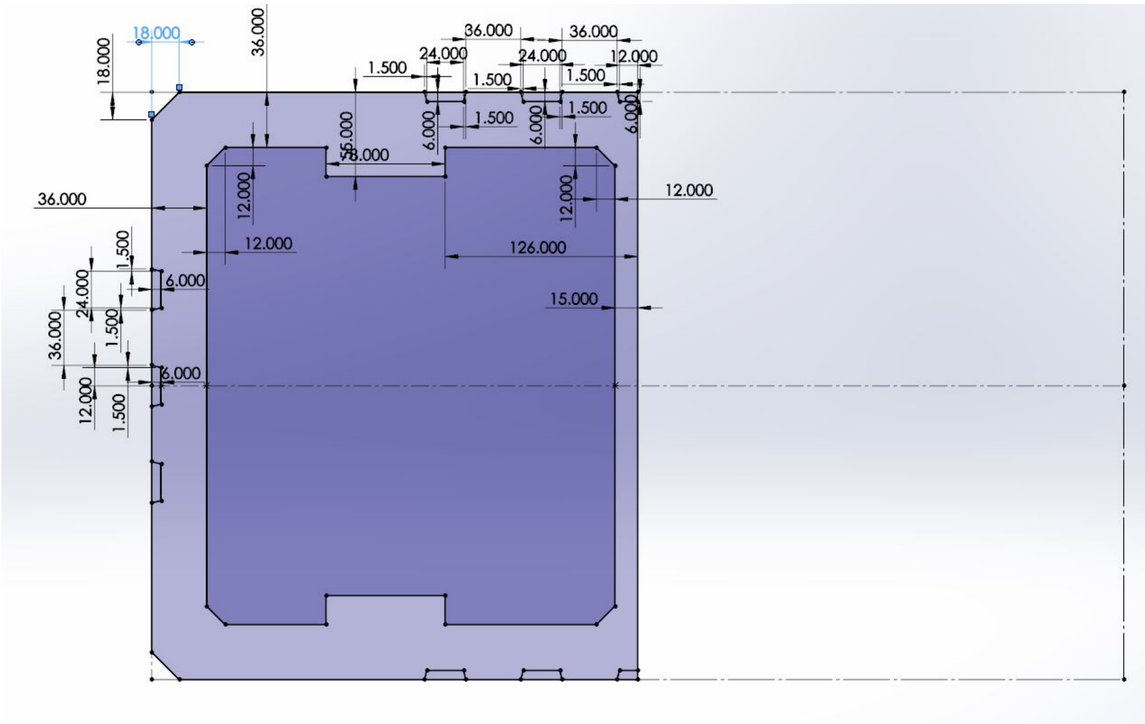

Figure 4.14: Lower Floor Cross Section

Going back to the structural assembly, we edit the tower concrete part and insert a derived sketch of the cross section onto the Zero Elevation Plane. Now we can take the new sketch and extrude the cross section using the elevations as we did before. The final result before mirroring is shown in Figure 4.15.

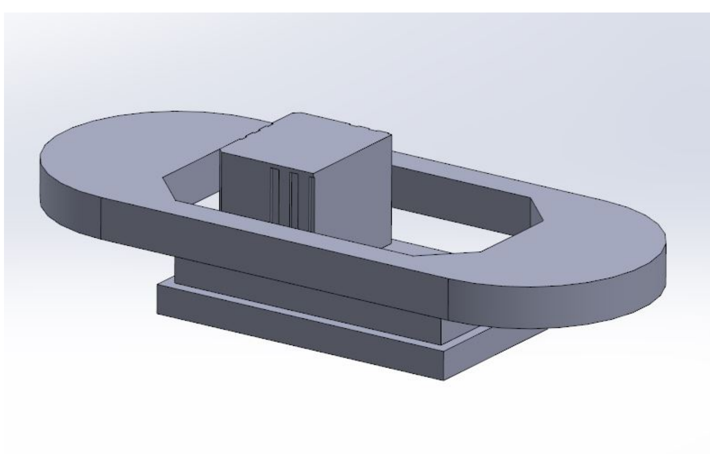

Figure 4.15: Lower Floor Cross Section Extruded

The same process will be repeated for each cross section of the tower. In this case we have two cross sections total. The sketch, resultant extrusion, and product after mirroring are shown in Figures 4.16 to 4.18. Depending which contours are selected we can make a hollow section or floor, or many other configurations.

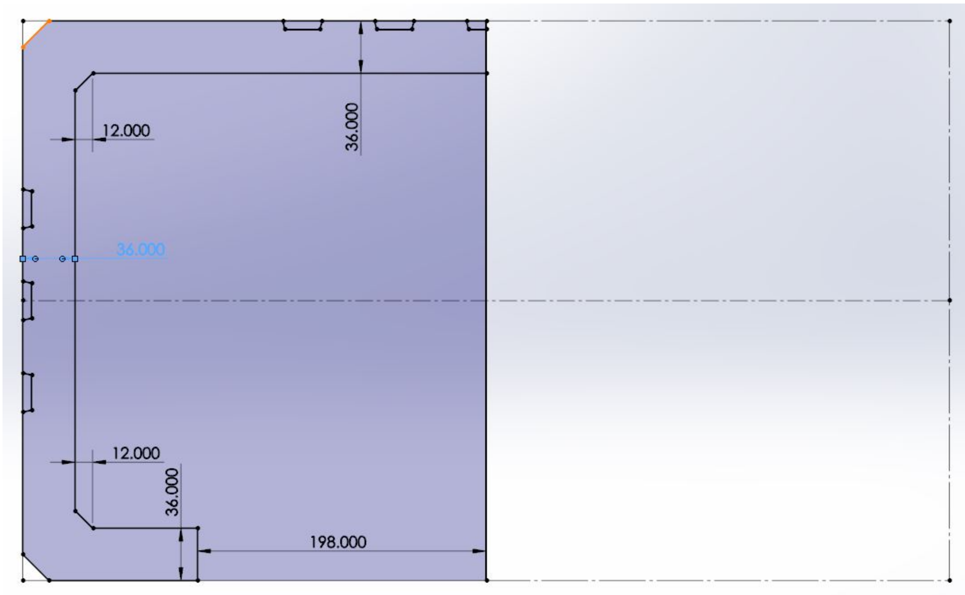

Figure 4.16: Machinery Floor Cross Section

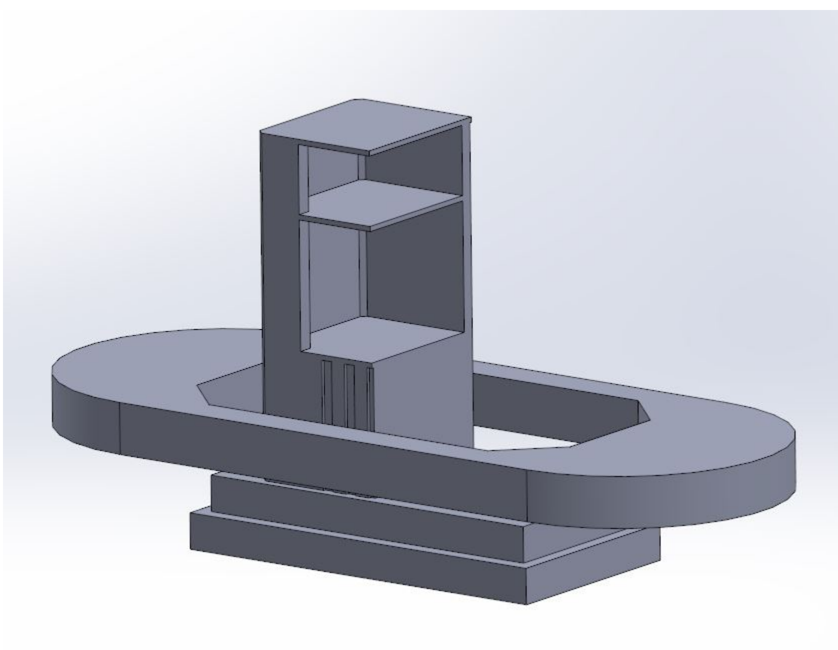

Figure 4.17: Machinery Floor Cross Section Extruded

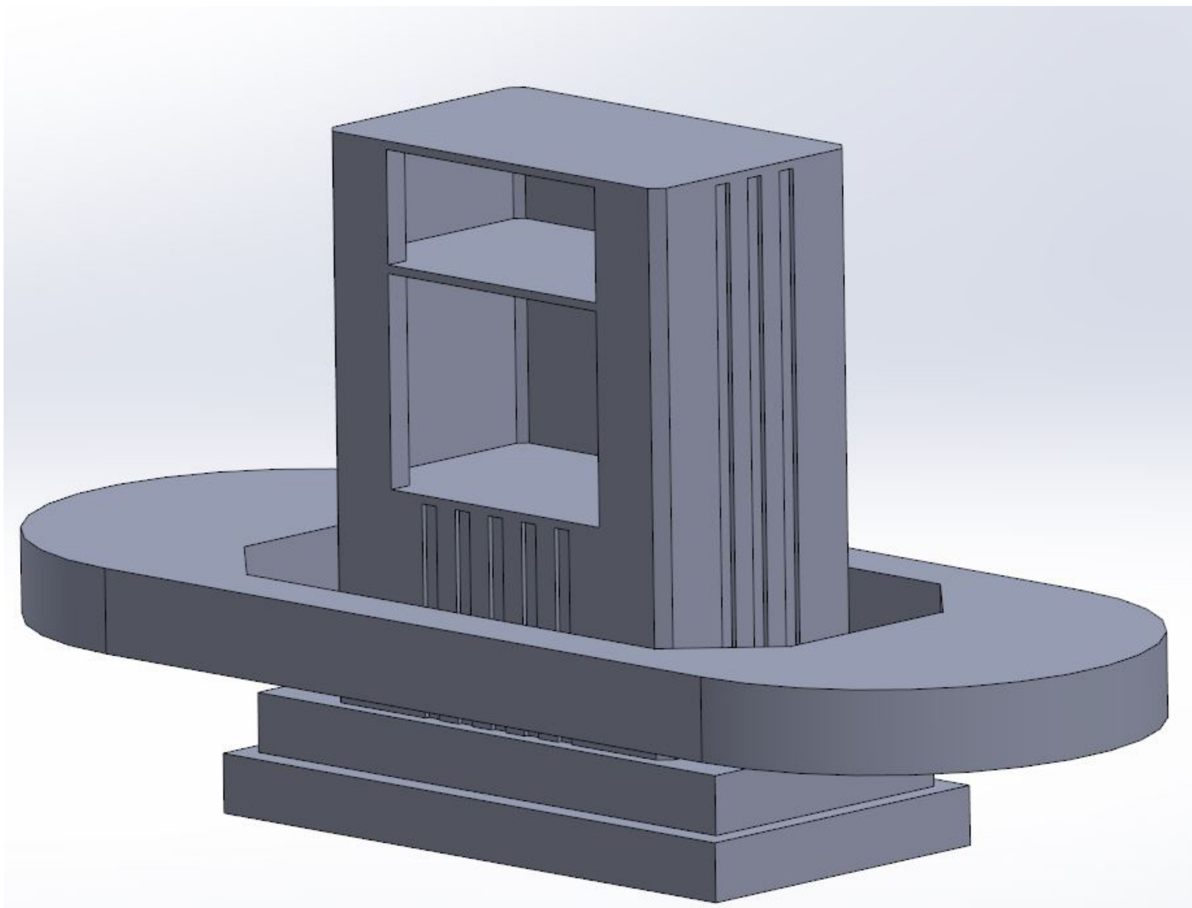

Figure 4.18: Tower After Cross Sections Are Mirrored

Some extra details will need to be added to the tower, as well as the roadway layout on the top of the tower. When there are small details like chamfers and local extrusions, it's usually best to add them after the overall model has been created. In the tower we added a few cuts, chamfers, and a couple small extrusions, such as the ones seen below the machinery floor. The final result is shown in Figure 4.19, it is also worth noting that I changed the floor plan of the machinery floor as well as the material. This change occurred fairly smoothly, and I only had to edit the selected contours in the extrusion feature. This image also shows the completed Pier Assembly with the Footing, Seal, Pier Protection Cell, and all the associated piles. The concrete portion of the tower is finally completed, but we still have to work on the steel supports inside, and the walkways and stairs.

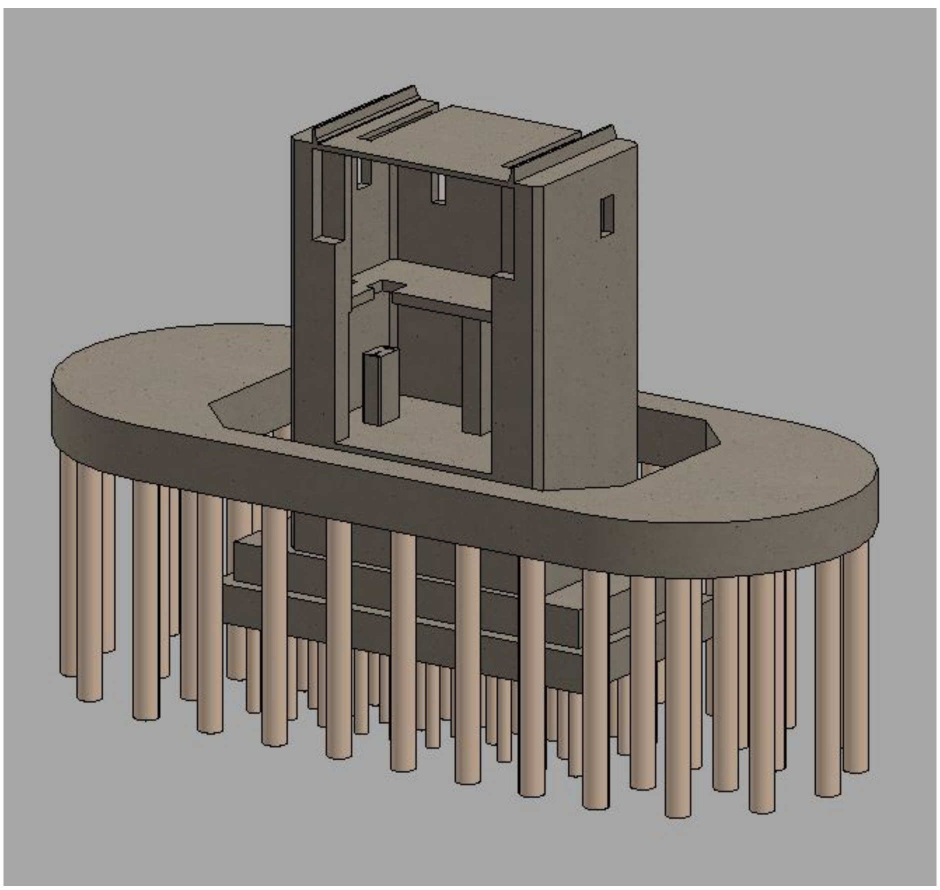

Figure 4.19: Final Tower Concrete

Now I will do a model a preliminary version of the steel supports within the tower assembly. At this time the steel supports are less developed than the concrete tower was, but even with a very broad idea of how the steel will look we can create a robust and versatile model. Special care will be taken to make sure that the majority of dimensions can be easily changed. Then once the final dimensions are determined, we can modify the SSP with minimal effort. I've started this process by creating a plane that is parallel with the middle plane, but located in the center of the tower as shown in Figure 4.20.

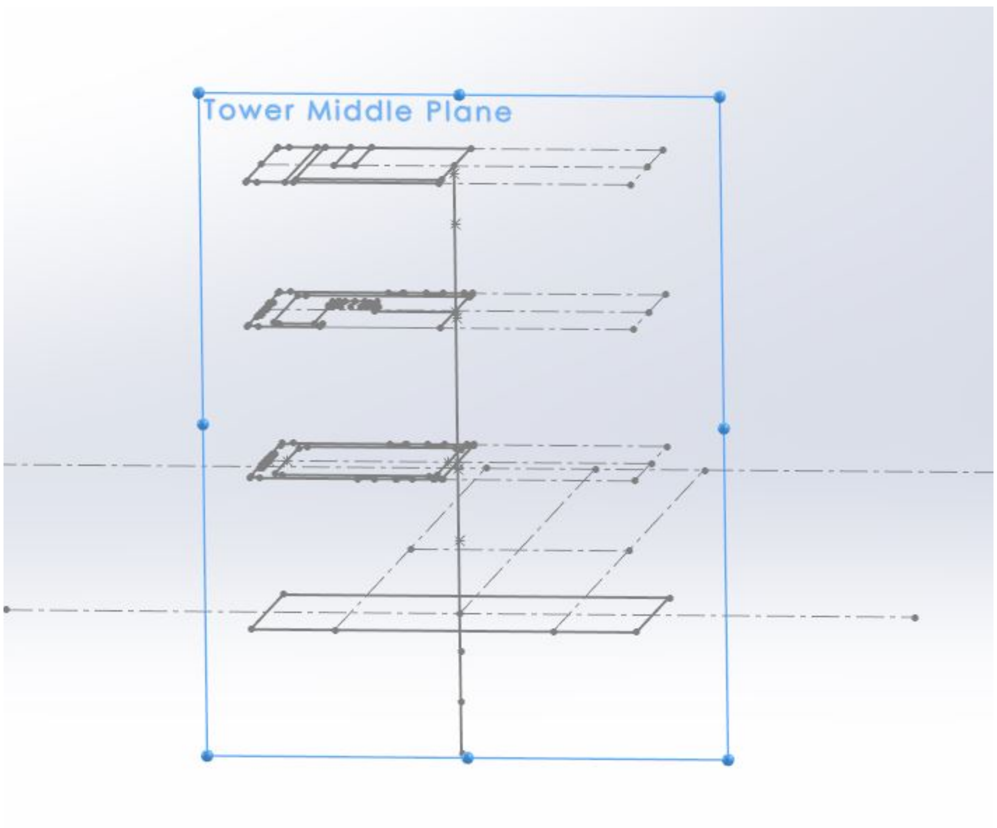

Figure 4.20: Tower Middle Plane

The main steel members' profiles have been drawn on either a plane or a surface of a part that is above the steel in the design tree. There are three main sketches that will drive most of the structural steel. The first is the member the actual trunnion bearing will sit on. The second is the member that will hold up the previous one. The final main member will be embedded in a concrete beam that will hold the first two members up. Figures 4.21 to 4.23 show the three sketches in order.

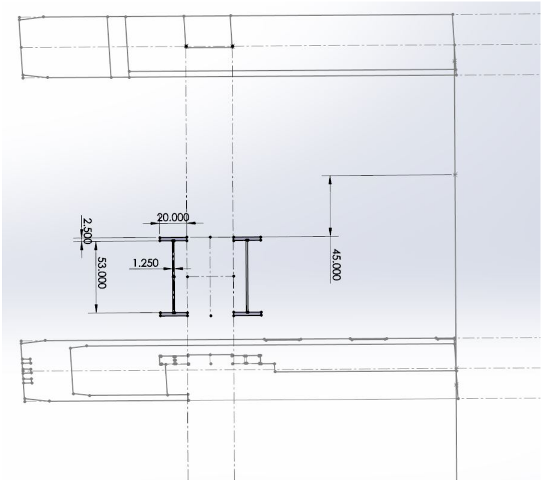

Figure 4.21: First Steel Member Sketch

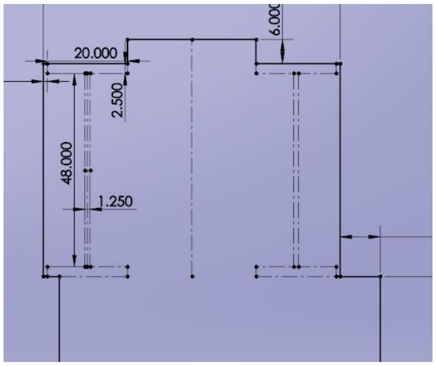

Figure 4.22: Second Steel Member Sketch

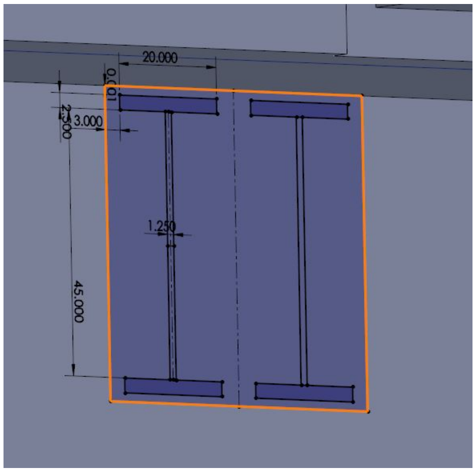

Figure 4.23: Third Steel Member Sketch

Now I will create the appropriate planes in the tower steel part and then derive these sketches onto it. I will then extrude them and show an image of the final extrusion. The parts were extruded to different vertices on the derived sketch of the machinery floor. The part before extruding is shown in Figure 4.24. The final extrusion is shown in Figure 4.25.

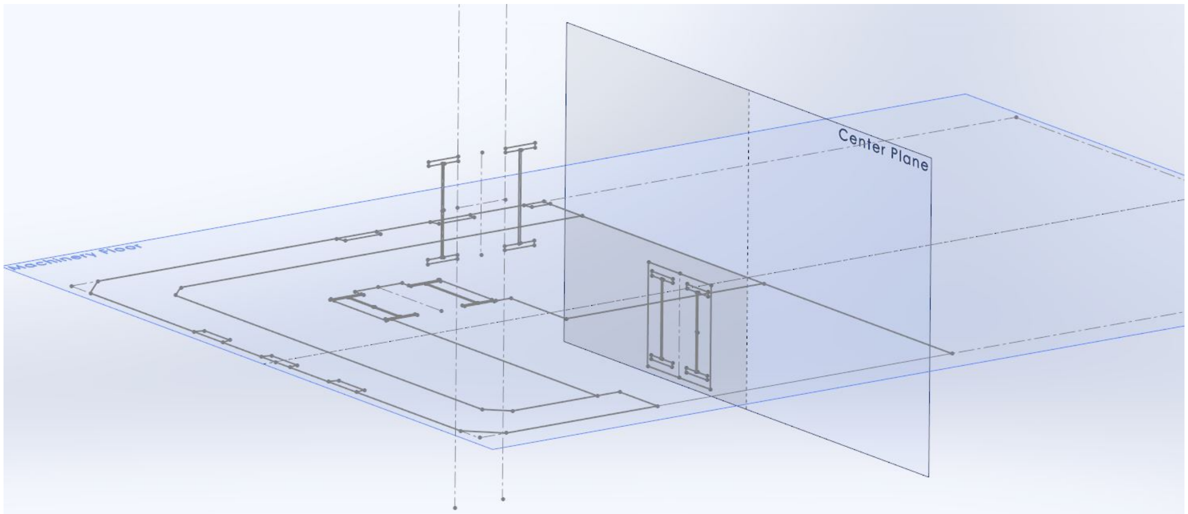

Figure 4.24: Steel Part Before Extrusions

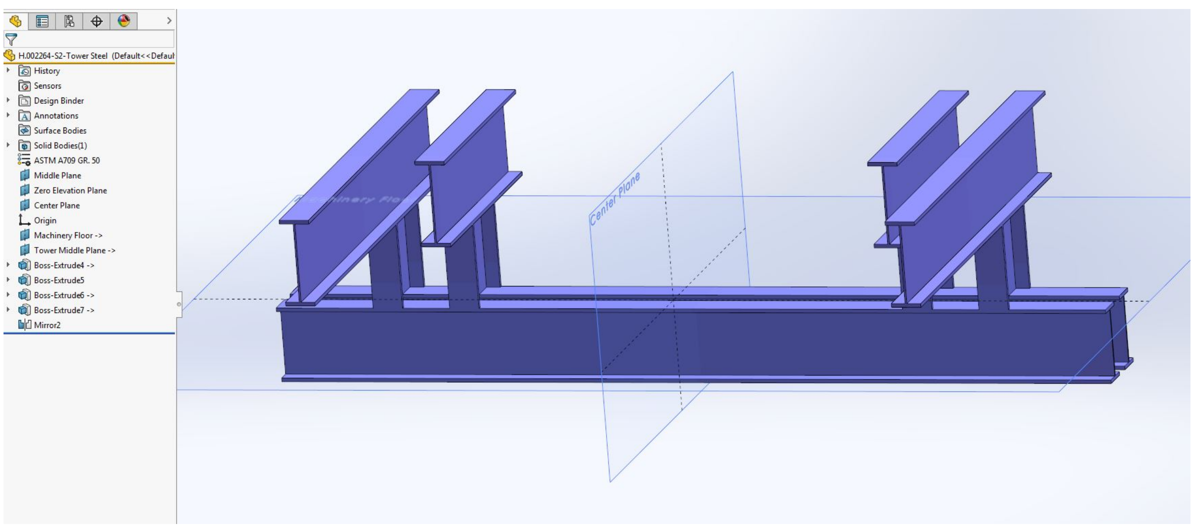

Figure 4.25: Steel Part After Extrusions

Details such as stiffeners, weldments, and other small beams will be added in the future. These details need not be sketched in an SSP, and will end up being drawn on the steel members shown. This will prevent clutter in the SSP and allow more flexibility. For now we are done with the tower. Without having the actual structure designed there is not much else we can do. I will also wait to put in the walkways until the machinery is completed

As the design progressed and major decisions were made the steel changed fairly dramatically.

We went to a single trunnion bearing on each main girder, so we didn't need the two major support columns on each side. Figure 4.26 shows the final steel design. Executing these changes proved to be very simple with the SSP technique. I just deleted the horizontal extrusion, and deselected one profile on two extrusions.

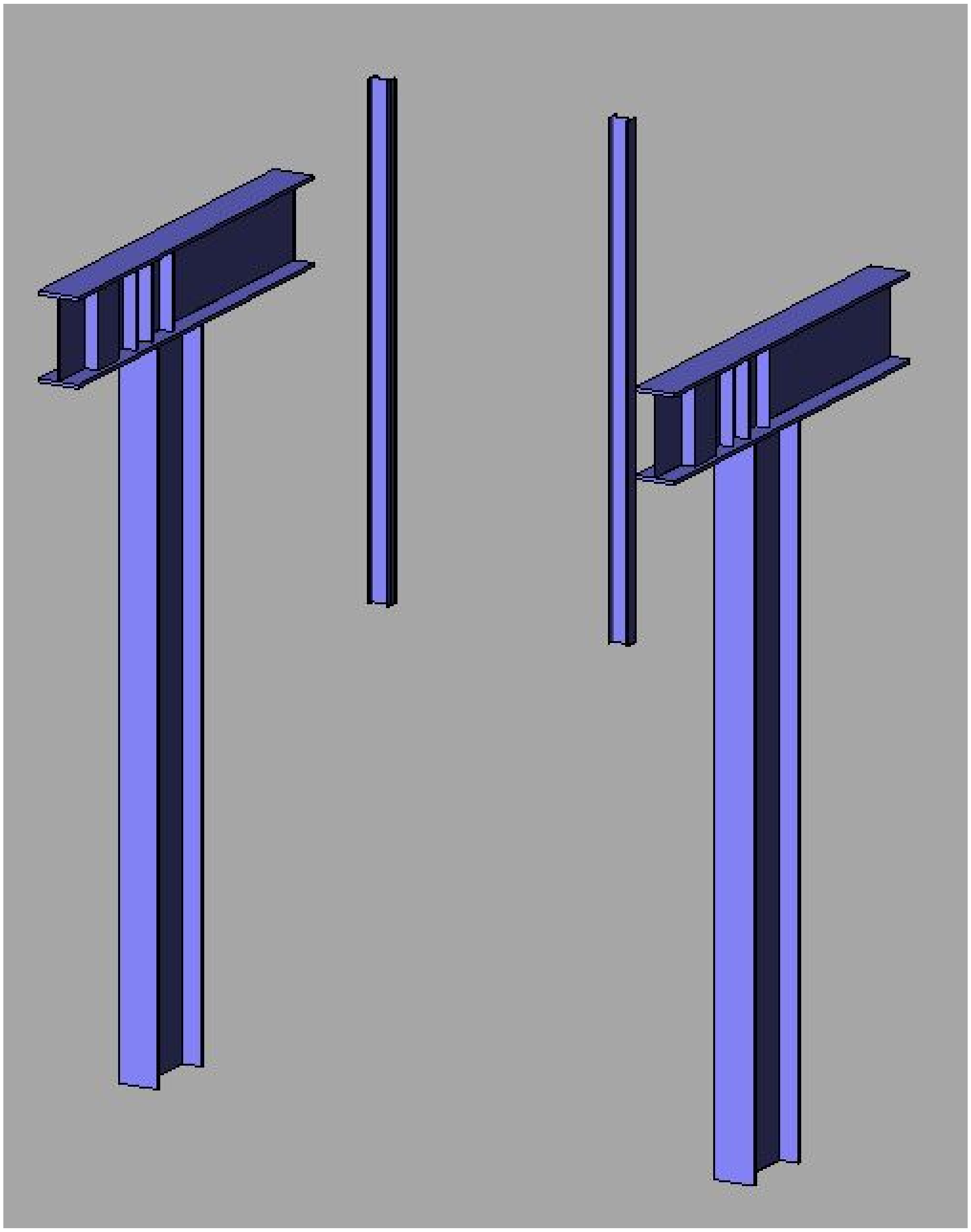

Figure 4.26: Steel Part After Changes

Movable Span

We will now move on to the movable span. This assembly will probably be the hardest to create for multiple reasons. The first and most obvious reason is that the structure has to be able to move. The only effective way to accomplish this would be to insert the part differently from the process described in Section 3.4. A few mates will be necessary to allow movement and positioning. The second reason is that there is a large amount of steel connections and details. If we want to get very in-depth with this assembly we will have multiple bolts and plates at every connection. The shapes can also get complicated, and there isn't much symmetry besides the center plane. To make matters worse there are not many repeated connections. These problems would still be present using other modeling techniques, but they are a bit more exasperated using the SSP method.

Before going any further we will need to figure out the Movable Span Assembly Design Tree up front. Figure 4.27 shows the breakdown of the top level of the design tree. Notice the three SSPs, one for the main span, one for the center locks, and one for the tail locks. These are separated to keep SSPs simple, and drive the design down from the main movable span SSP. They are also different areas of design, so it helps to keep each subassembly organized. Also notice the mechanical parts are separate from the structural parts. This is because our section is responsible for only the mechanical parts so our final drawings will exclude all structural components from the bill of materials.

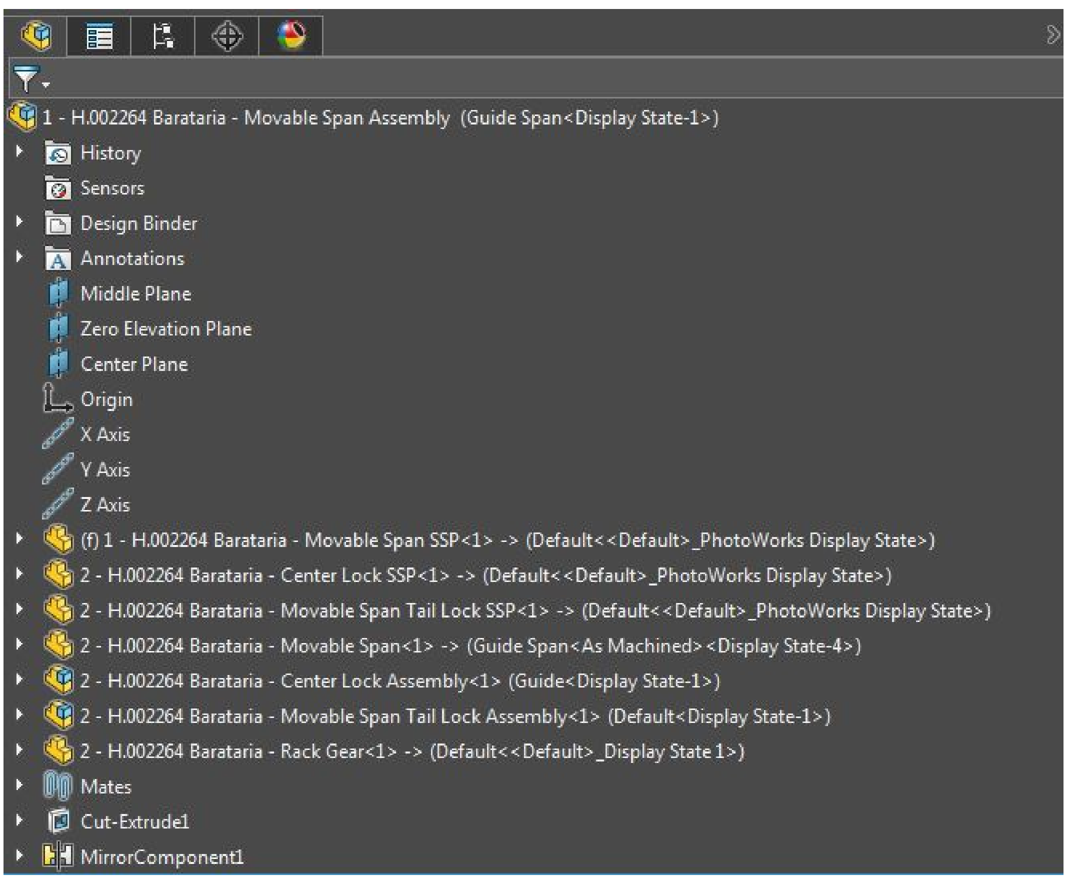

Figure 4.27: Movable Span Design Tree

For now we will leave out the connection details, mostly because they haven't been designed yet, and it would be a huge waste of time. The main girder is the most important part of this assembly, because almost every interaction this assembly has with other assemblies goes through the main girder. To start we need to create the movable span SSP. Then I derived a sketch from the center plane and main SSP elevation sketch. Another derived sketch was created from the main SSP plan view and the zero elevation plane. Then we need to create a new plane parallel to the center plane, but located on one of the main girder centerlines of the main SSP plan view sketch. Figure 4.28 shows the result of these steps. After the main girder we will model the movable span from the highest elevation down. This is how our structural engineers design the bridge, so it only makes sense to follow this method.

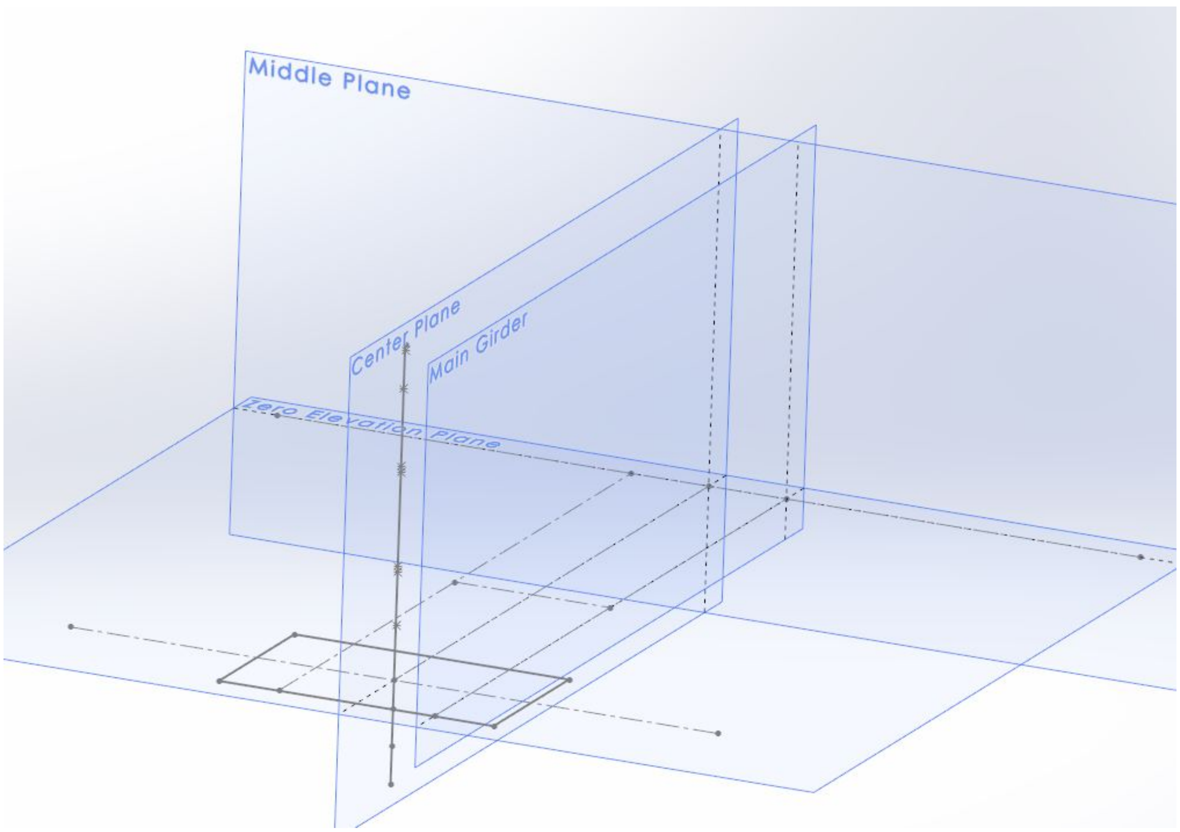

Figure 4.28: Beginning of Movable Span SSP

After drawing the outline of the girder shown in Figure 4.29 we need to insert a part for the main girder into the movable span assembly. We will create the same main girder plane, and derive the sketch onto it as usual.

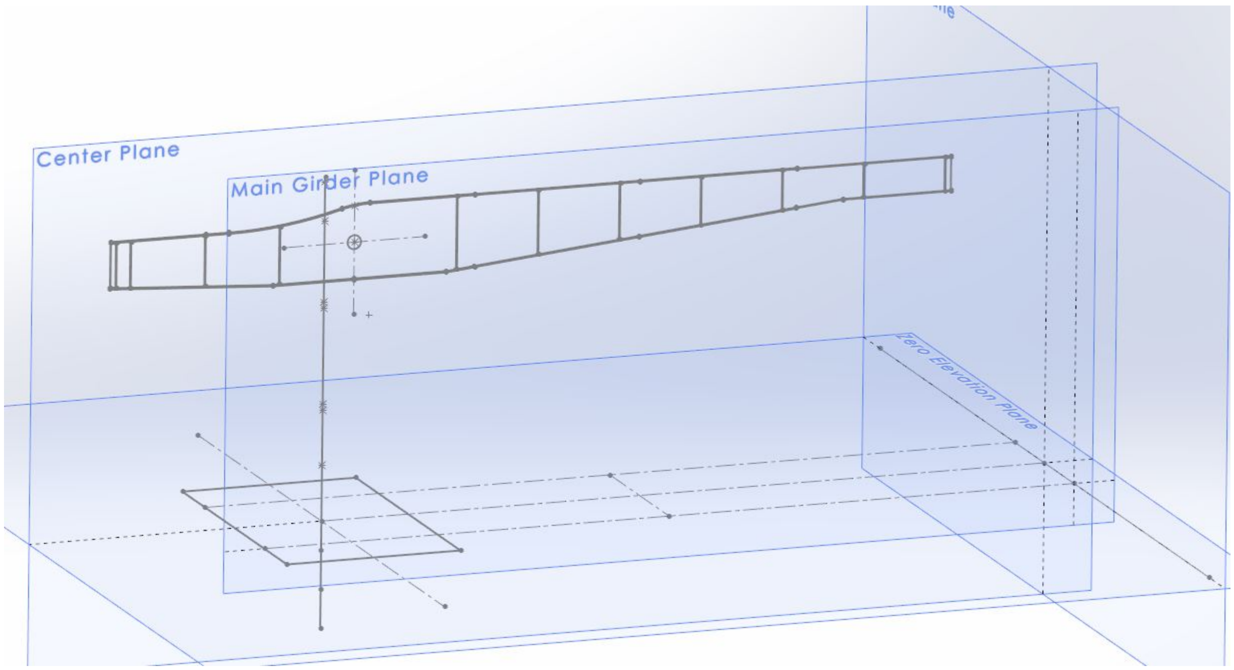

Figure 4.29: Main Girder Outline

Now we will extrude the girder's flange, web, and stiffeners. These features are some of the only ones to use a blind extrusion distance rather than using vertices or planes. In order to keep track of the different extrusions I named each feature. The final extrusion is shown in Figure 4.30 with the feature tree included, so you can see the different feature names. This pretty much sums up the main girder, and now we will start building the rest of the span from the top down.

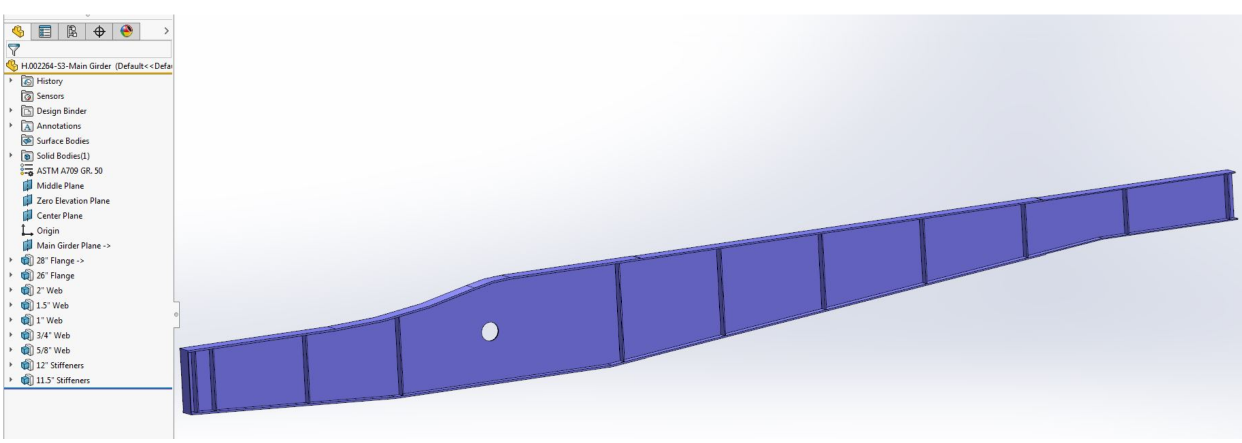

Figure 4.30: Main Girder Extruded

Next we will do the roadway. This is going to be a grid deck, but to save time and processing power, we will model it as a slab and set the material to a custom material with the same properties as a grid deck, and a texture that resembles a grid deck. The base sketch is shown in Figure 4.31, and it is extruded using a vertex extrusion set to the deck thickness. The final result is shown in Figure 4.32. Notice the highlighted sketch of the W member below the deck. We want to use weldments to create the stringers, but if we do, we have no way to locate the bottom of them without referencing the solid bodies. This would create a circular reference with the SSP and the Movable Span part. To get around this we draw a sketch of the stringer profile, but this does mean we need to go modify dimensions anytime the member changes.

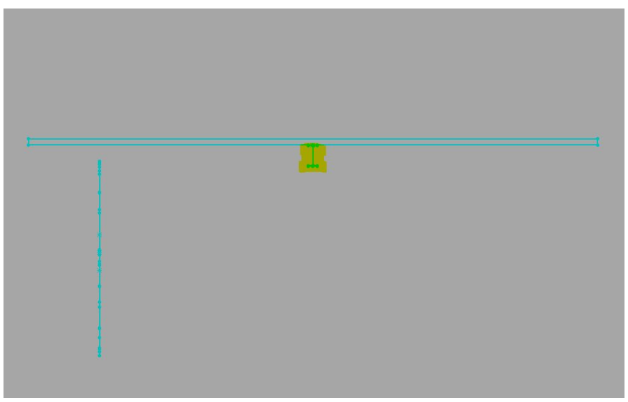

Figure 4.31: Grid Deck

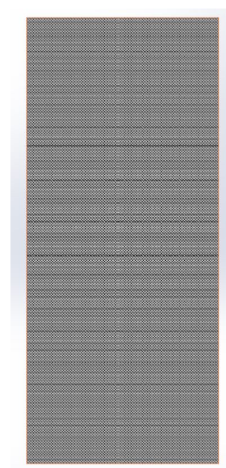

Figure 4.32: Deck

Next the stringers will be laid out using lines sketched on the "Roadway Plane" in the movable span SSP. I created a new plane in the Movable Span part on the bottom of the roadway deck. This plane represents the top of the stringers. I then derived the stringers sketch onto this new plane. Now I can add the appropriate weldments (W18x50) and locate the profile to the top of the "I". The stringers sketch in the movable span SSP is shown in Figure 4.33. I've also chosen to show the profile location process for the weldment in Figures 4.34 and 4.35.

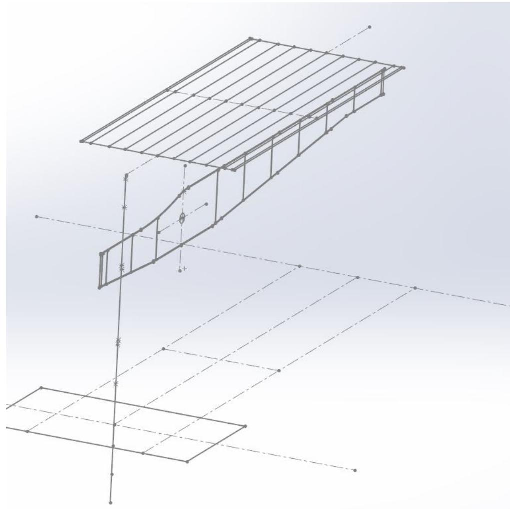

Figure 4.33: Sketch of Stringer Lines

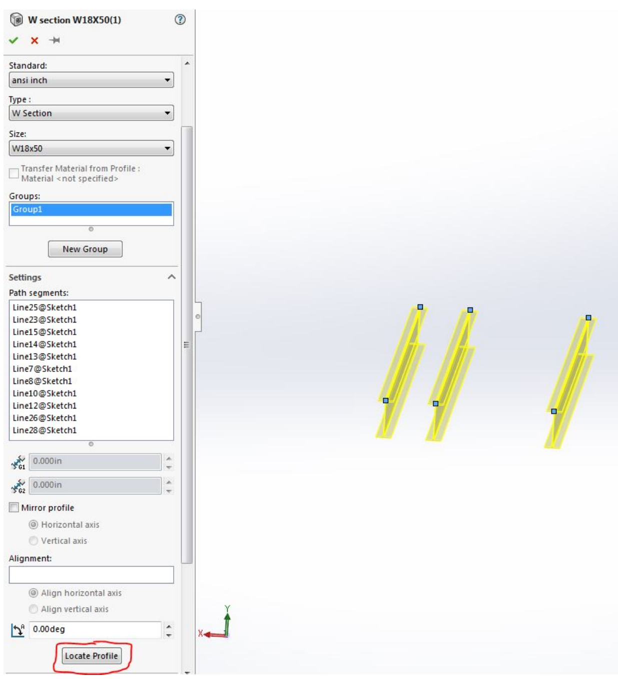

Figure 4.34: Locate Profile Button

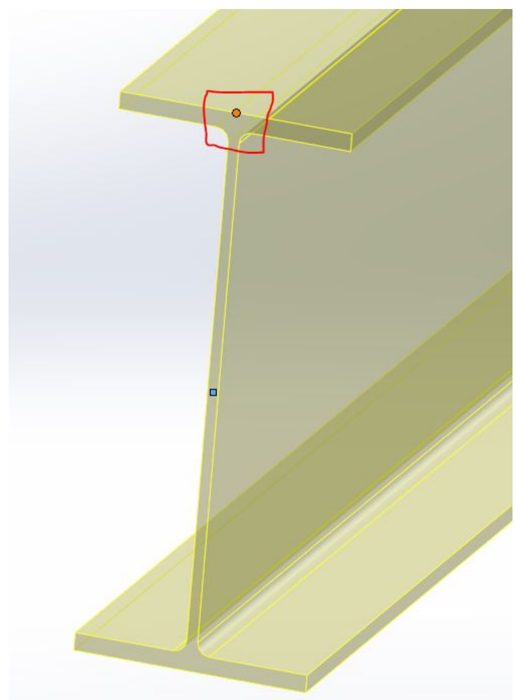

Figure 4.35: Desired Location of Line Through Profile

Now that the stringers have been created (there was some bracing added as well, but we wont cover that), we can start working on the next level, the floor beams. The floor beams are the most complicated and time consuming part of the movable span. I chose to just start each floor beam by sketching on the corresponding stiffener, and converting entities as shown in Figure 4.36. I felt it would be too complicated and not very beneficial to try and include the floor beams in the SSP, so all the information is included in the Movable Span part (other than the locations longitudinally along the main girder, which is determined by stiffener location).

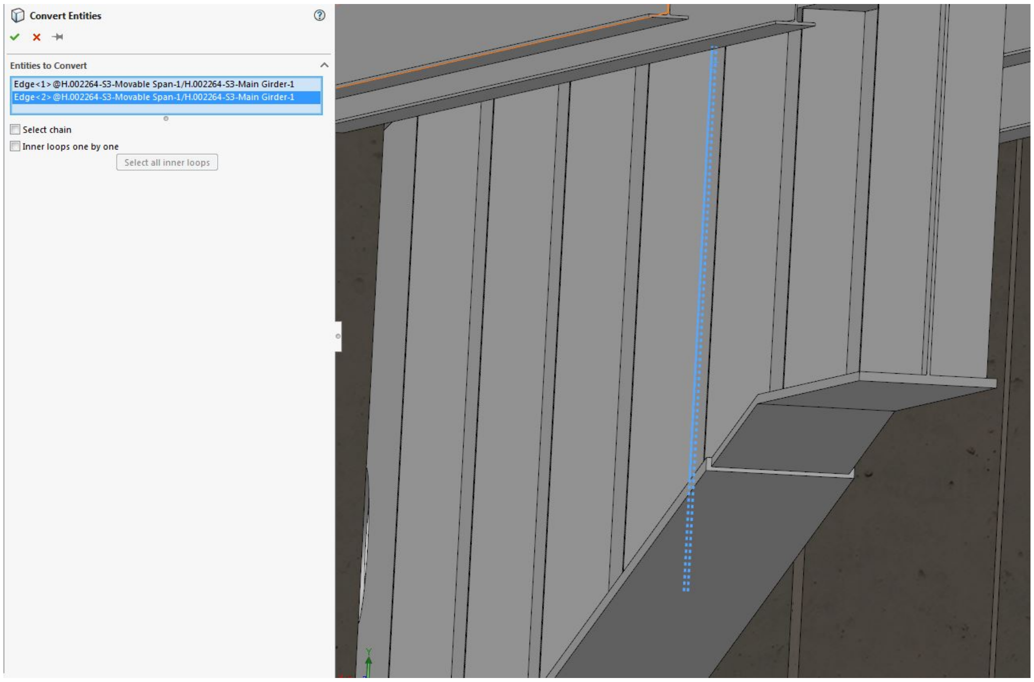

Figure 4.36: Stiffener Lines to be Converted

Floor beams A to C are full depth, and floor beams A and B are identical. I started by fully modeling half of the floor beam as shown in Figure 4.37.

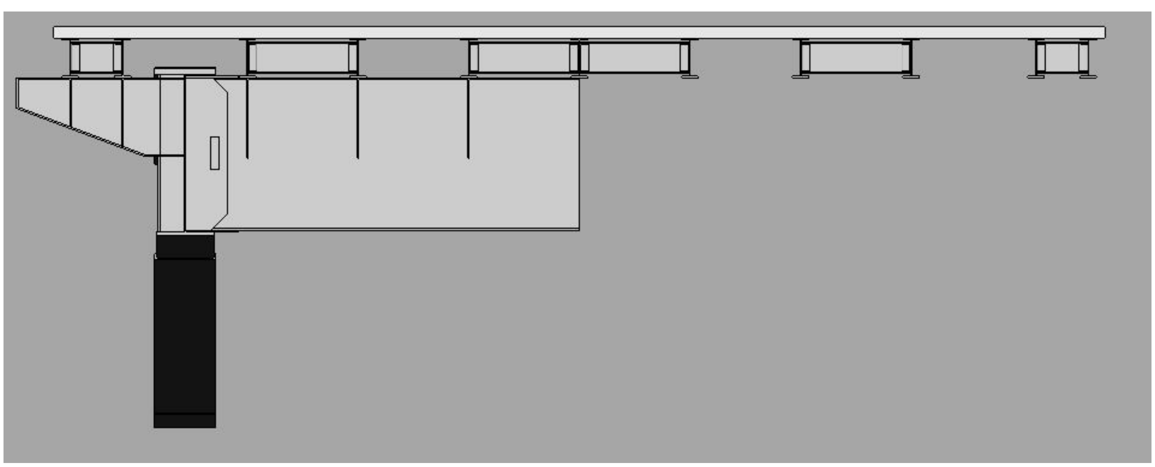

Figure 4.37: Floor Beam A Half Section

I then mirrored the floor beam and main girder across the Center Plane, and used a linear pattern to create floor beam B. I also went ahead and used another linear pattern to propagate the supports on the outside of the girder to every floor beam since they use the same detail. The result is shown in Figure 4.38.

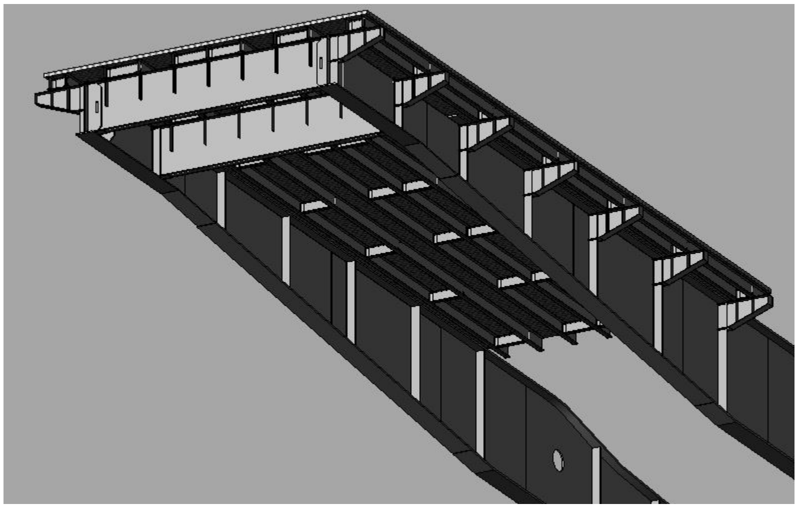

Figure 4.38: Floor Beam A and B

Floor beam C was modeled in the same fashion. The only difference between each full depth floor beam (and each braced floor beam as well) is its height. I haven't been able to find a way to easily propagate floor beams without individually modeling each one (aside from patterning any identical components). The typical braced floor beam is shown in Figure 4.39.

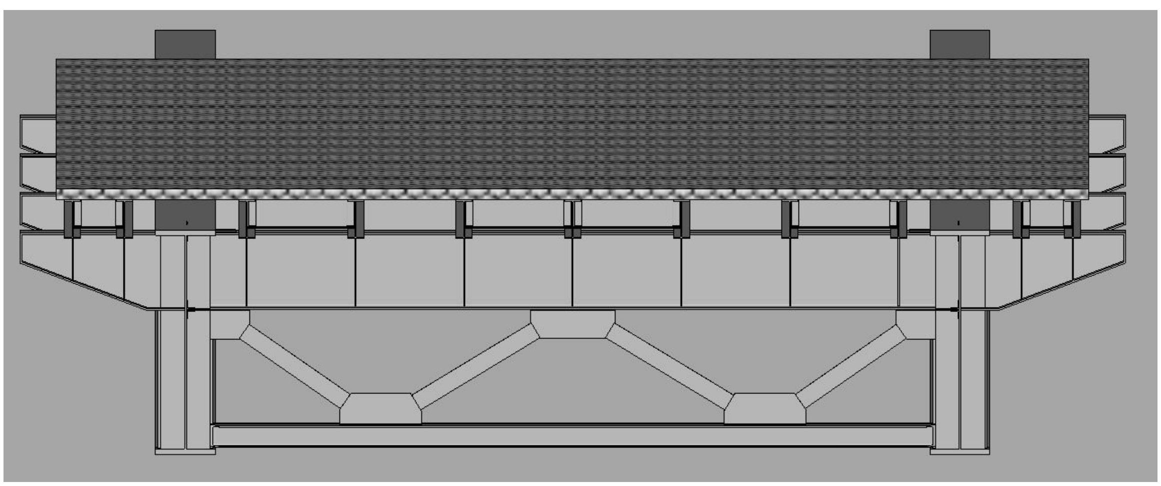

Figure 4.39: Typical Braced Floor Beam

The top and bottom members are both W Beam Weldments that are the same for each floor beam of this type. This means we can pattern these features to make the remaining floor beams a little easier to model. The bottom weldment follows a slope, so I had to select the inclined edge of the girder as my guiding line (and do a little math to get the spacing correct). I did find a more robust and flexible way of accomplishing this using a sketch driven pattern, but I will cover that in the Approaches Assembly.

Figure 4.40 shows the sketch used to model the bracing. The gusset plates are extruded, and the T Beams are weldments. The half-bracing is then mirrored and the floor beam is complete. This is continued for each of the remaining floor beams.

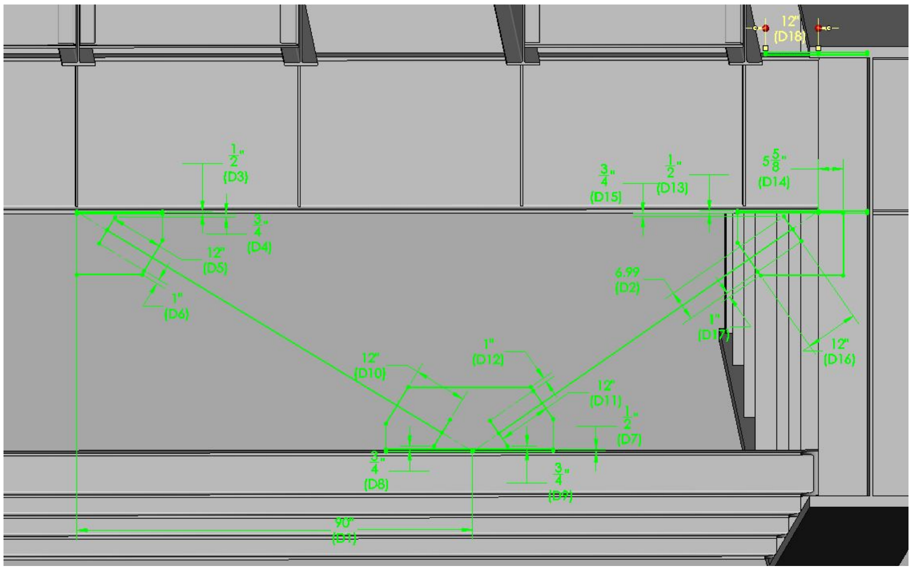

Figure 4.40: Typical Bracing Sketch

There are also upper and lower lateral bracing between the floor beams. This is done in a similar way to the floor beams. Figure 4.41 shows the sketch for the upper laterals (the bracing is already modeled in the figure). Once the extrusions and weldments were completed they were mirrored, and because floor beam spacing was the same between all floor beams, we can use a linear pattern to finish.

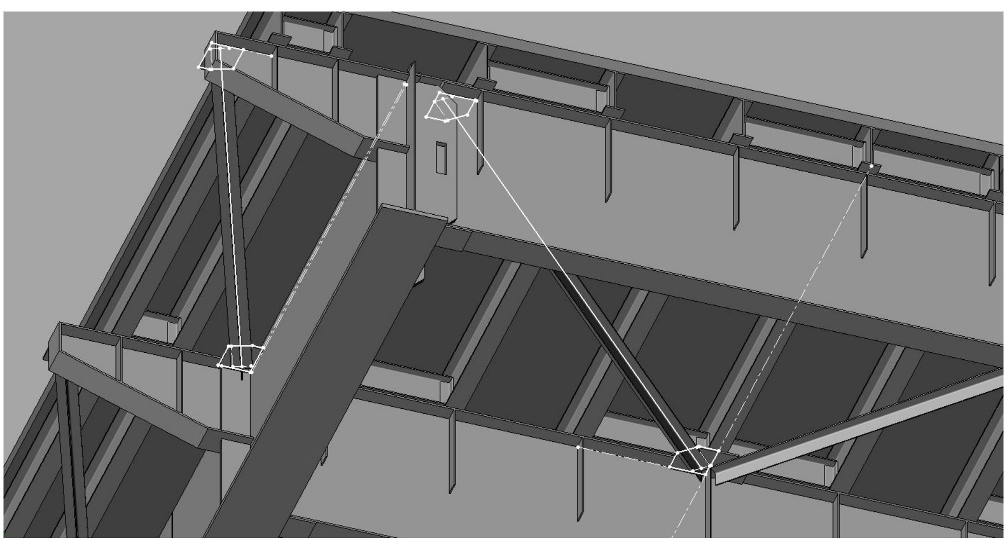

Figure 4.41: Typical Lateral Bracing Sketch

The lower laterals were done the same way, except they were on an incline, so a 3D sketch was used. This was a little more time intensive, but still fairly effective. This wraps up the bulk of the work. Some extra details and smaller floor beams were added on the backside, and the final model is shown in Figure 4.42.

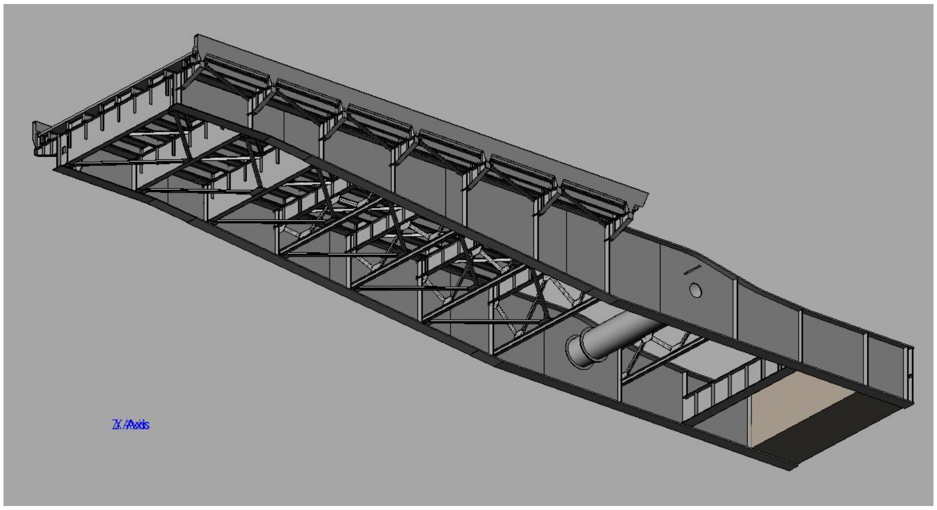

Figure 4.42: Finalized Movable Span Part

The Movable Span part is complete, but the Movable Span assembly isn't. The assembly not only contains the structural span, but also any machinery located on the span. Figure 4.43 shows the final SSP for the movable span. Movable Span Structural sketches are teal, Main Assembly sketches are black, and Movable Span Machinery sketches are orange. The machinery sketches drive the models of any machinery on the span. We will get into this more in the machinery section.

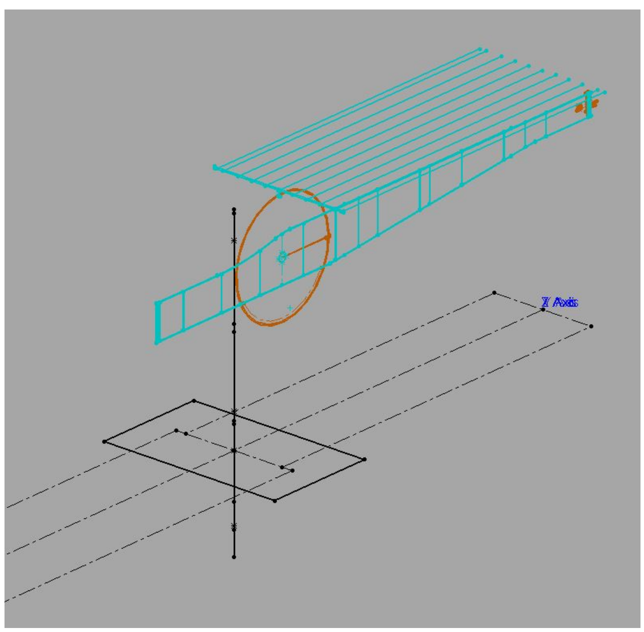

Figure 4.43: Finalized Movable Span SSP

Approaches

The Approaches are the same type of span as the movable span (Steel Girder), so we will spend less time diving into exactly how the model was created. I will describe, in detail, the features that make it different, and any lessons I learned. Figure 4.44 shows the Approaches SSP. It has a lot of the same features as the Tower SSP and Movable Span SSP. The approach specific sketches are shown in light blue. Notice the pier sketches on the left, the main girder, and the roadway sketch.

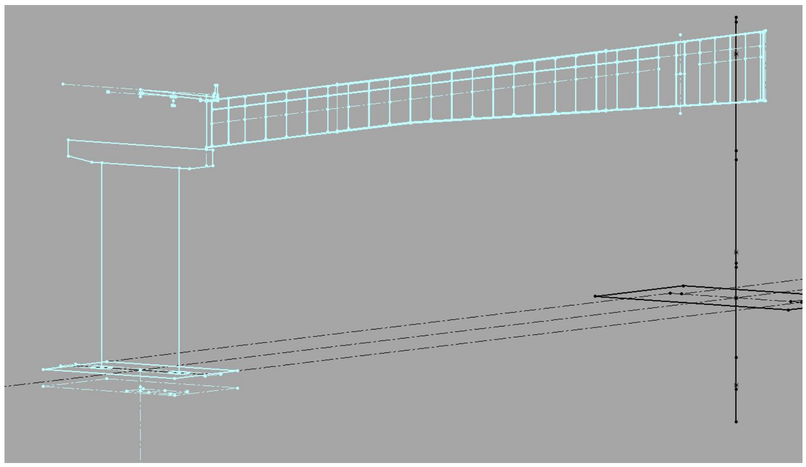

Figure 4.44: Finalized Approaches SSP

The pier, footing, and piles were made in the same way as the tower concrete. The main girder was made in the same way as the movable span. One of the more notable differences is the the roadway starts off sloped on the pier side and transitions to flat at the other end. This was accomplished by using a loft extrusion between the sloped sketch and flat sketch. The final approach model is shown in Figure 4.45.

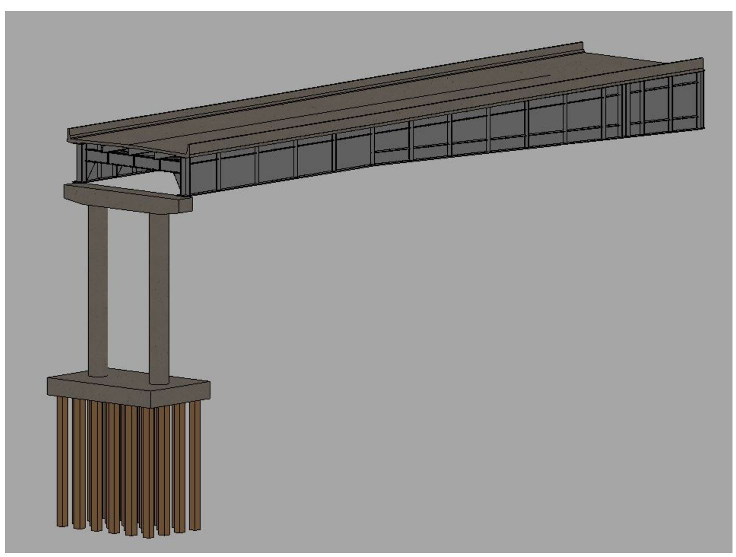

Figure 4.45: Finalized Approaches

As stated previously in the Movable Span section, modeling the floor beams is very time consuming. Normally I would pattern any of the repeating aspects, but I would usually have to rely on distances that wouldn't automatically update if the model changed. I discovered the sketch driven pattern and I believe this is a perfect fix. Now I can create a sketch that converts vertices of an existing sketch (like the main girder sketch) at the locations of the floor beams. These sketches are shown in Figure 4.46. This directly ties the pattern features to the SSP and allows the floor beams to move with any changes to the SSP. The sketch in the red section locates the bottom W beam of the braced floor beams, and the vertices in the blue section locate the flat part floor beams.

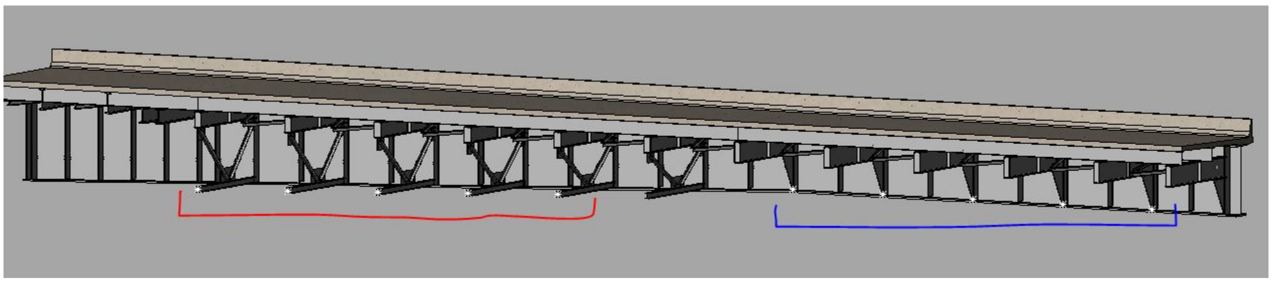

Figure 4.46: Sketch Driven Patterns

This sums up the modeling of the major structural components of the Bayou Barataria Bascule Bridge. Next we will analyze the mechanical components.

4.4.3 Mechanical Components

Most of the mechanical components will be modeled in the same way as the structural components, but a few are purchased components that come with their own models. Now these parts could be remodeled, but that is a lot of extra work that doesn't need to be done. We want to use these premade models, so we need to figure out a way to simply and stably incorporate them into the assembly.

Before adding the bought components to the assembly we want each one to be a single part. A lot of these premade components come in large assemblies that need to be converted to a single part. This is a relatively simple procedure, but it is sort of hidden within Solidworks. Figure 4.47 shows a typical motor brake model we got straight from the manufacturer. As you can see there are many sub-assemblies within the main motor brake assembly. These sub-assemblies each contain many parts and even other sub-assemblies. You may also notice that all the part names are in German, as this is from a German company.

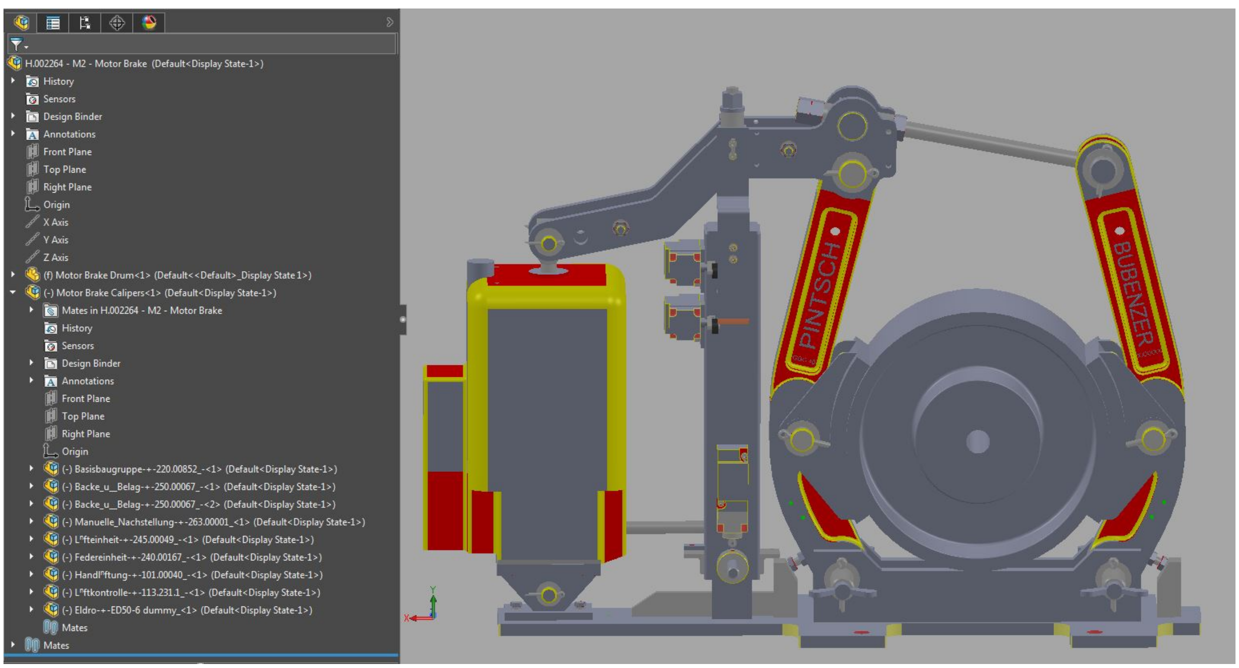

Figure 4.47: Typical Motor Brake Manufacturer's Model

Leaving this part as it is would take up a lot of computing resources, and complicate the bill of materials. The first step is to add a part in the top level of the assembly using the **Insert Component > New Part** command. Name the part according to your naming convention, then select a plane and exit the sketch. The only place I have been able to find the **Join** command is by searching in the command search bar. Once the **Join** command is executed select all of the parts/bodies you want to create as one new part as shown in Figure 4.48.

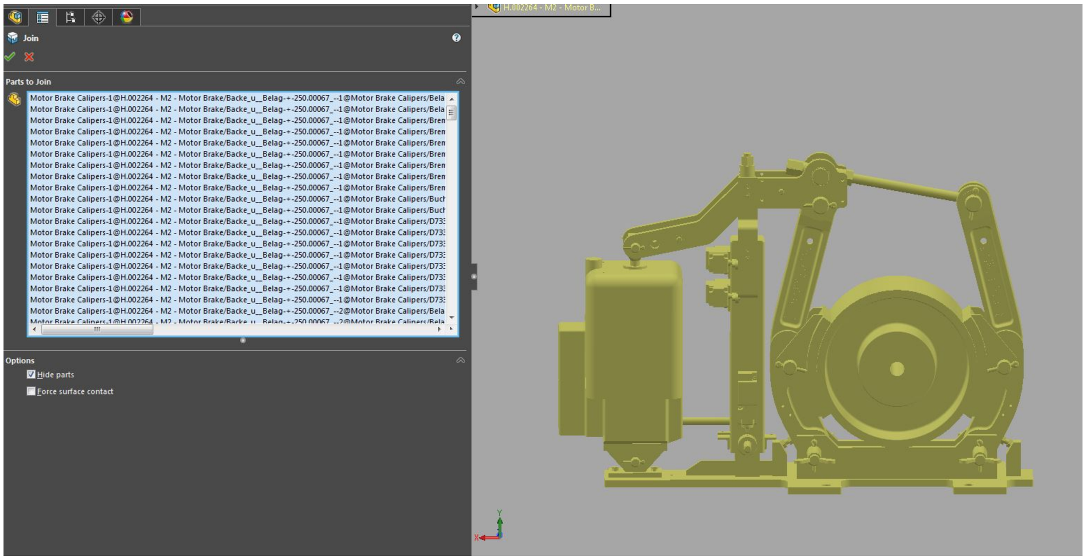

Figure 4.48: Join Command Execution

Click the check mark and now the assembly contains all of the original parts and the new joined part. I only work with the joined part for the rest of the process. In order to incorporate these premade models in our bridge model we will have to use a mate. I have found the most effective method to mate the model to the sketch is to put coordinate systems on the sketch and on the model and use a coincident mate between them. This will be covered in the next section.

Drive Machinery

The Drive Machinery Assembly really starts with the movable span, which is why it must be down stream from the Movable Span Assembly (and SSP). Figure 4.49 shows the Movable Span SSP, and specifically the Rack Sketch in orange. The drive machinery is located by the angle and center distance between the rack and pinion. This sketch and the two Main SSP sketches are derived into the Drive Machinery SSP.

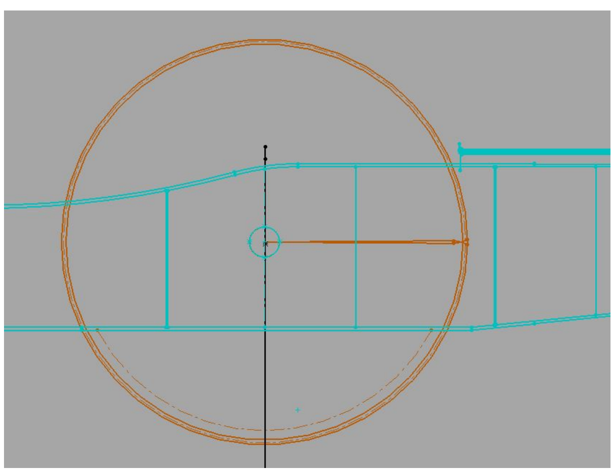

Figure 4.49: Rack Sketch

From here we start the pinion sketch. The Rack Sketch and the Pinion Sketch were connected using a tangent mate between the two pitch circles, and a center line with an angle defined between it and a vertical line. Figure 4.50 shows the final Pinion Sketch.

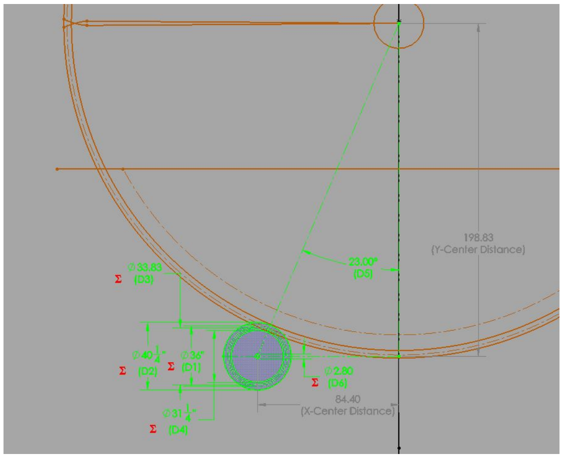

Figure 4.50: Pinion Sketch

A plane was then created parallel to the Zero Elevation Plane at the center of the pinion. Then the Machinery Floor Sketch from the Tower SSP was derived on this plane to give us our boundaries. Then straight lines were drawn coming out of the pinion to represent different shaft/bearing/coupling lengths and center lines. Finally I drew circles to represent the different shaft diameters on the Center Plane, centered on the shaft center lines. These circles would be extruded along the lines using a vertex to vertex extrusion.

I later found a more efficient method to create shafts that was easier to visualize as well. This involves a revolved sketch rather than extruded, and it will be covered in the Trunnion Machinery section. The last step in creating the Drive Machinery SSP is to add coordinate systems to the sketches to attach bought components to. Figure 4.51 shows the final Drive Machinery SSP. Another useful tip I've learned is to name the coordinate systems and use the principal axes to define it if possible.

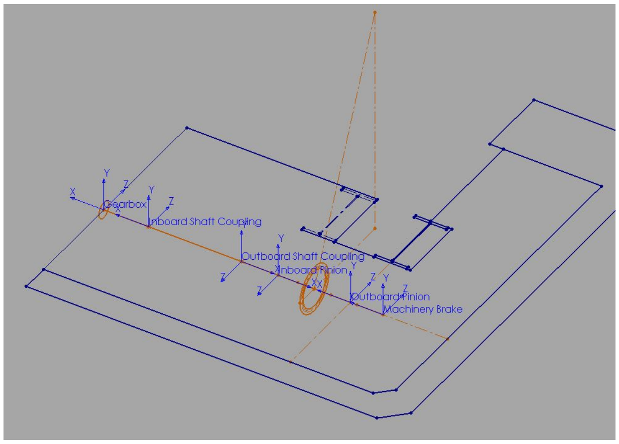

Figure 4.51: Final Machinery SSP

Now we will go back to the Motor Brake to insert the coordinate system that will mate with the coordinate system on the SSP. A plane was created in the center of the part, and then I made a sketch by converting the drum outer diameter to create a circle. The coordinate system was attached to the center of this circle. Figure 4.52 shows the final location of the coordinate system.

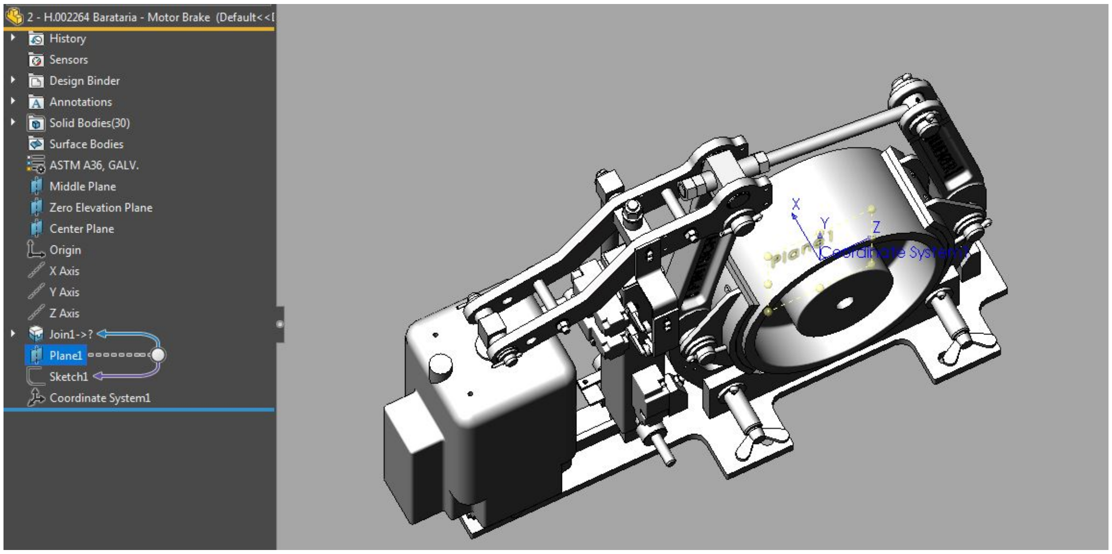

Figure 4.52: Coordinate System Location

The same technique was used to mate the bearings, machinery brake, couplings, motor, and gear box to the SSP. Figure 4.53 shows the final layout of the drive machinery.

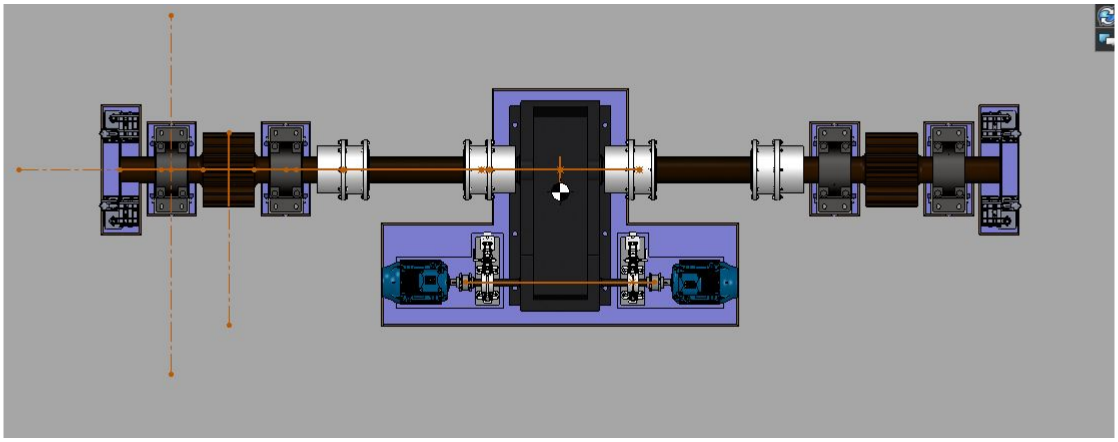

Figure 4.53: Final Drive Machinery

Trunnion Machinery

The Trunnion Machinery is a pretty small assembly, that contains the trunnion, trunnion bearings, the trunnion hub, and some limit switches and brackets. It is located in a different area from all the other machinery, so it was given its own assembly. The SSP is still a top level SSP, so its located in the Main Assembly below the Main SSP, Tower SSP, and Movable Span SSP. The derived sketches include the two in the Main SSP, the main girder sketch from the Movable Span SSP, and finally the trunnion steel sketch from the Tower SSP.

These sketches were chosen to get the proper locations of the trunnion and the base of the trunnion bearings. Two planes were created at the trunnion center line, one parallel to the Center Plane, and one parallel to the Zero Elevation Plane. Other than the two planes and four derived sketch, the Trunnion Machinery SSP only has two other sketches. The Trunnion Revolve Sketch, and the Trunnion Bearing Sketch.

The Trunnion Revolve Sketch contains a half section of the trunnion, trunnion bearing insert, and the trunnion hub. The half section is then revolved around the center line to create all of the before mentioned parts. I found this method to be superior to the vertex to vertex extruded sketch method that was used on the drive machinery shafts. This is because the shaft can be visualized in the sketch, resulting in quicker modification of the parts when needed. Figure 4.54 shows the final Trunnion Revolve Sketch.

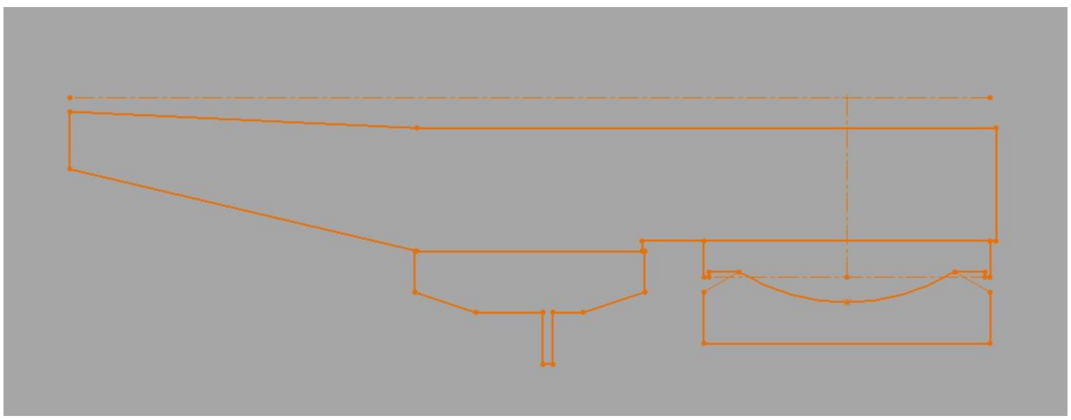

Figure 4.54: Final Trunnion Revolve Sketch

The Trunnion Bearing Sketch is more of a compliment to the Trunnion Revolve Sketch, with the major diameters tied to the first sketch. The rest of the sketch just contains the body of the trunnion bearing. Figure 4.55 Shows this sketch.

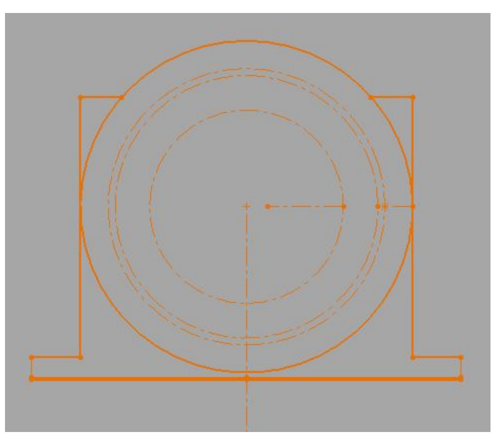

Figure 4.55: Final Trunnion Bearing Sketch

All the components were created in the Trunnion Machinery Assembly and mirrored to take advantage of symmetry. A limit switch and limit switch bracket were created as well, but they were not complex enough to include in the SSP, nor did they affect other parts. Figure 4.56 shows the final Trunnion Machinery Assembly before it was mirrored.

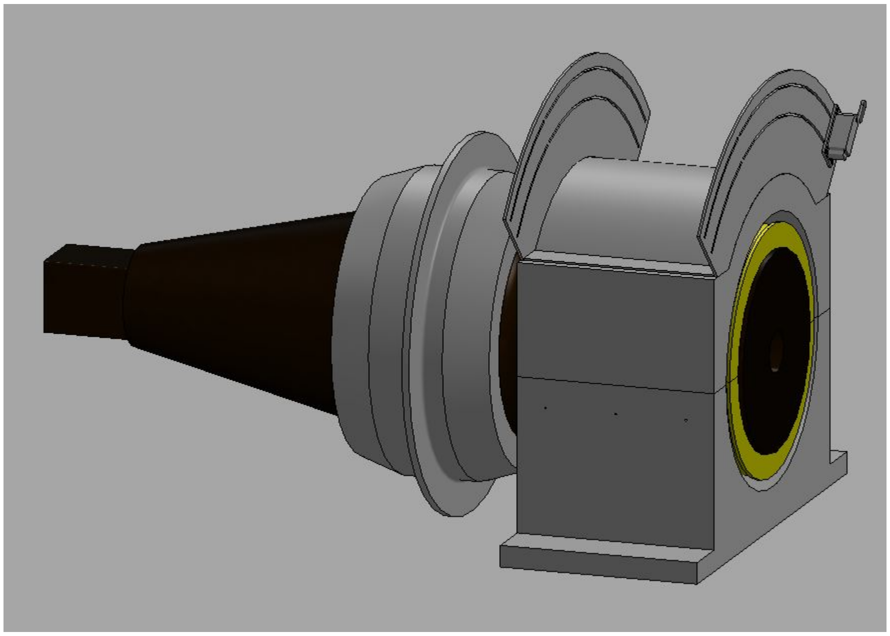

Figure 4.56: Final Trunnion Machinery