AS323927

Case Study of Design, Documentation and Construction of Curved Stone Wall

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Learning Objectives

- Get familiar with new method of modeling a curved stone wall in Revit using adaptive component families
- Understand how the adaptive component model of the wall was used to document and construct the wall on site
- Summarize the benefit of this modeling method in design/documentation and construction of the wall in comparison to conventional method.
- Discuss the significance of using adaptive component modeling method for complex geometry such as curved stone wall

Description

This class illustrates an integrated design/construction process achieved through using more advanced method of modeling/documentation of curved stone wall for a courthouse building. 2-dimensional documentation of the complex geometries might not lead into the most efficient workflow between the design/construction team. The case study demonstrates using adaptive component families in Revit to model, document and construct a 40'x440' curved stone wall with punched openings for Johnson County Courthouse Project in Olathe, KS. This class will explain the modeling method of the wall in Revit, documentation for contactor and construction of the wall on job site. As a conclusion, pros and cons for using this method will be discussed and what were learned during this process.

Project: This feature wall is being constructed for Johnson County's new 28-courtroom courthouse in Olathe KS. The anticipated completion date is fourth quarter of 2020. The anticipated cost is 175 million dollars. The contractor is JE Dunn and the design team is Treanor HL and Fentress Architects. **Modeling method:** Using adaptive component family (Revit), different types of stone panel in the curved wall were modeled precisely according to design intent, each panel is a flat segment on a curved wall. Then the adaptive panels were placed/repeated on the parametric rig which was created based on the form of the wall. Class will briefly explain the model's parameters, modeling process of adaptive components, and how it was linked into the main building model. **Documentation and construction**: the curving geometry of the wall on all sides makes it harder to document the wall in conventional method of using plan, elevation and section. Therefore, the XYZ coordinates of all the corners and stone joints' centerlines were generated using this model and were issued along with conventional 2D drawings to the contractor. Contractor used this 3D information to locate the extracted XYZ points using laser and construct the form on the construction site using the architect's model. Utilization of this workflow helped the design team to convey the design intent more effectively and efficiently to the general contractor and sub-contractors. Also, modeling the rig and panels parametrically helped the design team to tweak the form in the design process and build the mockup wall to test the method before the actual wall construction. Through illustration of this case study, using adaptive component to design and document a complex geometry and how it effectively can improve the coordination between the trades and decrease the amount of change or error in construction, is explained in this paper. The conclusion will be lessons learned in this project and pros and cons of using this method.

Speakers

- Zahra Mirian Hosseinabadi:

Zahra Mirian Assoc. AIA is architectural designer whose work focuses on building information modeling and integration of design and construction process for more effective workflow. She has worked on wide range of commercial project such as airport and courthouse around United States. She received her Master of Architecture from North Carolina State University and Master of Building Construction Science and Management from Virginia Tech and is currently working for Colorado-based design firm, Fentress Architects. She also has previous work experience as BIM Specialist. Her passion is using new tools to optimize the design/construction workflow.

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- Brian Mackey:

Known as "The Revit Geek", Brian has spent more than 25 years in the industry, more than 10 of which have been focused on Revit. Over a decade of working with Architects and Engineers to advance BIM in their companies, Brian started his BIM consulting company in 2011 to focus on custom high-level training/mentoring. Brian has clients all over the US/Canada that generally tolerate his sarcastic nature in exchange for his wide breadth of BIM knowledge. Brian showcases his love of talking about Revit, or maybe just his love talking, in a monthly light-hearted, occasionally irreverent, free Q&A webcast, Revit Radio.
Brian is a regular speaker at many conferences, including Autodesk University, BIM Workshops and BiLT, where he has been awarded top speaker several times. Brian and his wife, who met at AU, welcomed Vienna in 2013, for a total of three daughters and in 2016 welcomed a son Paxton.

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- Dylan Lowder

Dylan has a Bachelor of Science in Architectural Studies and a Masters of Architecture from Southern Illinois University (SIU). While in school he found his interests were really in understanding how designs were to be built. It was during Dylan's time working in the digital fabrication shop at SIU that this passion grew. After graduating he spent a brief time working in a fabrication shop where I was a detailer and did tool-pathing for CNC milling. In 2011, Dylan joined the Virtual Design and Construction (VDC) team at JE Dunn Construction. For the last four years, his focus at JE Dunn has really been in what capabilities and with what resources can the VDC team work with and help the Self Perform Group. Dylan's interests are focused around self-perform drawing creation, the layout process, and working directly with our superintendents and foremen to deliver exceptional products to our clients. *"At JE Dunn Construction we are builders and the digital tools I have allow me to directly have an impact on the work that is being put in place every day."*

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1- Design

1-1- Project Introduction

The design/construction of Johnson County Courthouse project was completed under design-build delivery method with JE Dunn Construction as the General Contractor, Treanor HL as Architect of Record and Fentress Architects as the Design Architect. The client was facilities management department of the Johnson County.

DESIGN/CONSTRUCTION TEAM

Johnson County Courthouse project located in Olathe, Kansas with the overall project budget of 175 million dollars, is meant to replace the existing courthouse at the time of completion. The total building area is 350,000 with 7 floors and 1 basement level and the total of 140 ft tall building. The program is consisted of a total of 28 courtrooms for the project.

The concept design began December 2017, ground breaking on July 2018 and the construction is expected to be complete on the fall of 2020.

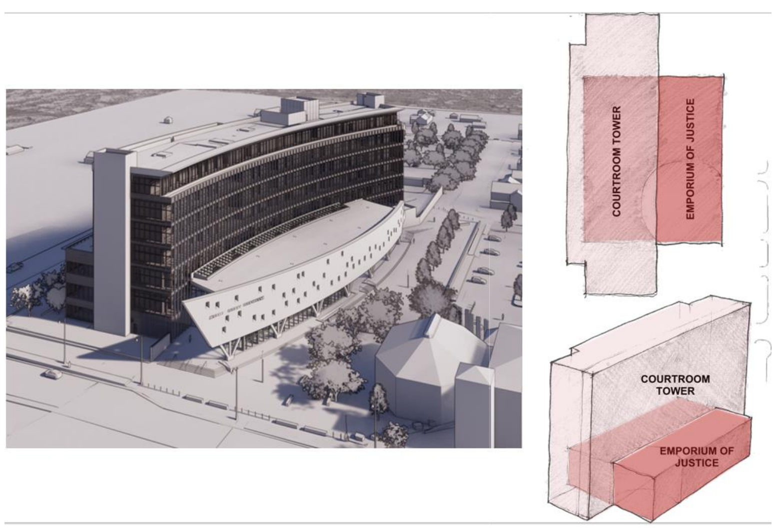
MAY 2019 - CONSTRUCTION PROGRESS

SEPTEMBER 2019 – CONSTRUCTION PROGRESS

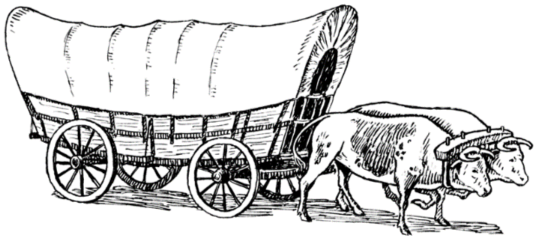
OCTOBER 2019 - CONSTRUCTION PROGRESS

1-2- Project Design and Ribbon Wall Design

The Courthouse Project massing is illustrated here and is comprised of two main blocks being the courtroom tower and the Emporium of Justice. The most prominent feature of the courthouse design is the long-curved wall along the east side of the building, known as the Ribbon Wall. This wall forms the eastern edge of the two-story podium containing the public functions of the courthouse. The form of this wall was derived from a historical reference to Olathe, Kansas, the location of the project. In the early 1800s, the Oregon Trail, the great migratory route west, passed through Olathe. One of the great symbols of that migration is the Conestoga Wagon, also referred to as the Prairie Schooner. The profile of the Ribbon Wall is an interpretation of the shape of the Prairie Schooner. The diagonal structure supporting the wall references the structural bracing for the wagon's canopy. The wall is also faced with local Kansas limestone, quarried near Olathe.



OVERALL MASSING

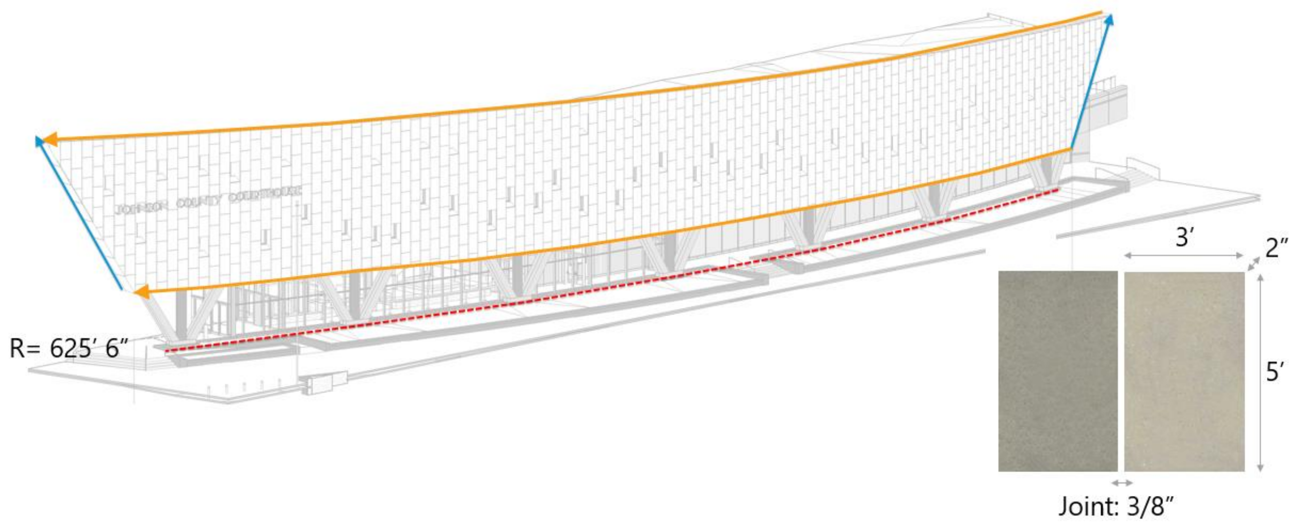


Conestoga Wagon – image is taken from: https://commons.wikimedia.org/wiki/File:Prairie_schooner_(PSF).png

Overall Exterior View of the Courthouse

Interior View of the Lobby with Ribbon Wall Enclosure

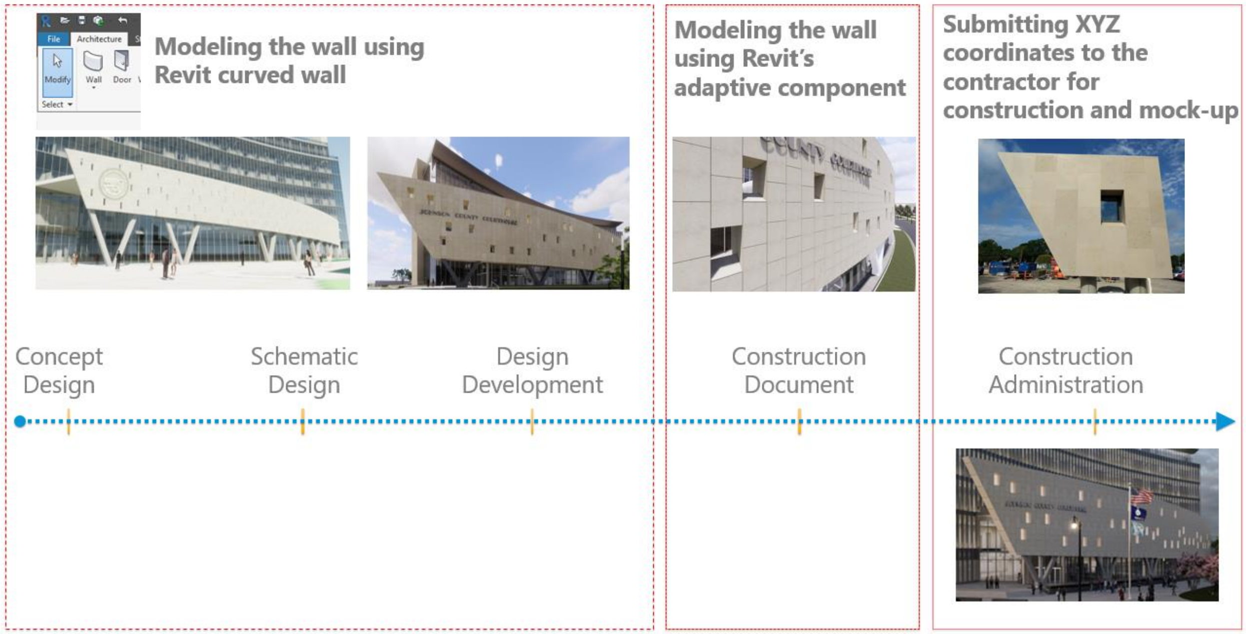
The image below illustrates the overall characteristics of the Ribbon Wall form. The wall is curved on the 625' 6" radius with approximately 440' length and 40 feet at the tallest part. To ends of the wall is sloped up and the top and bottom of the wall is also sloped. The finish material of the wall is limestone with a 3' x 5' module repeated with 3/8" joints in between. The stones are laid in staggered pattern along the wall. The overall thickness of the wall is 4'7".



RIBBON WALL (STONE WALL)

1-3- Design / Modeling / Construction Process

The figure below illustrates the different phases of the project in relation to the design and documentation of the Ribbon Wall. Concept Design and Schematic Design where the design team was going through the form finding process, the forms were modeled using Revit Default wall tool. As the project progressed, a more precise modeling technique was integral to be able to convey the design intent accurately. Revit's adaptive component was chosen as a platform to model the wall in Construction Document phase which allowed the design team to model all the stone panels, openings and windows precisely according to the design intent (explained in section 2-Modeling). And finally, at the end of the CD phase, the 3D geometry was documented both conventionally and by submitting the XYZ of all the corners and centerline of the joints. (explained in section 3) Then contractor, used these points to construct the wall accurately according to the design intent. (explained in section 4-Construction)



DESIGN AND DOCUMENTATION IN RELATION TO PROJECT TIMELINE

2- Modeling

2-1- The Revit Families

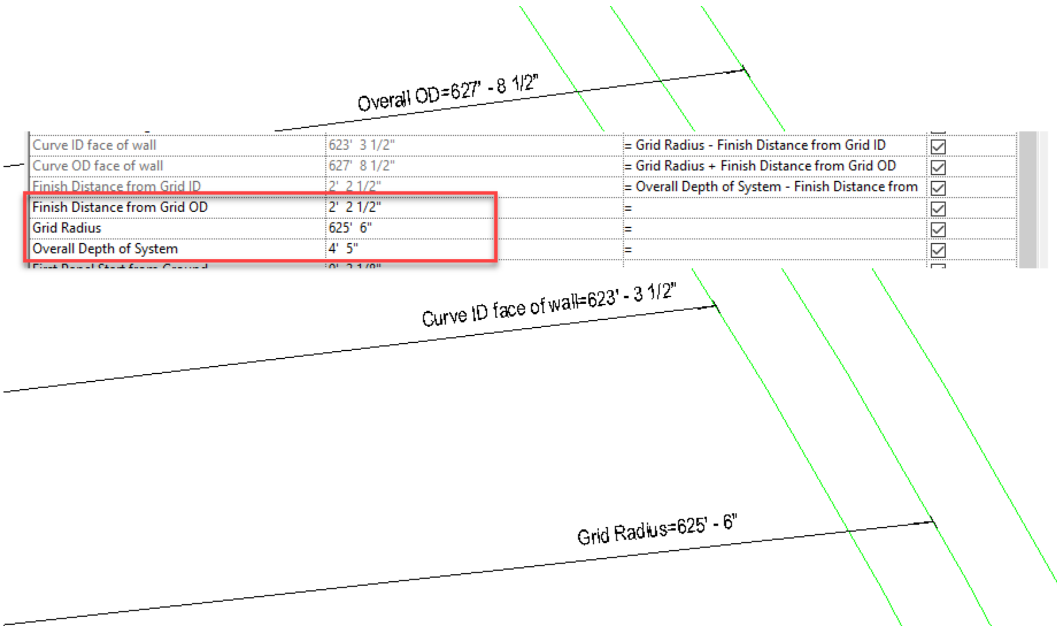
This project had two requirements for the panel; Maximum width of 36" (915 mm) from center of reveal to center of reveal, and for the reveals to align to the center point of the circle. Which means the panels on the inside radius (ID) would be narrower than the outside radius (OD). The other was to make as many panels the same size as possible. With the exception of the outside panels all of the inside panels should be the same size. The grid radius had been set in the project environment, the rest of the wall variables were not set and there was potential for change. Knowing all of this could be done natively inside Revit it was determined that this would be done with massing and adaptive components. All of the panels were to be adaptive components which would be nested into a mass family rig which utilized reference points and surfaces to where the panels would be hosted. Those surfaces were divided by intersects thus creating nodes for the adaptive panels to be hosted. This was the chosen method instead of curtain panel pattern systems due to the needed flexibility, irregular layout and the placing openings in lieu of panels.

2-1-1- The Rig

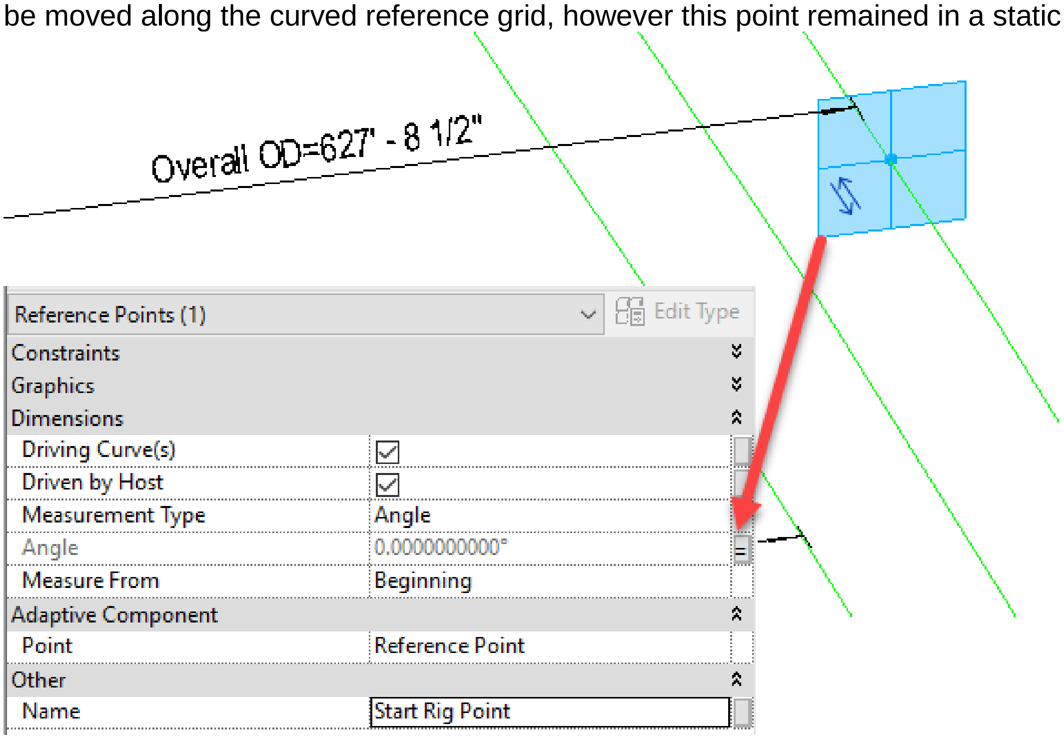
The rig or framework to host the adaptive families was started with the Mass family template. Inside this family curved reference lines were established as the base, then reference points were associated to those lines. Once points were established additional reference lines were hosted onto those points in which the surfaces were created to be divided by intersects. Once all of that was established adaptive families were created and loaded to host onto the nodes of the surfaces.

- Base Reference Lines

The radius of the grid line in the project was established and the only know value we had to work with when starting the system. The OD and possibly ID were going to change as the details were figure out, along with the overall depth of the system. With all of these defined the logical place to start was with a reference for the grid value from the project. Therefore, a reference line was drawn with a parameter to match the radius of the grid from the project. There were additional parameters added for distance from grid to outside and overall wall thickness, these were then added to a formula to calculate the OD and ID values.



Once these radii were set a reference point was hosted on the OD reference line, which would determine the start or base of the panel system. This point was parametrized such that it could be moved along the curved reference grid, however this point remained in a static location.

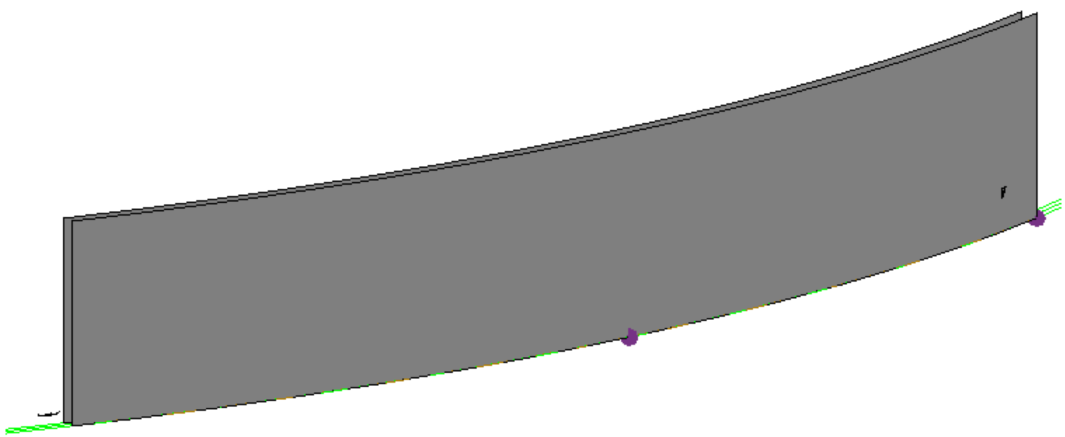


An additional point was hosted on the OD reference line and parametrized for the end of the entire wall segment. Additionally, there were the same points hosted to the ID reference line. Since all of these points were set to have a Measurement Type of Angle and that Angle was then parametrized this keeps all of the point's perpendicular to each other or relative to the center of the radius.
Additionally, there will need to be a reference point at the midpoint between these two points so additional points were hosted and assigned to a parameter who's value was half of the other two.

Layers			
End Angle	-34.1711711521°	=	☑
Mid Angle	-17.0855855761°	= (End Angle - Start Angle) / 2	☑
Start Angle	0.0000000000°	=	☑

- Creating the Surface

Now these six points were placed as the foundation for the rig surfaces need to be added. To accomplish this a curved reference line was created using the three points on the OD as well as one using the points on the ID. The newly created reference lines were selected independently, and the create form command was selected. This in turn created a vertical surface for each line. These surfaces will serve as the base for later dividing to create host nodes.

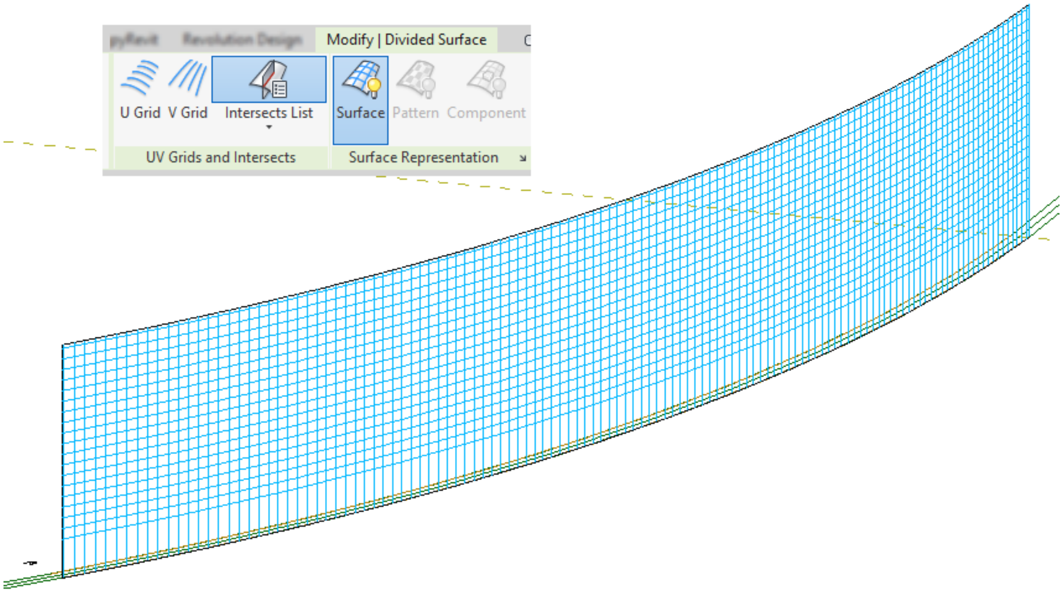


- Dividing the Surface

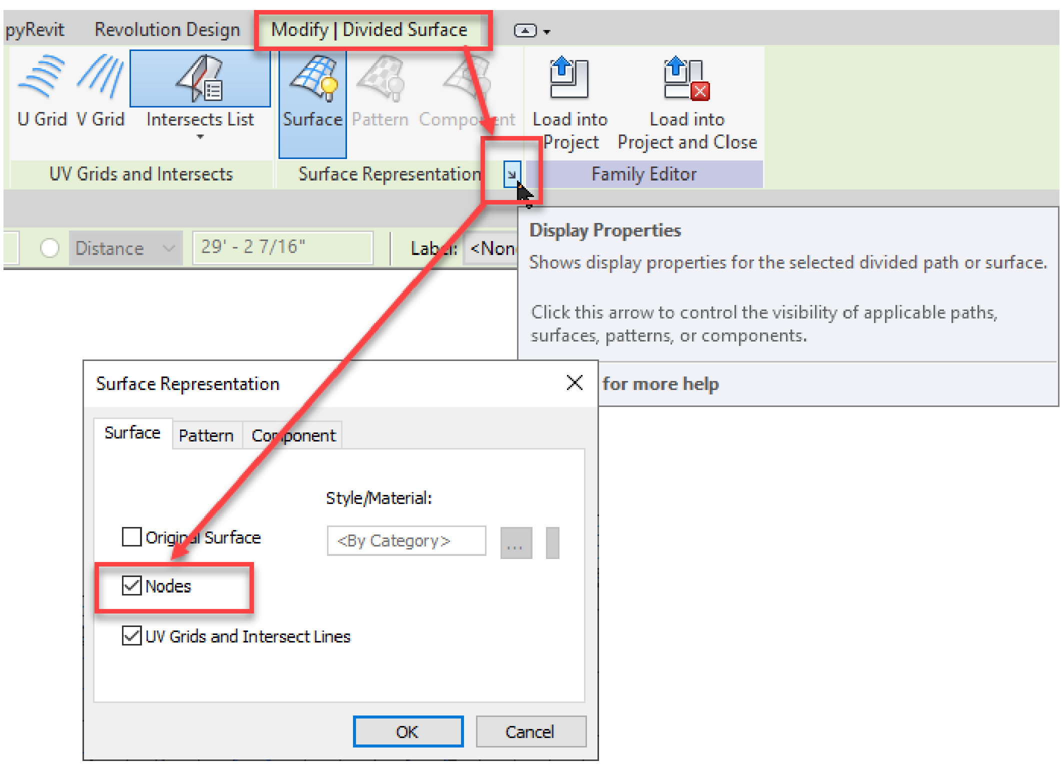
Once the surface has been created it will need to be divided. There are a couple of ways to do this, one is to divide it by U&V Grids and the other is to divide it by Intersects. U&V grids would work in this situation, but a formula would be needed to calculate the chord length of the surface based upon the radius. In this case dividing by intersects was the desired choice.

- Intersects

Intersects can be done several different ways. One is to choose from a drop-down list which can contain named Reference Planes or Levels (Grids in the project environment). The other intersects can be selected on screen which may also include Reference or Model lines. In this project both reference planes and lines were utilized. Reference planes were used for the horizontal intersects and reference lines were used for the vertical intersects.



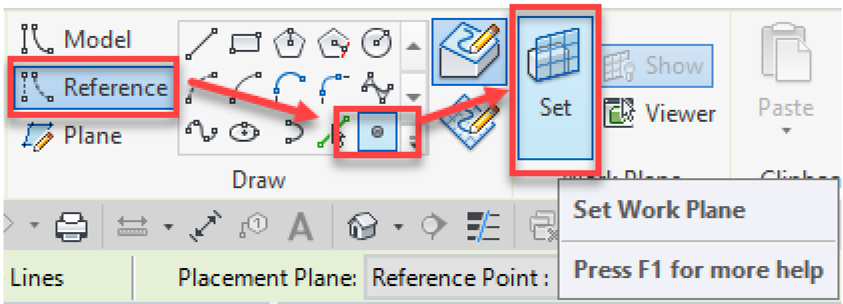
Once a surface has been divided it is possible to change the visual representation. When placing adaptive components, the nodes will need to be visible. To do this select the surface and in the contextual ribbon use the flyout arrow on the Surface Representation panel, then check the nodes for that surface. This will allow for the future placement of the adaptive component families.



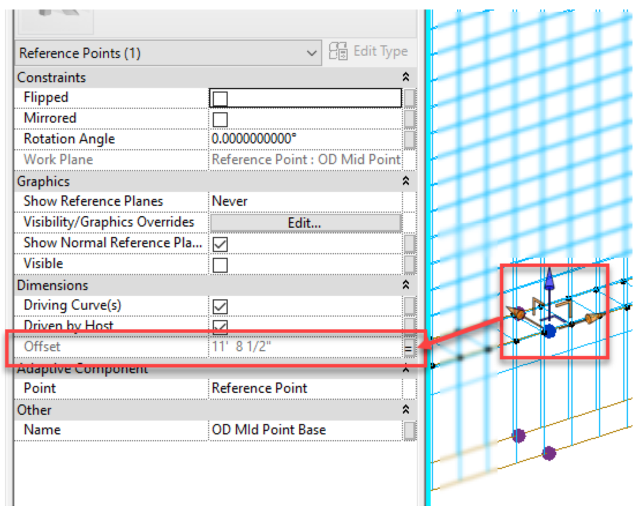
- Panel Planes

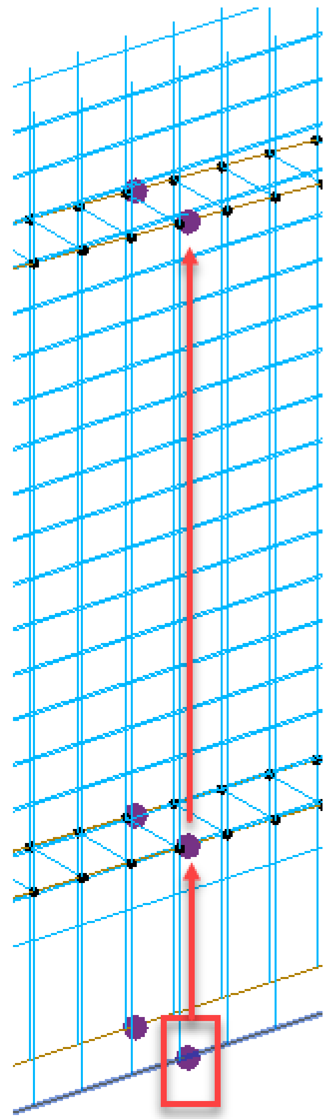
Once the two vertical surfaces were created and divided the real shape and size of the wall system then needed to be created. This was done by adding additional points to the control points and then creating reference lines associated to those points. This in turn gave the outline of what was required for all the final surfaces.

The first step was to host new reference points onto the OD & ID start, mid and end control points. To accomplish this the work plane of the desire point must be set before hosting a new point.

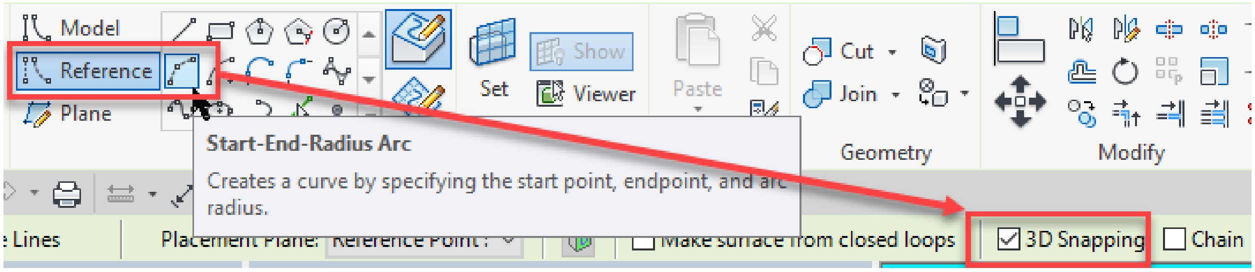


Once the work plane is set then tabbing through the three different planes of the point until the desired one is highlighted. Once the point is placed assign a parameter to the offset value. This process was repeated for the top and bottom slopes at each end as well as the middle.

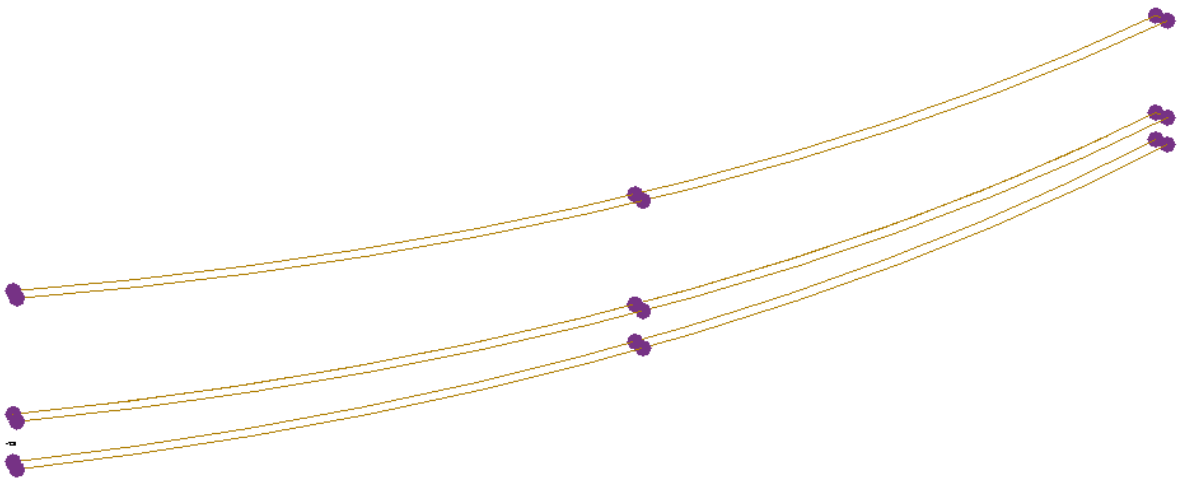




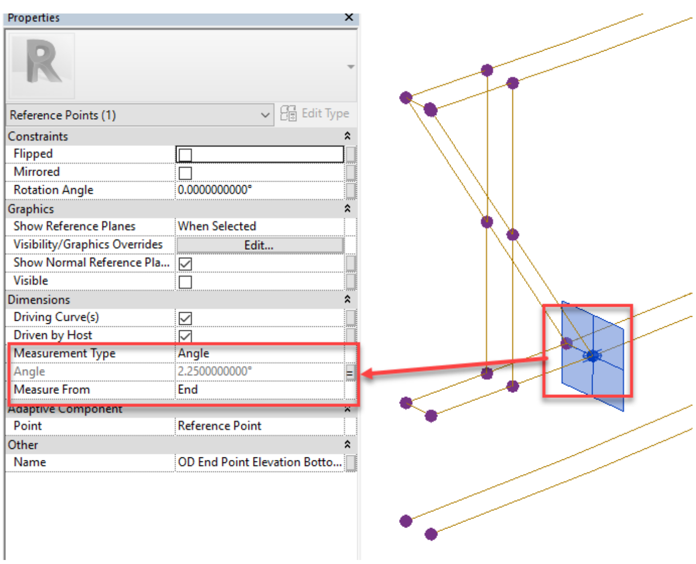
Now that all the true surface control points have been created curved reference lines associated to the appropriate points will be needed. This was accomplished using the “Start-End-Radius Arc” command was used while utilizing the 3D snapping option.



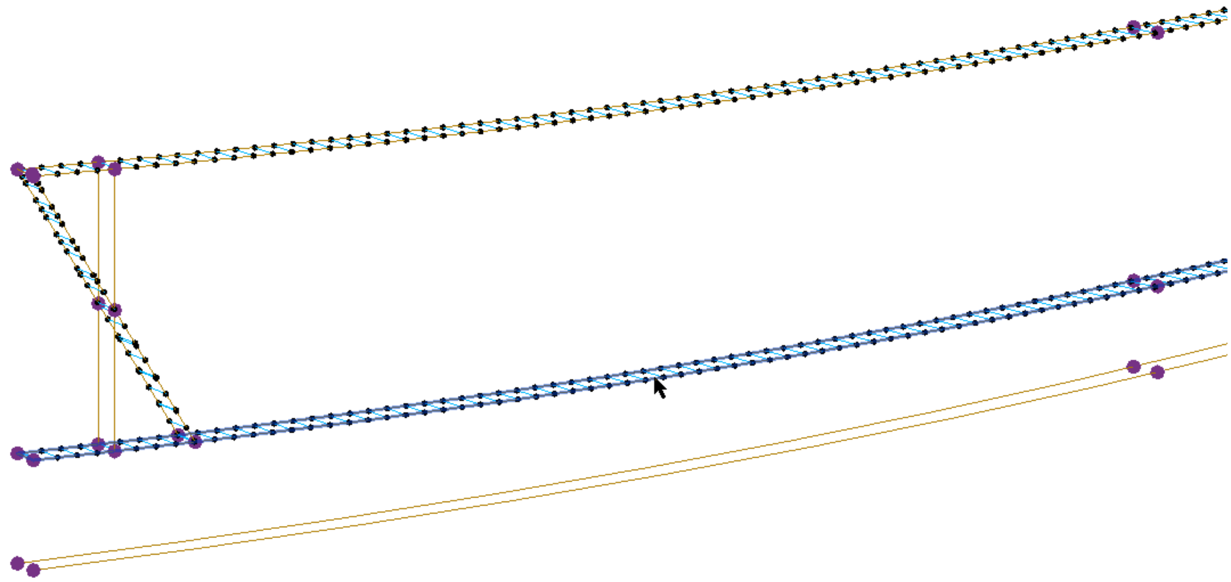
This was repeated for both the ID & OD top and bottom to generate the basis of the slopes for each.



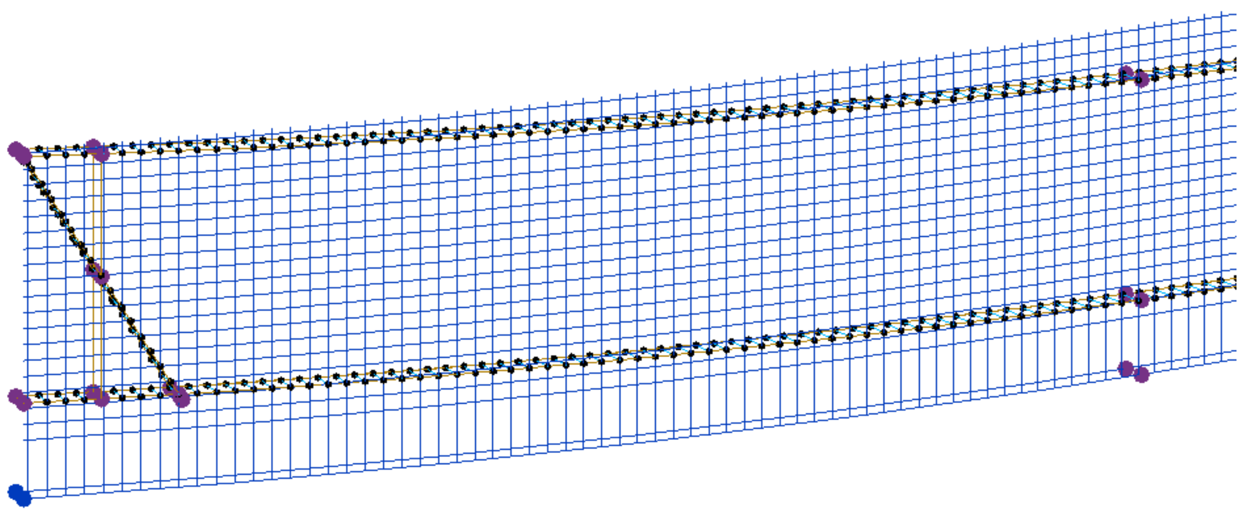
For the end angles additional reference points were hosted on the newly created reference lines and these were associated to an angle value. Then reference lines were used to connecting the points to create the basis of the end surface



The reference lines were then selected to create faces and those faces were divided using the same intersect as the vertical faces.



The end result with all of the nodes represented for all of the non-vertical surfaces as well as only the OD surface visible.

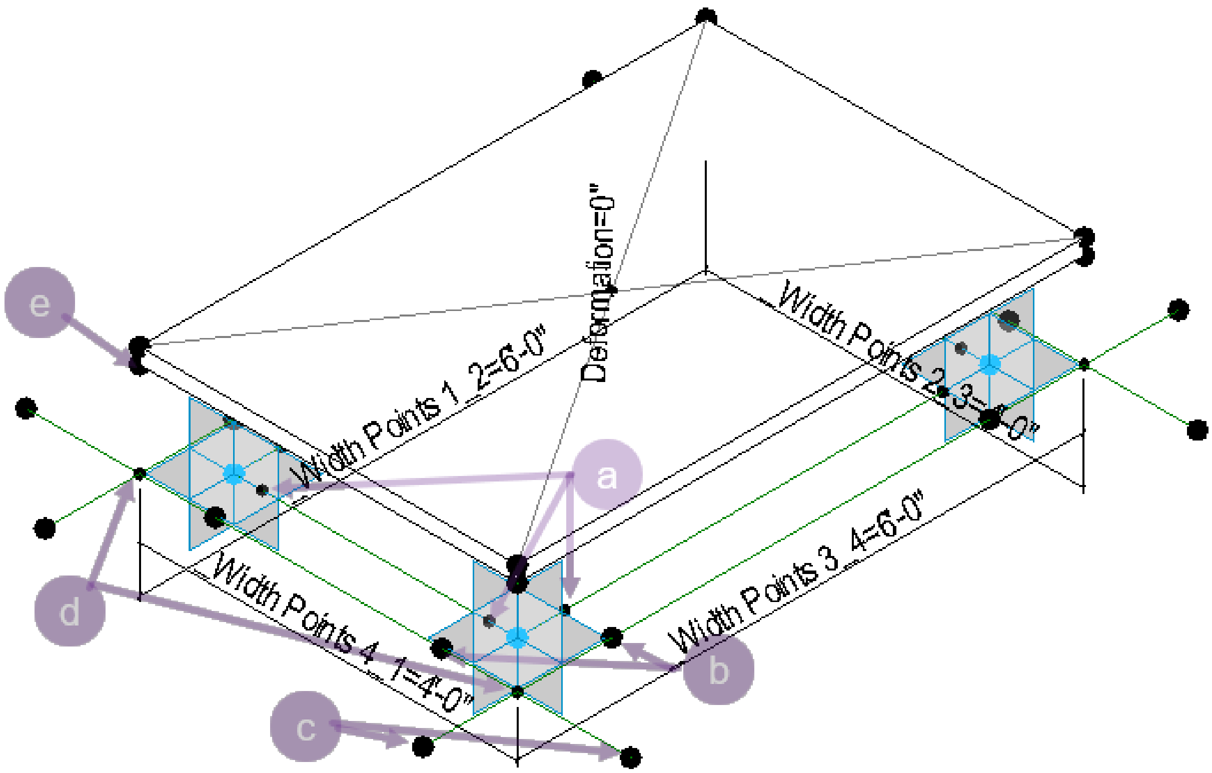


2-2- The Panel Families

Sticking with the theme of adaptive families all the panelization utilized custom adaptive component families. This project only had 3 different family types. One for all the standard flat panels, one for the openings and one for the edges. As the design changed an additional panel was needed for the edges certain opening, so an additional family was created and loaded into the project.

2-2-1- Standard Flat Panel

If a firm is doing a lot of work with panelization or simply utilizing adaptive families then a standard family type should be a rectangular panel. This family could be utilized in many different situations. For example, railing panel families, stone panels, wall panelization etc. This particular family is one of those families. This family is a 4 point adaptive family that will allow for each side of the panel to independently be inset or extend past the placement points. As well as be above or below the placement points. It will also report any deformation from corner to corner such that it can be verified flat. It will also report the length of every side.



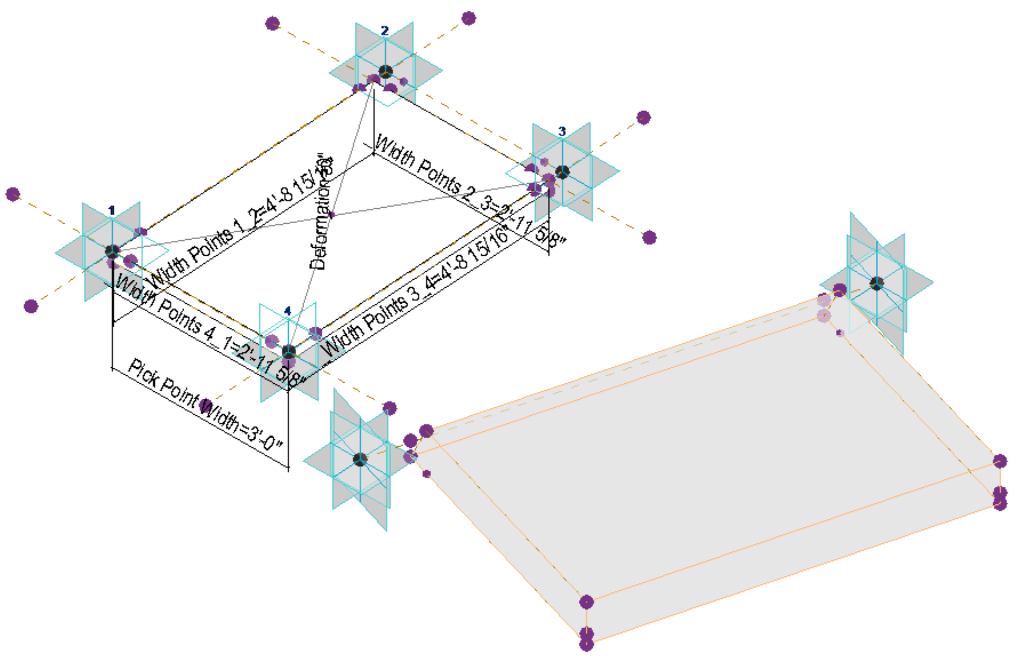
This family is done in a similar fashion to the overall rig as stated above. There are 4 adaptive points which then have reference lines modeled between them. On each of those lines there is are two reference points (a) hosted, each of which has an offset from end value. These points are simply there to be a host for an additional point (b) which will represent the offset for each panel edge. Hosted to point (b) is an additional point (c) which will allow for a reference line to extend past the overall surface. Between all the (c) points a reference line is created to connect those points. Upon that reference line, point (d) is hosted and then set to be hosted at the intersections of these reference lines. Then point (e) is hosted to point (d) an offset value is added, making it possible to offset the entire panel from the adaptive points. To finish the panel reference lines were drawn between all the (e) points and a solid was created from those lines.

Once the solid for the panel was created model lines were drawn diagonally from each corner and reference points were hosted on the midpoint of each line. These points then had a dimension which was set as a reporting parameter to indicate the value of any deformation.

Additionally, reporting parameters were associated to all of the (d) points to indicate the length of the panel edges.

2-2-2- Edge Panel

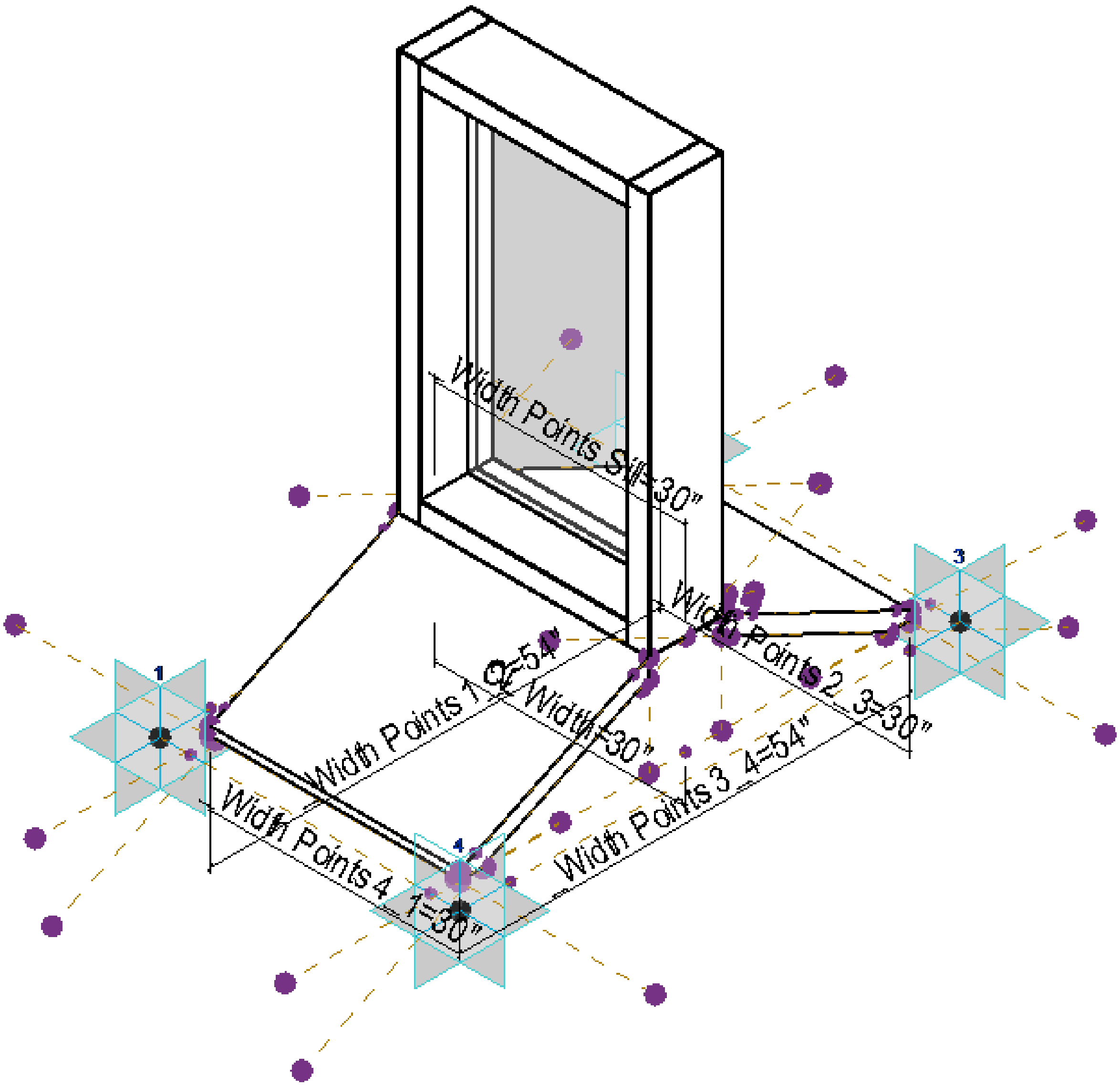
At the end locations of the wall the panels are cut at an angle. This couldn't be completed with a 4 point adaptive family. One of two solutions were needed several different families that had different placemen point configurations or a single panel family that would have 2 additional placement points that would host a void to cut the panel. Since loading fewer families into a project helps the speed of Revit it was decided to go with the later. The standard panel family was saved as a new family and two additional shape handle points were added. Shape handle points are still adaptive points however they are different to placement points in that they are not part of the placement process. They are selected after the family is placed and hosted to elements within the model.



The shape handle points have a reference line drawn between then, then points are hosted to the reference lines and points are hosted to points etc.

2-2-3- Opening Panel

The opening family had the same 4-point adaptive base rig as the standard panel family. However, this family has additional points to allow for the panel to slope in two directions. Thusly it also has a nested window family that can be turned on or off as needed.



2-3- Placing the families

Once the rig was created and the adaptive families were created it was time to place the families. Due to the shape of the surfaces as well as the randomness of the windows the repeater command was not used. Instead each panel was placed manually by selecting all 4 points.

2-4- Shameless Plug

For additional information on adaptive components see these previous AU sessions:
https://www.autodesk.com/autodesk-university/class/Using-Revit-Structure-Investigative-Engineering-2013

https://www.autodesk.com/autodesk-university/class/Conceptual-Structural-Design-Using-Revit-Adaptive-Components-and-Dynamo-2017

3- Documentation

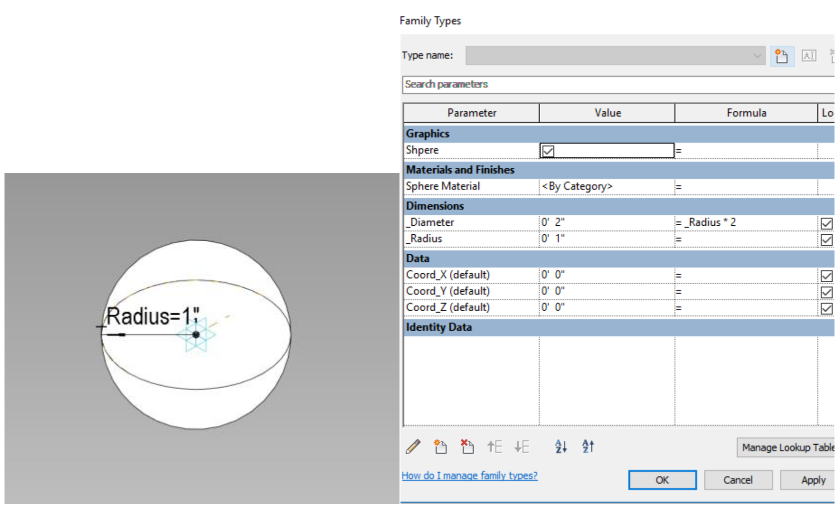
To convey the design intent precisely, the wall was documented using two techniques:

1- Conventional Plans, elevations, sections and wall sections. The curving wall makes the documentation of the stone panels and joints very challenging since It is hard to annotate stone panels in true elevations. Therefore, design/construction team agreed on using second method of documentation for construction

2- BIM assisted documentation of the ribbon wall allowed the design /construction team to install the wall with minimal amount of change and rework.

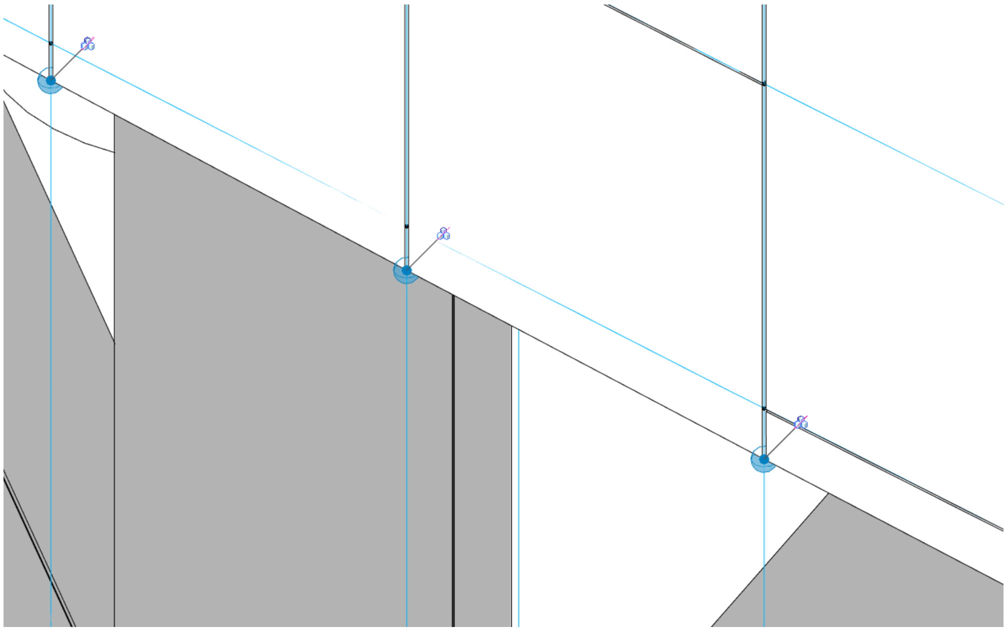
For this purpose, adaptive Point Sphere was used for XYZ data extraction for contractors. Then contractor was able to locate the wall in space using these points.

RIBBON WALL STONE PANELS

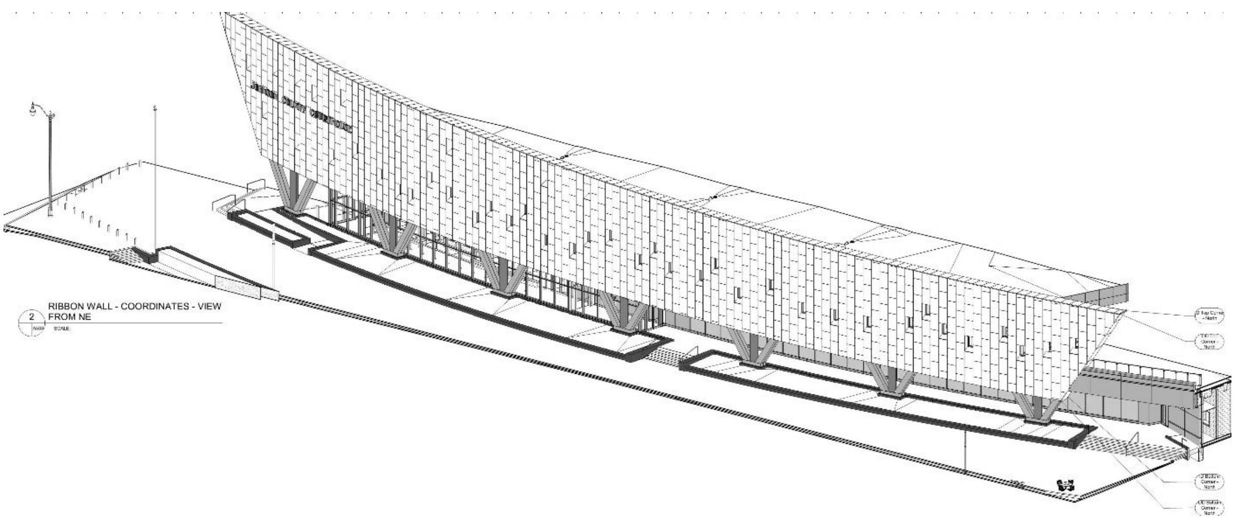


ADAPTIVE POINT SPHERE

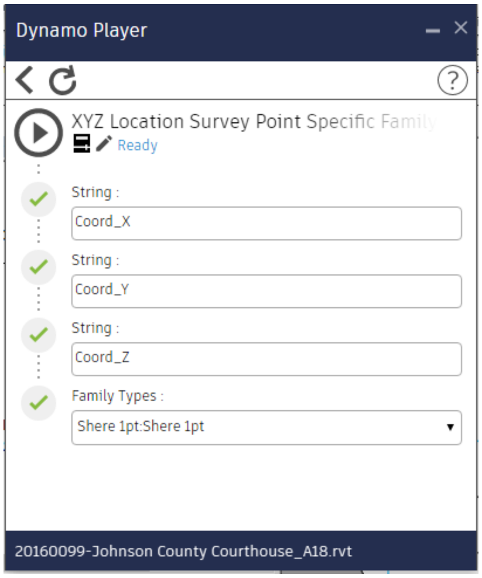
The adaptive point sphere was placed on the outside corners of the wall as well as the centerline of all the stone joints. All the points were named according to their location. As next step, a Dynamo script was run to generate the XYZ coordinates of where the points are located. And finally, the XYZ table was generated in Revit Schedule format and handed off to contractor as a sheet in the construction document. It is also important to mention that the design/construction team tested this method of modeling/documentation/construction by building the mockup of the wall in smaller scale. Due to the parametric nature of the adaptive families, same families were used to model the mock up wall. Parameters of the families were changed to adjust the model for the mock up size.



ADAPTIVE POINT SPHERE PLACEMENT ON THE MODEL



NAMING ALL THE ADAPTIVE POINT SPHERES AND ANNOTATING THEM



DYNAMO SCRIPT FOR XYZ EXTRACTION OF ALL THE ADAPTIVE POINT SPHERES

Point Locations XYZ

Comments	Coord_X	Coord_Y	Coord_Z
OD Bottom Corner - North	161.274	-11.749	108.730
ID Bottom Corner - North	160.965	-7.343	108.750
OD Bottom Corner - South	-159.348	50.932	114.602
ID Bottom Corner - South	-157.391	54.891	114.581
ID Top Corner - South	-179.121	66.090	153.662
OD Top Corner - South	-181.355	62.289	153.916
OD Top Corner - North	181.059	-10.045	139.074
ID Top Corner - North	180.452	-5.667	138.831
OD PG 1	-159.194	50.856	114.599
OD PG 2	-156.422	49.504	114.545
OD PG 3	-153.719	48.203	114.493
OD PG 4	-151.010	46.914	114.441
OD PG 5	-148.295	45.639	114.388
OD PG 6	-145.573	44.376	114.336
OD PG 7	-142.846	43.127	114.283
OD PG 8	-140.113	41.890	114.231
OD PG 9	-137.374	40.667	114.178
OD PG 10	-134.629	39.456	114.126
OD PG 11	-131.878	38.259	114.073
OD PG 12	-129.122	37.075	114.020
OD PG 13	-126.360	35.904	113.967
OD PG 14	-123.592	34.746	113.915
OD PG 15	-120.819	33.602	113.862
OD PG 16	-118.040	32.471	113.809
OD PG 17	-115.256	31.353	113.756
OD PG 18	-112.467	30.248	113.703
OD PG 19	-109.673	29.157	113.650
OD PG 20	-106.873	28.079	113.596
OD PG 21	-104.068	27.015	113.543
OD PG 22	-101.259	25.964	113.490
OD PG 23	-98.444	24.926	113.437
OD PG 24	-95.624	23.902	113.383
OD PG 25	-92.799	22.892	113.330
OD PG 26	-89.970	21.895	113.277
OD PG 27	-87.136	20.911	113.223
OD PG 28	-84.297	19.941	113.170
OD PG 29	-81.454	18.985	113.116
OD PG 30	-78.606	18.042	113.063
OD PG 31	-75.753	17.112	113.009
OD PG 32	-72.897	16.197	112.956
OD PG 33	-70.035	15.295	112.902
OD PG 34	-67.170	14.407	112.848
OD PG 35	-64.300	13.532	112.795
OD PG 36	-61.427	12.671	112.741
OD PG 37	-58.549	11.824	112.687
OD PG 38	-55.667	10.991	112.634
OD PG 39	-52.781	10.171	112.580
OD PG 40	-49.891	9.366	112.526
OD PG 41	-46.998	8.574	112.472
OD PG 42	-44.100	7.796	112.419
OD PG 43	-41.199	7.032	112.365
OD PG 44	-38.295	6.281	112.311
OD PG 45	-35.387	5.545	112.257
OD PG 46	-32.475	4.822	112.203

Point Locations XYZ

Comments	Coord_X	Coord_Y	Coord_Z
OD PG 47	-29.560	4.114	112.149
OD PG 48	-26.642	3.419	112.095
OD PG 49	-23.720	2.738	112.042
OD PG 50	-20.795	2.072	111.988
OD PG 51	-17.867	1.419	111.934
OD PG 52	-14.936	0.780	111.880
OD PG 53	-12.001	0.155	111.826
OD PG 54	-9.064	-0.455	111.772
OD PG 55	-6.124	-1.052	111.718
OD PG 56	-3.181	-1.635	111.664
OD PG 57	-0.236	-2.203	111.610
OD PG 58	2.712	-2.758	111.556
OD PG 59	5.663	-3.298	111.502
OD PG 60	8.617	-3.824	111.448
OD PG 61	11.573	-4.336	111.395
OD PG 62	14.531	-4.834	111.341
OD PG 63	17.492	-5.318	111.287
OD PG 64	20.455	-5.788	111.233
OD PG 65	23.420	-6.243	111.179
OD PG 66	26.387	-6.685	111.125
OD PG 67	29.356	-7.112	111.071
OD PG 68	32.328	-7.525	111.017
OD PG 69	35.301	-7.924	110.964
OD PG 70	38.276	-8.308	110.910
OD PG 71	41.253	-8.678	110.856
OD PG 72	44.232	-9.035	110.802
OD PG 73	47.212	-9.376	110.749
OD PG 74	50.195	-9.704	110.695
OD PG 75	53.178	-10.017	110.641
OD PG 76	56.163	-10.316	110.587
OD PG 77	59.149	-10.601	110.534
OD PG 78	62.137	-10.872	110.480
OD PG 79	65.126	-11.128	110.427
OD PG 80	68.116	-11.370	110.373
OD PG 81	71.108	-11.598	110.319
OD PG 82	74.100	-11.811	110.266
OD PG 83	77.093	-12.010	110.213
OD PG 84	80.088	-12.195	110.159
OD PG 85	83.083	-12.365	110.106
OD PG 86	86.079	-12.521	110.052
OD PG 87	89.075	-12.663	109.999
OD PG 88	92.072	-12.791	109.946
OD PG 89	95.070	-12.904	109.893
OD PG 90	98.069	-13.003	109.839
OD PG 91	101.067	-13.087	109.786
OD PG 92	104.066	-13.157	109.733
OD PG 93	107.066	-13.213	109.680
OD PG 94	110.066	-13.255	109.627
OD PG 95	113.065	-13.282	109.574
OD PG 96	116.065	-13.295	109.521
OD PG 97	119.065	-13.293	109.468
OD PG 98	122.065	-13.277	109.415
OD PG 99	125.065	-13.247	109.363
OD PG 100	128.065	-13.203	109.310

Point Locations XYZ

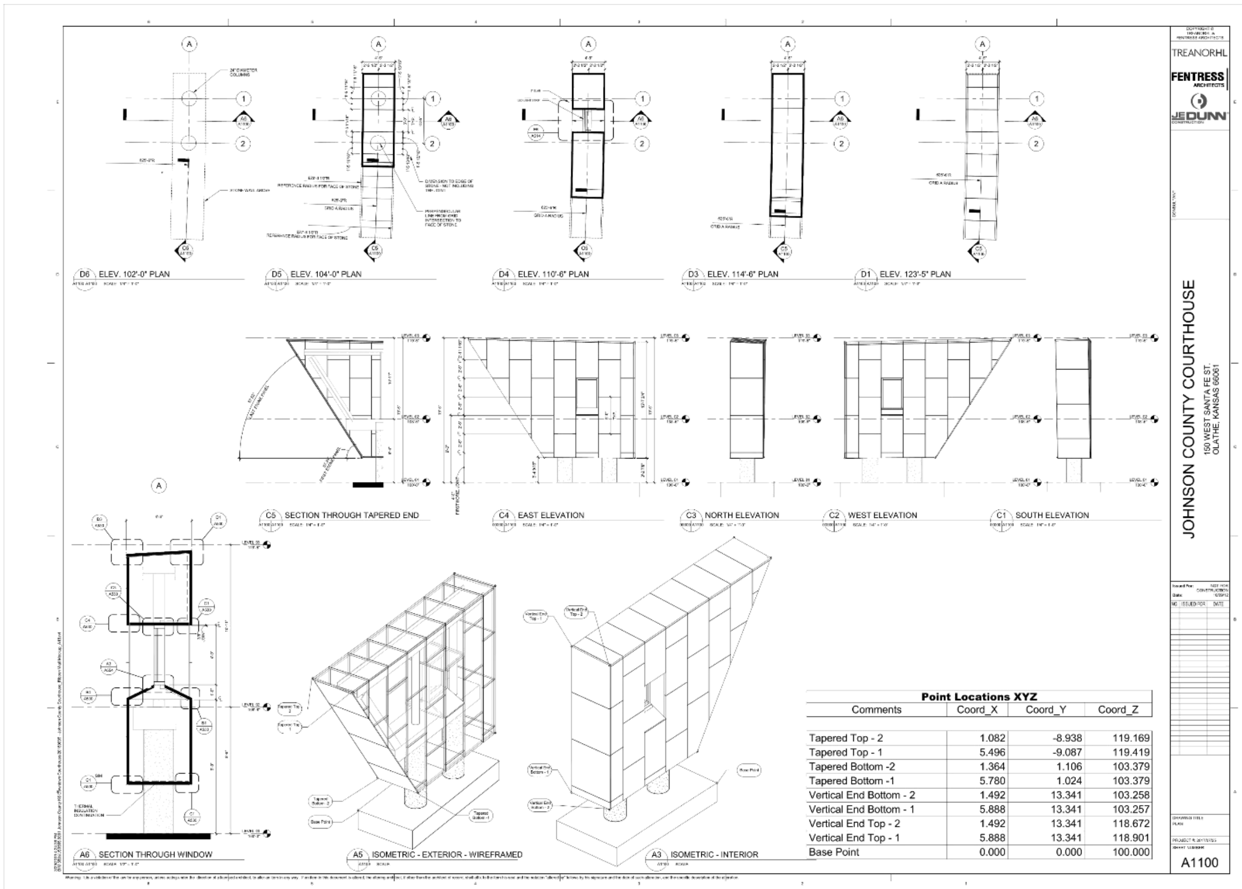
Comments	Coord_X	Coord_Y	Coord_Z
OD PG 101	131.064	-13.144	109.257
OD PG 102	134.063	-13.071	109.205
OD PG 103	137.062	-12.983	109.152
OD PG 104	140.060	-12.881	109.100
OD PG 105	143.058	-12.765	109.047
OD PG 106	146.055	-12.635	108.995
OD PG 107	149.051	-12.490	108.942
OD PG 108	152.047	-12.331	108.890
OD PG 109	155.042	-12.157	108.838
OD PG 110	158.036	-11.969	108.786
OD PG 111	161.029	-11.767	108.734
Base Point	0.000	0.000	0.000

NOTES:

BASE POINT IS LOCATED AT THE INTERSECTION OF GRID XA AND GRID X4
BASE POINT AT LEVEL 1 IS:
X: 0
Y: 0
Z: 100'

OD PG POINTS REFER TO ALL THE VERTICAL STONE JOINTS ON THE RIBBON WALL WITH THE Z VALUE = THE BOTTOM OF THE SOFFIT ELEVATION

XYZ REVIT SCHEDULE SUBMITTED TO CONTRACTOR



RIBBON WALL MOCKUP SHEET – DOCUMENTATION WITH SAME METHOD

RIBBON WALL MOCKUP – COMPLETED CONSTRUCTION

4- Construction

4-1- Verifying Ribbon Wall Coordinates

Fentress and Treanor HL provided in the construction documents all coordinates for the center of the stone joints and the corners of the Ribbon wall. These coordinates were in relative coordinates. Relative coordinates are what most design teams work in. Base point for the Ribbon Wall (0,0) was the intersection of Grid XA (center of wall) and X4 (center of wall perpendicular). JE Dunn verified that the provided Ribbon Wall and it's panels joints matched what was provided in the CD's. *See Figure 1*

When all panel joints and corner extents were verified Autodesk Point Layout was used to place points on the center of panel joints and corner extents of the Ribbon Wall. Those points were then exported out as State Plane Coordinates, JE Dunn prefers to do all our layout in real world coordinates. This allows points be loaded into our data collectors and laid out using one of our robotic total stations. The State Plane coordinates are shown in the boxes on the bottom of image above. *See Figure 2*

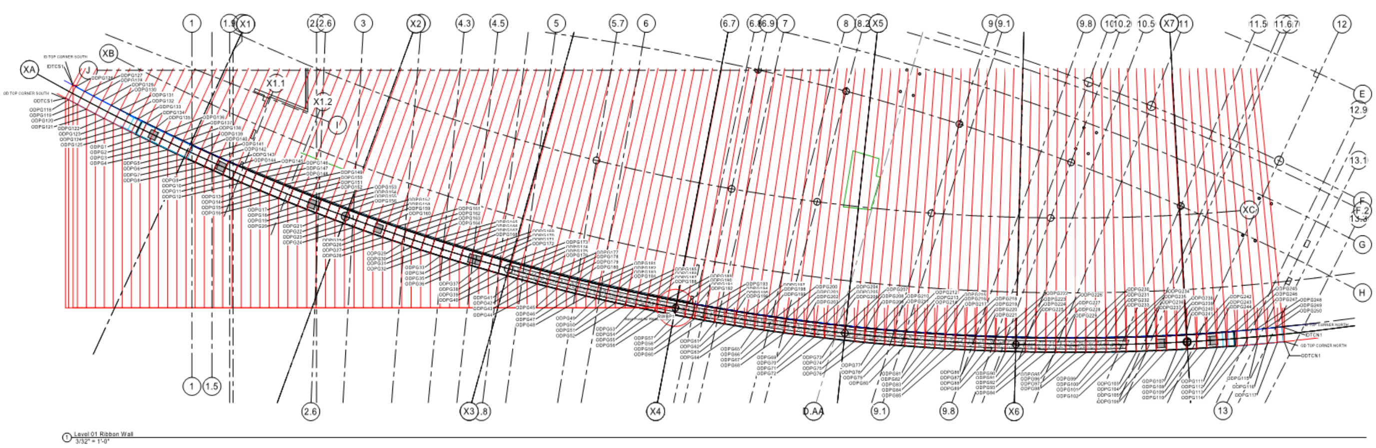


FIGURE 1

Ribbon Wall Center of Panel Points_Top Corner_Bottom Corner Points - Notepad

File Edit Format View Help

```
POINT NUMBER,Y,X,Z,DESCRIPTION
IDBCS1,216369.0722783,2217437.71601247,30,Control Point
ODBCN1,216689.88439643,2217493.16864935,30,Control Point
ODBCS1,216367.26475587,2217441.74937111,30,Control Point
RWBP1,216528.29796277,2217487.07221308,16,Control Point
ODPG1,216367.42137419,2217441.82009859,16,Control Point
IDTCN1,216708.83774392,2217486.41905478,16,Control Point
ODTCN1,216709.59762291,2217490.77312379,16,Control Point
IDTCS1,216346.97327119,2217427.29281058,16,Control Point
ODTCS1,216344.87369353,2217431.16968183,16,Control Point
IDBCN1,216689.42135467,2217488.77616607,30,Control Point
ODPG2,216370.23897275,2217443.07369631,16,Control Point
ODPG3,216372.98580613,2217444.27976598,16,Control Point
ODPG4,216375.73837208,2217445.47269445,16,Control Point
ODPG5,216378.49660774,2217446.65245448,16,Control Point
ODPG6,216381.26045013,2217447.81901909,16,Control Point
ODPG7,216384.02983612,2217448.97236164,16,Control Point
ODPG8,216386.80470247,2217450.11245576,16,Control Point
ODPG9,216389.58498581,2217451.2392754,16,Control Point
ODPG10,216392.37062263,2217452.35279482,16,Control Point
ODPG11,216395.16154932,2217453.45298856,16,Control Point
ODPG12,216397.95770214,2217454.53983149,16,Control Point
```

Point Locations XYZ

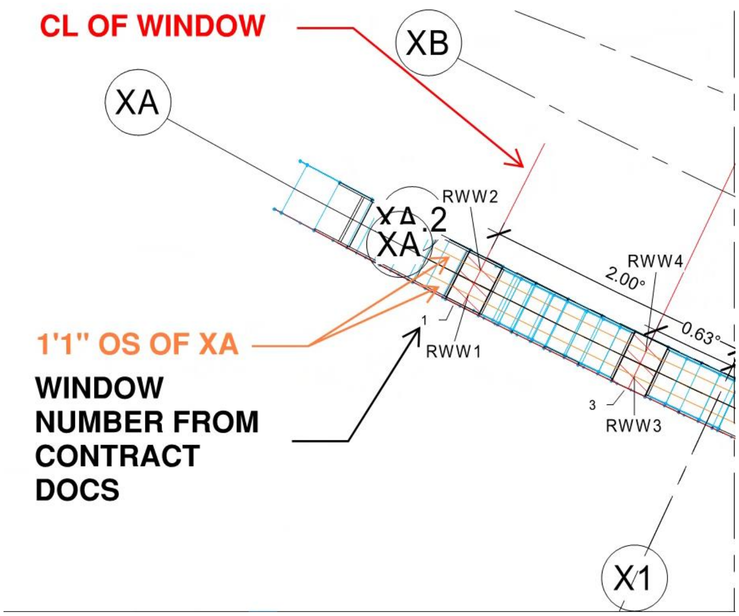
Comments	Coord_X	Coord_Y	Coord_Z
OD Bottom Corner - North	161.274	-11.749	108.730
ID Bottom Corner - North	160.965	-7.343	108.750
OD Bottom Corner - South	-159.348	50.932	114.602
ID Bottom Corner - South	-157.391	54.891	114.581
ID Top Corner - South	-179.121	66.090	153.662
OD Top Corner - South	-181.355	62.289	153.916
OD Top Corner - North	181.059	-10.045	139.074
ID Top Corner - North	180.452	-5.667	138.831
OD PG 1	-159.194	50.856	114.599
OD PG 2	-156.422	49.504	114.545
OD PG 3	-153.719	48.203	114.493
OD PG 4	-151.010	46.914	114.441
OD PG 5	-148.295	45.639	114.388
OD PG 6	-145.573	44.376	114.336
OD PG 7	-142.846	43.127	114.283
OD PG 8	-140.113	41.890	114.231
OD PG 9	-137.374	40.667	114.178
OD PG 10	-134.629	39.456	114.126
OD PG 11	-131.878	38.259	114.073
OD PG 12	-129.122	37.075	114.020

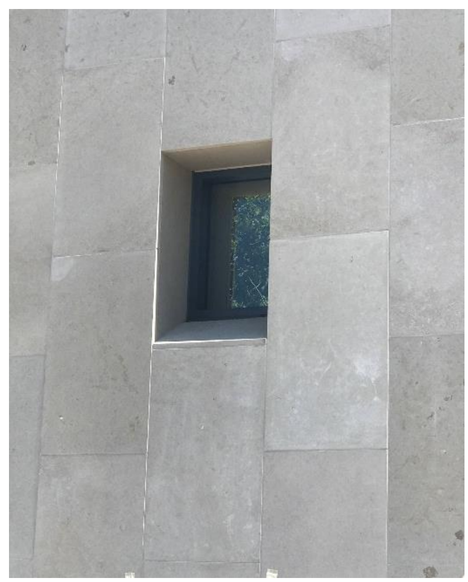
FIGURE 2

4-2- Verifying Window Locations and Center Line of window Layout

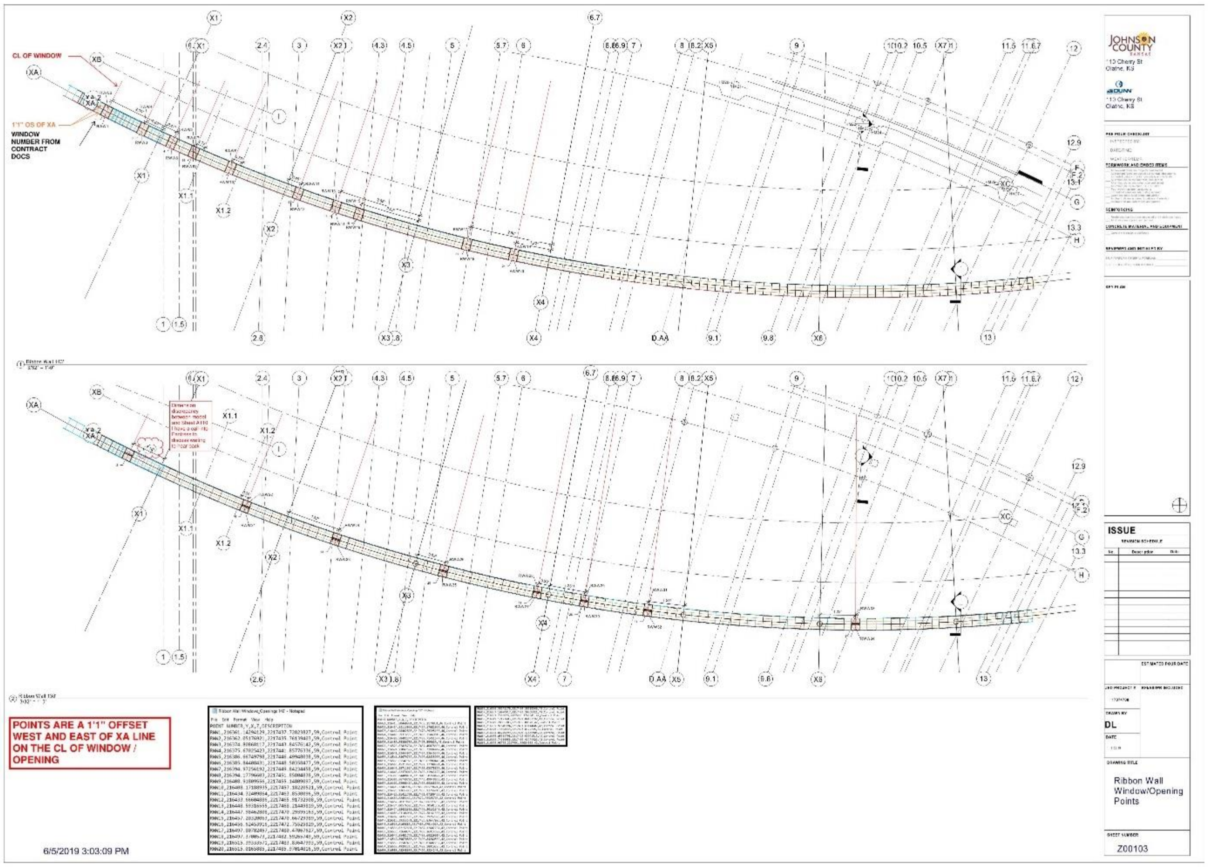
Before any framing construction started on the Ribbon Wall, JE Dunn decided that a template would be created and placed on the concrete and steel beams that support the ribbon wall. The width of the template is the distance from back of framing on the East to back of framing on the West. The template gave all trades a surface to do layout upon. *See Figures 6,7*

When creating the template, we had grid XA, which is the center of the wall, etched into the sheet metal. Utilizing sheet A110 all window locations in the Ribbon Wall model were verified against the contract documents. Once dimensions were verified center line of window was laid-out in the model. Two points offset 1’1” from XA were created with Autodesk Point Layout and exported. The offset was 1’1” because this meant that when the lines were marked they would fall within the extents of the template. PCI used the template to also mark jamb stud locations as well. *See Figures 3,5*





FIGURES 3,4



FIGURES 5

FIGURES 6,7

4-3- Jamb Stud Elevations

Prior to framing starting on the ribbon JE Dunn and PCI had discussions regarding elevations for top and bottom of stud as well as the head and sill elevations for the windows. It was decided that JE Dunn would provide drawings that gave PCI those elevations. The image below is an example of one of those provided sheets. Two sections were cut through each window(s) one looking right (North) and another looking left (South.) This would allow PCI to set each jamb stud. Having the elevations allowed them to cut the studs to length on the ground and then measure down to mark the head, sill and level 2 elevation. Following the slope of the top and bottom of the wall PCI was able to precut the infill studs as well. Utilizing this process drastically reduced the number of studs that needed to be cut in the air from a lift. So much so that only two studs on the entire wall were cut in the air. *See Figures 8,9,10*

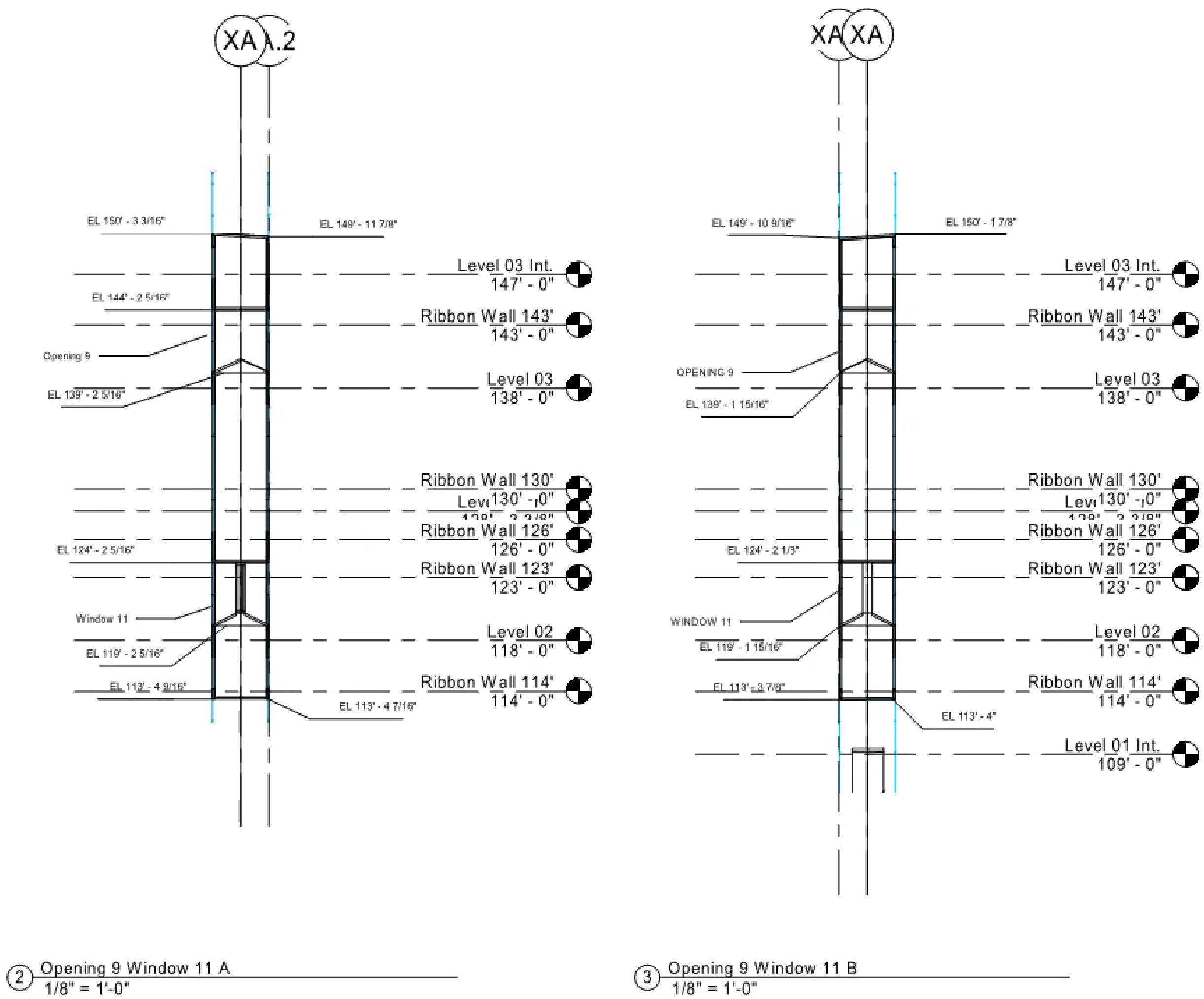


FIGURE 8

FIGURE 9,10

4-4- Laser Scanning The Ribbon Wall Framing

Once framing was complete JE Dunn decided to laser scan the Ribbon Wall. This allowed us to verify that the windows were in the correct location when linked into the Ribbon Wall model. It also allowed us to study and analyze the framing to make sure it was plumb and within tolerance. *See Figure 11*

Performing the scan soon after framing finished gave us a window to make any corrections before sheathing and air and vapor barrier were applied. We were also able to inform U.S. Stone, our stone manufacturer, of any variances they would need to take into account. This was important as the engineered stone was being pre-cut to all specified sizes before being shipped on site.

At JE Dunn we perform all our own laser scanning. We register the scan and then bring those files into Autodesk Recap for indexing. We also utilize spheres when performing our scans as another added level of security. We feel the spheres allow us to further tighten up the scan. Specifically, in instances where we may not have many good surfaces to use during registration. *See Figures 12,13,14*

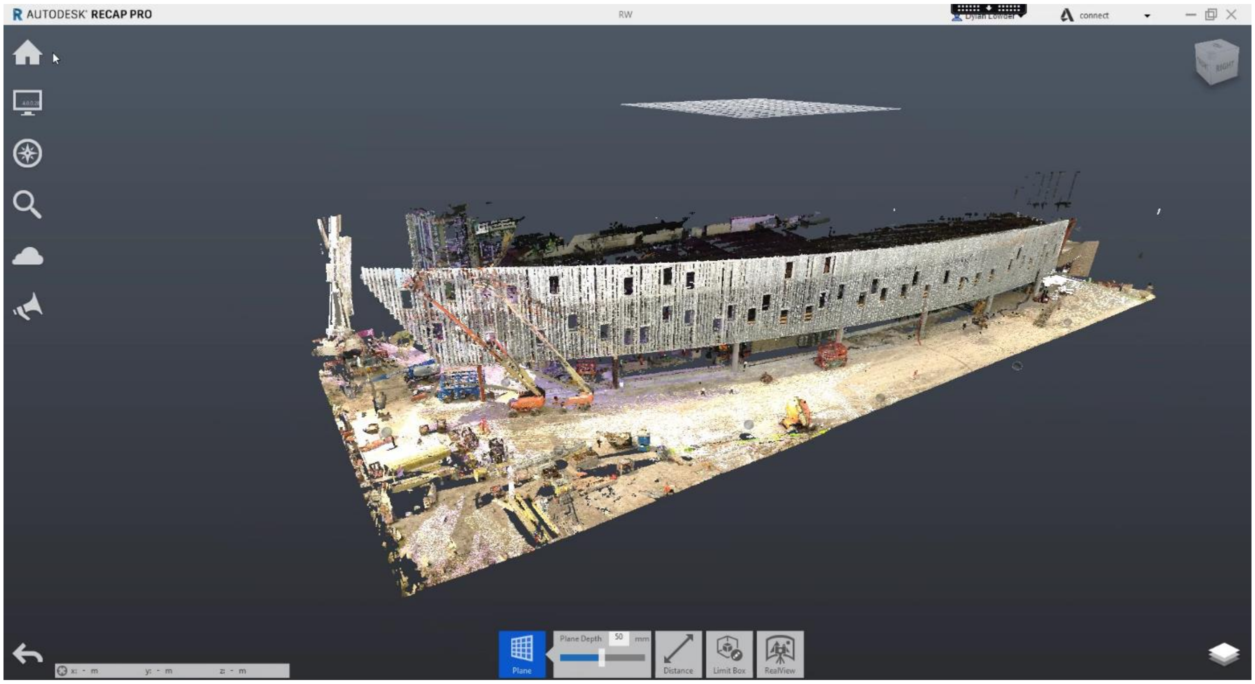


FIGURE 11

FIGURES 12,13,14

4-5- Faux Column Layout

At JE Dunn we perform all our own laser scanning. We register the scan and then bring those files into Autodesk Recap for indexing. We also utilize spheres when performing our scans as another added level of security. We feel the spheres allow us to further tighten up the scan. Specifically, in instances where we may not have many good surfaces to use during registration.JE Dunn self-performed the masonry on the wall. After discussions with the masonry foreman it was decided that we would lay the center of joints out on the mud slab as well. Having this layout meant they very easily could check while setting the stone that they were staying on the joint locations all while staying plumb. By setting a laser on the mud slab over the layout they could plumb up the face of the wall. *See Figures 15,16,17*

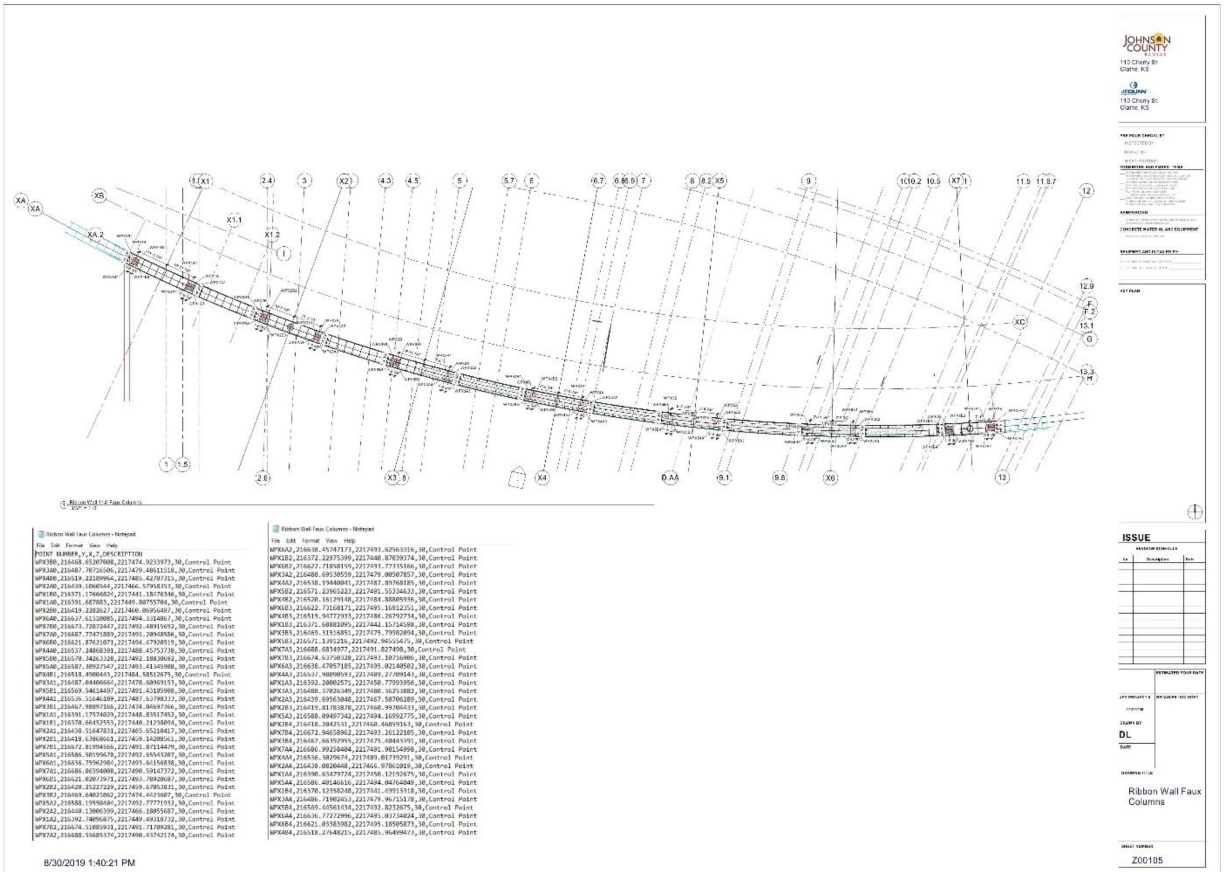
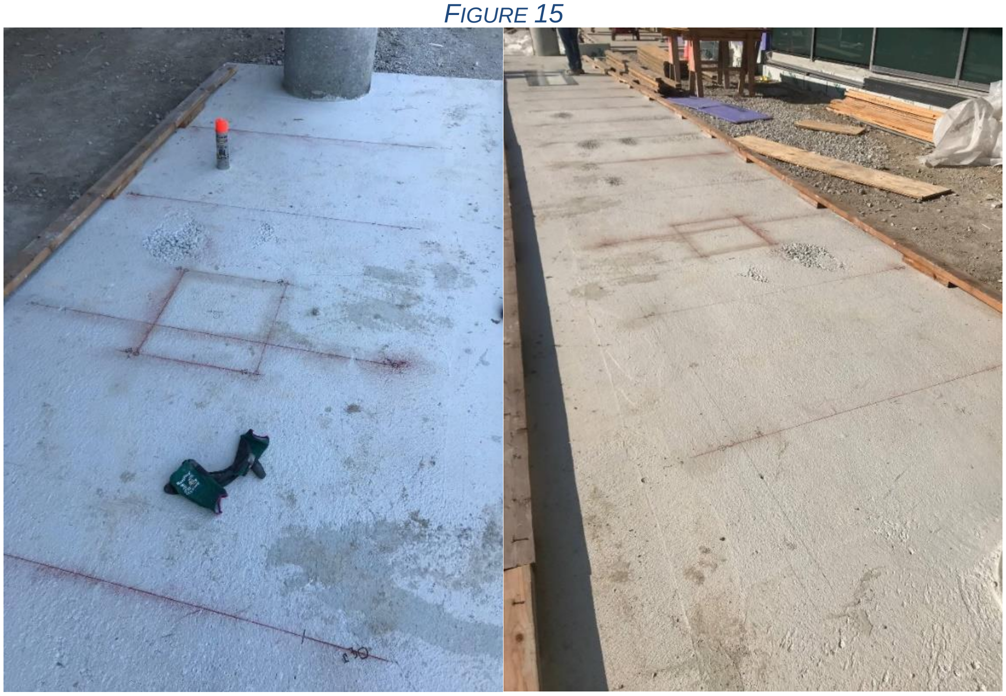


FIGURE 15



FIGURES 16,17

4-6- Sequencing the Stone

We started fabricating and placing stone on soffits 1,2, and 4first. This established the vertical joints on the outside and inside face of the wall. We then identified all “typical” 3x5 pieces because of schedule requirement all typical pieces of stone needed to be set first. A second crew started sequence 3 working left or South or left. When complete a 3rd crew starts on sequence 6 working North or right. An EZ Scaffold system is being utilized by the JE Dunn Masons to set the stone panels on the wall. Breaking the wall into sequences this way allowed US Stone to fill a delivery truck completely maximizing on site deliveries.
See Figures 18,19

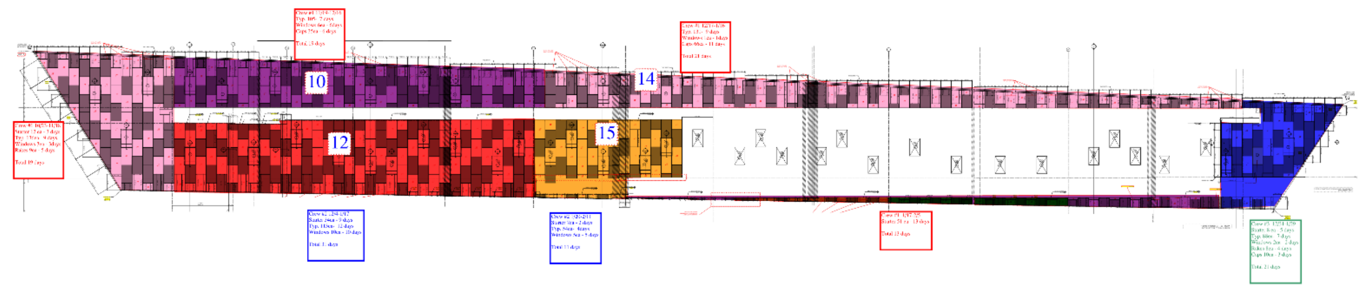


FIGURE 18

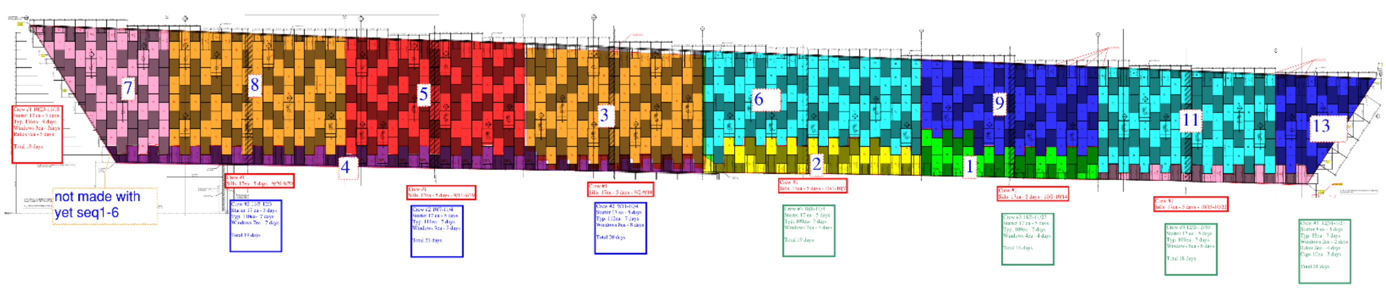


FIGURE 19