CI11198

REVITalize Bridge Design

Matthias Stark
Technical Specialist AEC EMEA / Autodesk GmbH, Germany

Lejla Secerbegovic
Technical Specialist AEC EMEA / Autodesk GmbH, Germany

Learning Objectives

- Understand the challenges of bridge modeling in general

- Understand how to import alignment into Revit using Dynamo

- Understand how to use adaptive components for bridge modeling

- Understand how to use Dynamo for bridge modeling

Description

In this class you will learn how to create a detailed bridge model using mainly Revit software, Dynamo software and AutoCAD Civil 3D software as a data source for alignments and profiles. This class won't touch the Bridge Modeling Revit software extensions—we'll be showing tips and tricks for modeling from scratch to fulfill the required accuracy.

Furthermore, we'll be giving insight to a developed workflow that has been created for customers in Europe, the Middle East, and Africa. Upfront there will be a brief introduction about challenges that planners and engineers have to face when creating those very complex shaped projects. The bridge itself will be a real project that was designed by a German planning office the "old" 2D way and was built in the past.

The content Matthias Stark will show in this class is based on results of an internal workshop with Andrzej Samsonowicz (Autodesk) and Oliver Langwich (Contelos) as well as days of extra work beside his actual job. It hasn´t been a finished workflow yet but will show what´s possible in terms of bridges.

Your AU Experts

Matthias Stark is working as a technical sales specialist in the Europe, Middle East, and Africa / Germany, Austria, and Switzerland region taking care of the infrastructure business, including product solutions like AutoCAD Civil 3D software, InfraWorks 360 software and Vehicle Tracking software. Before he joined Autodesk GmbH, in 2014, he had worked for a well-known planning office in Munich—SSF Engineers AG. One of SSF´s core business is preliminary and detailed design of all types of bridges. In his role as a project manager, Matthias was responsible for geometric construction of several road bridges, pedestrian bridges, and also tunnel projects. In addition, he was member of a small team in the company dealing with implementation of 3D software and Building Information Modeling (BIM), as well as developing new workflows for bridge modeling. | matthias.stark@autodesk.com

Introduction

The content of this class is based on customers' demands I´m experiencing at almost every second customer meeting. Those customers I´m talking to are used to use Revit within their building industry projects and appreciate it a lot. In terms of Revit´s parametric architecture, it´s object-orientation, it´s functionalities regarding BIM and not least the abilities to create 3D reinforcement / structural analysis they want to utilize these benefits also for their bridge projects for instance.

Most of them tried this in the past, having more or less success. The more complicated the geometric requirements of the bridge project got the more they weren´t able to model it within native Revit environment. As a result they remain on using their 2D tools like they are used to use for bridges.

The possibility to use the Bridge Modeler Extensions for Revit and Civil 3D getting rid of these challenge doesn´t work in my region. Bridge Modeler is a great tool which is very easy to handle, very fast in modeling and has got associative behavior connecting Civil 3D and Revit with each other. The content however Bridge Modeler is providing so far isn´t sufficient and too standardized in terms of our (DACH region = Germany / Austria / Switzerland) industry requirements.

Taking this as an initiation I started searching for a solution within our Autodesk product portfolio. Having heard so much positive stuff about Dynamo and the fact that Dynamo can create geometry which hasn´t been possible before in Revit I tried to dive in deeper. The content I will show in this class is based on results of an internally initiated workshop and Dynamo training with Andrzej Samsonowicz (Technical Specialist for Revit and Dynamo / Autodesk) and Oliver Langwich (Application Engineer for Revit / Contelos) as well as days of extra work beside my actual job. It hasn´t been a finished workflow yet but will show what´s possible in terms of bridges.

Challenges of bridge modeling

Bridges are very complex structures. In Germany for instance bridges won´t be designed just due to economic aspects – meaning going from A to B by a straight – but mostly due to the alignment. This means is there an arch or a spiral in the bridge´s sector it doesn´t matter – the bridge won´t be moved to another spot / the alignment won´t be changed normally.

Most of the time we have to deal with **curved alignment**. Sometimes there are **widening'**s or **narrowing´s** because of an adjacent intersection or exit road. Basically there´s always **longitudinal inclination** getting rid of the water in the bridge area. Talking about longitudinal inclination it´s also important additionally to understand that people working in the infrastructure industry thinking in **vertical cross sections**. Doing a sweeping operation generally a traditional modeling software – also Revit - would place a cross section / profile perpendicular to a 3D path. In this case this isn´t the desired behavior – it needs to be placed perfectly vertical. Having also **cross-fall**, **variable cross-fall**, **skewed substructures** like piers or abutments and last but not least **variable bottom edges** this will result in almost just double-curved free-form surfaces.

From a planners or even building companies perspective doing detailed design and construction drawings this a big challenge. The usual accuracy of their deliverables needs to have an accuracy of +/- 1 millimeter.

Dynamo – what is it about?

As mentioned before the approach of this session is to get these challenges handled by adding Dynamo to the workflow. Let´s briefly talk about Dynamo itself – what is it about?


Dynamo is a **generative design application** and it's equipped with a very unusual interface based on **Visual Programming**. It's a language which provides users ability to script without any deep programming knowledge and experience. Generative design is a **design method** in which the output is generated by a set of **rules** or an **algorithm**. It is based on **parametric modeling** and it is a fast method of **exploring design possibilities**. It allows designers and engineers to create **geometry relationships** based on rules and logic rather than traditional sculpting / push-pull manipulations. Furthermore Dynamo allows to generate geometry which normally would be very **time consuming** or would be even **impossible to create**.

User interface of Dynamo:
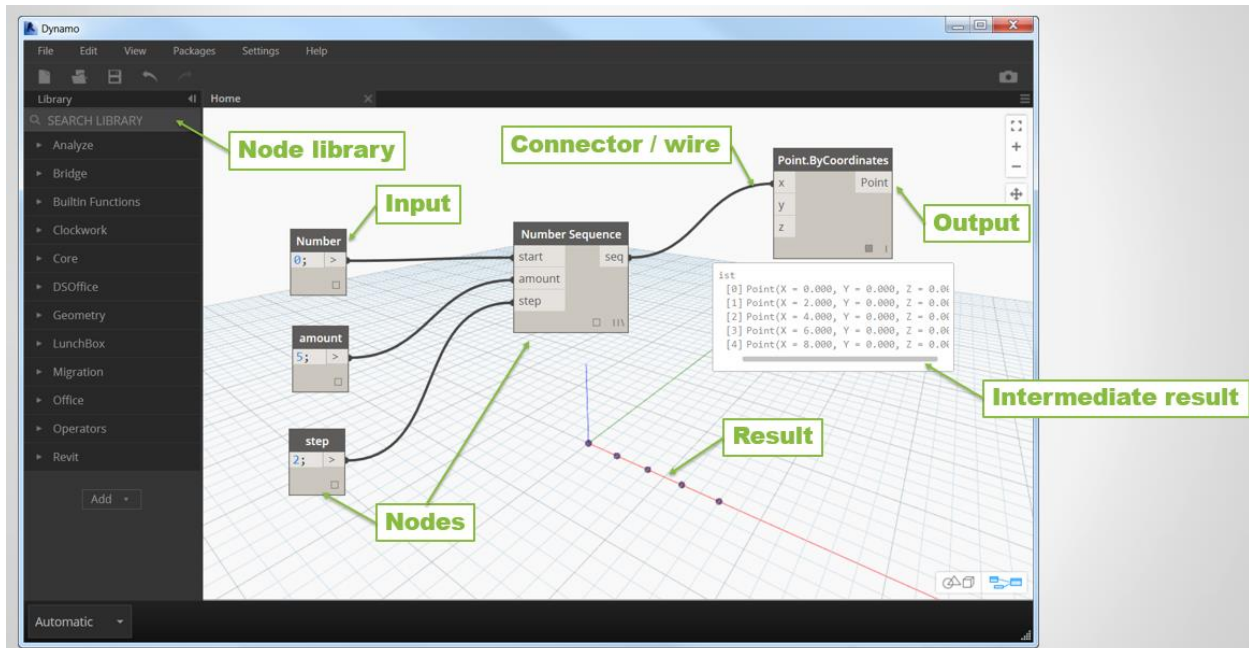
Dynamo also perfectly **integrates with Revit** software. As a result the user is being able to create generative / parametric structures and **complex geometry** in Dynamo which can be pushed / imported into Revit family or project environment.
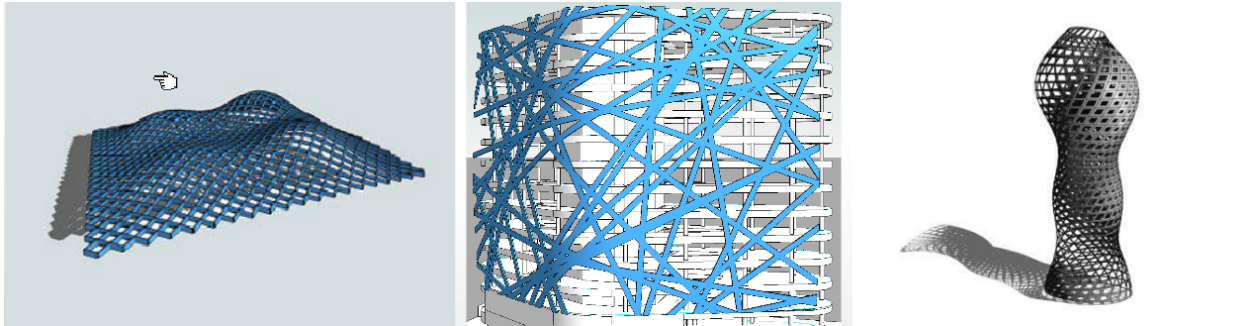
Another use case can also be **data manipulation**. Let Dynamo literally grab elements from Revit, manipulate them, add additional information or attributes, analyze them and push it back to Revit or even Excel.
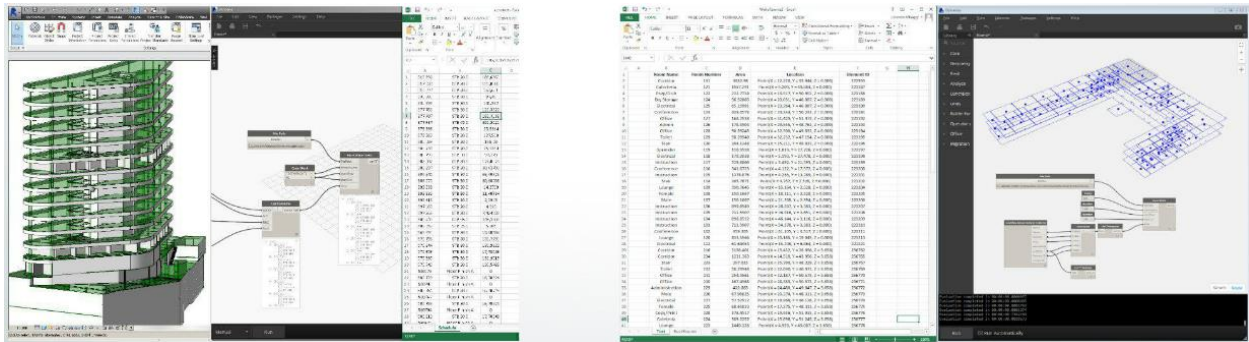

As a third bullet point Dynamo provides **additional functions for Revit** by using the Revit API (for instance automatic creation of plan views for all rooms of a building).
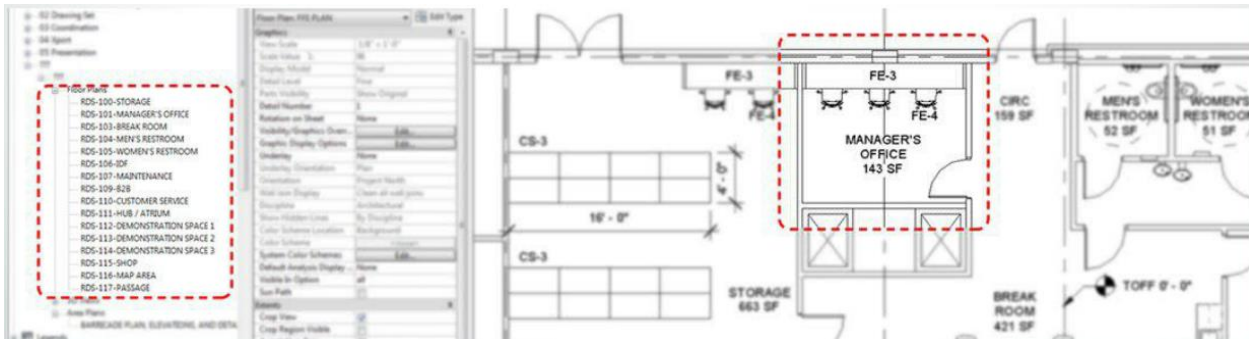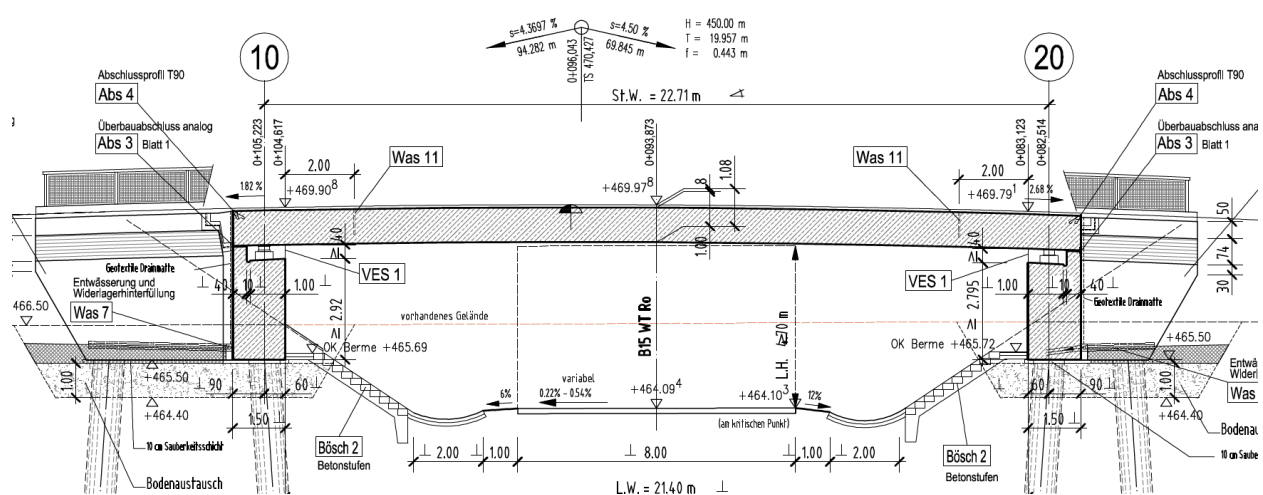
The sample project

During this class we will work on a sample project representing a little bridge made of cast-in-place concrete. The bridge itself has a curved (S-shaped) alignment and skewed angles on both abutments. The wing-walls of the bridge are also curved.

Top view:
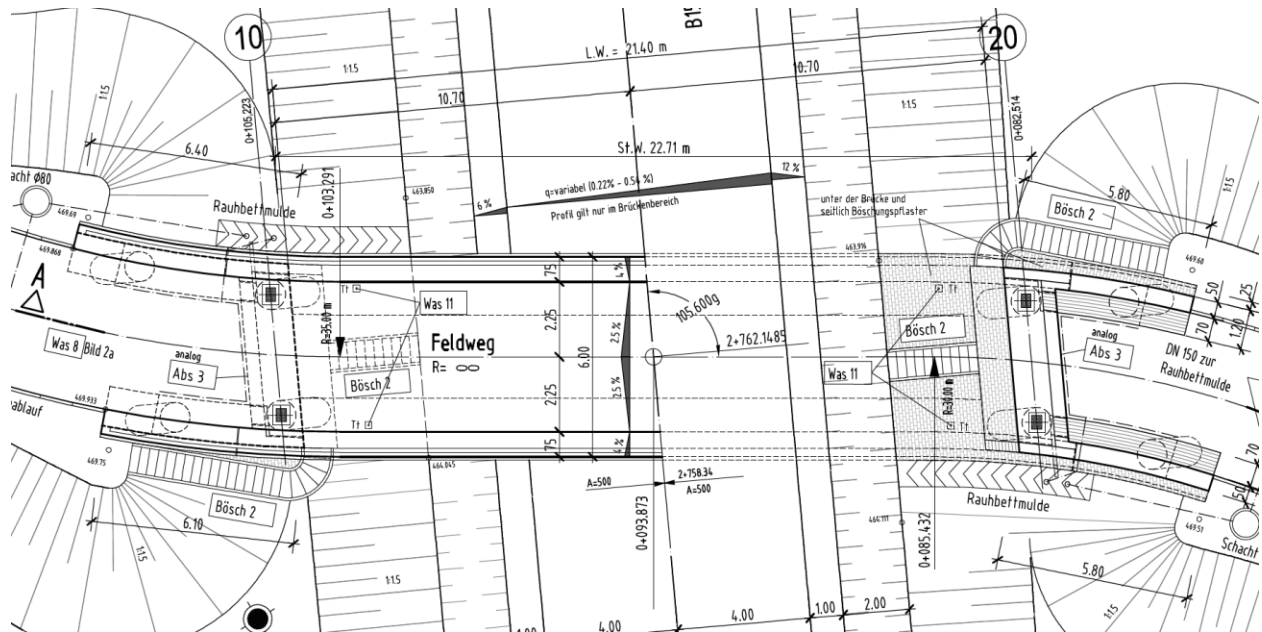
The bridge also got a longitudinal inclination.

Unrolled section along the alignment:

Here´s the cross section of that bridge. It has a constant 2.5% cross-fall on the right and left-hand side. Lane width is 2.05 meters on each side till there´s a change in the slope at the low-points pointing in the opposite direction.

Cross section:
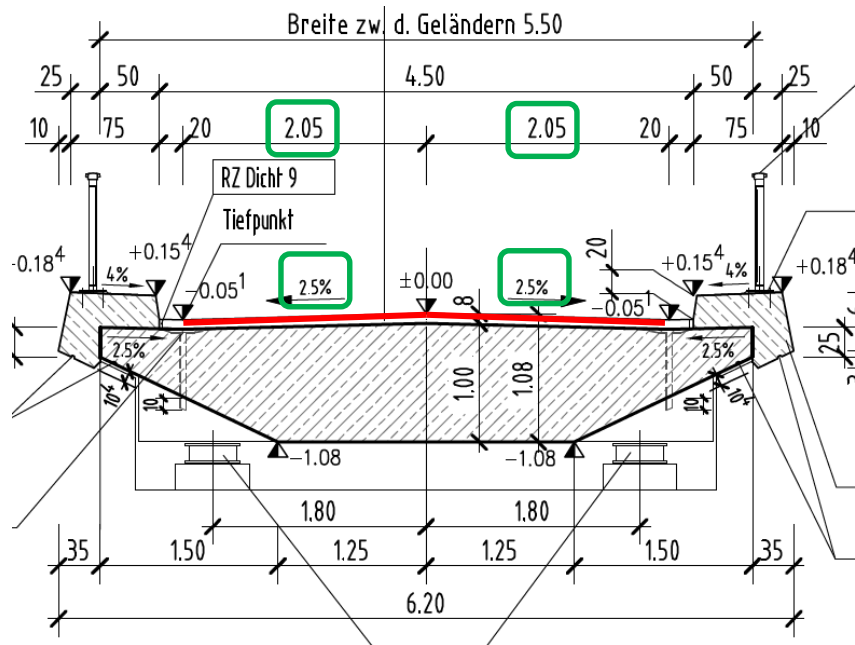
Preliminary work – prepare your alignment and cross sections

Before we can start working in Dynamo and Revit let´s do some preparation of our basic data. We want to create some certain points along our alignment and profile. These points will be utilized to recreate our alignment and profile in Dynamo and Revit later on.

Note: There will be no original alignment in Dynamo / Revit but a very close approximation by using points and splines.

To optionally introduce also the ability to drive variable behavior along the bridge (variable cross-fall & widening's) we´re also interested in the low points of that bridge.
In General all points described above can come from every software which is able to create points along certain alignments. In this specific case let´s use AutoCAD Civil 3D for that.

AutoCAD Civil 3D 2016

*This chapter expects basic understanding and knowledge of AutoCAD Civil 3D.*

In AutoCAD Civil 3D we need to create the bridges **alignment and profile** first. Civil 3D gives you the right tools to easily do this. These objects can also be imported by using XML-formats for instance. In that case I created them myself by using the information given on the drawings I got.
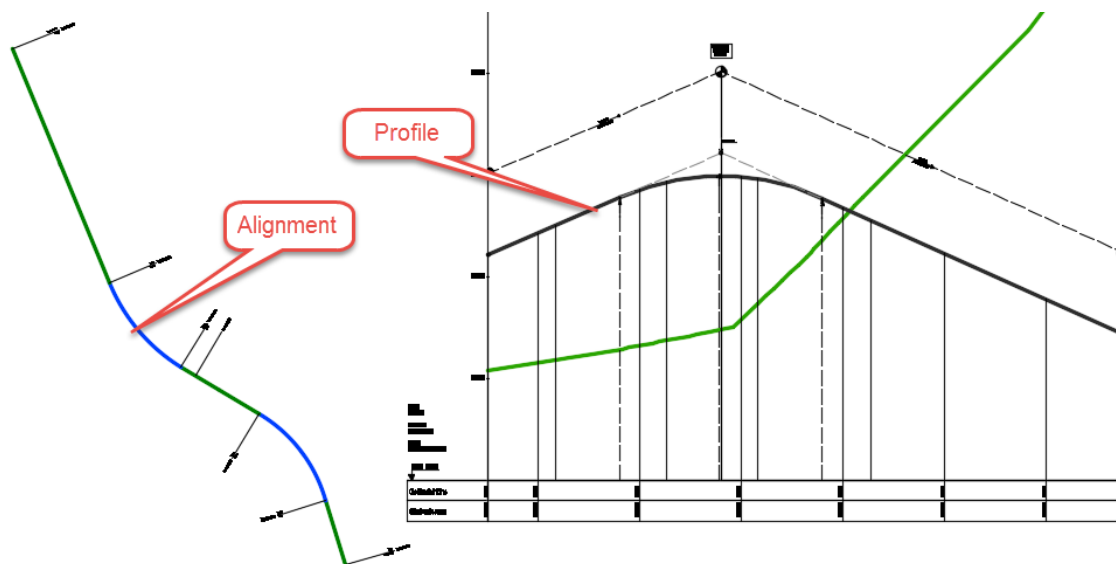
After having finished this task we have to create an **auxiliary corridor assembly** which represents the **top surface of the lanes from left to right low point** (marked in red – see cross section above). We have to use just an assembly baseline with two *LaneSuperelevationAOR* subassemblies attached. To easily create and manage the points later let´s also attach some simple *Marked Code Points* – don´t forget to code them accordingly to their names as shown below.
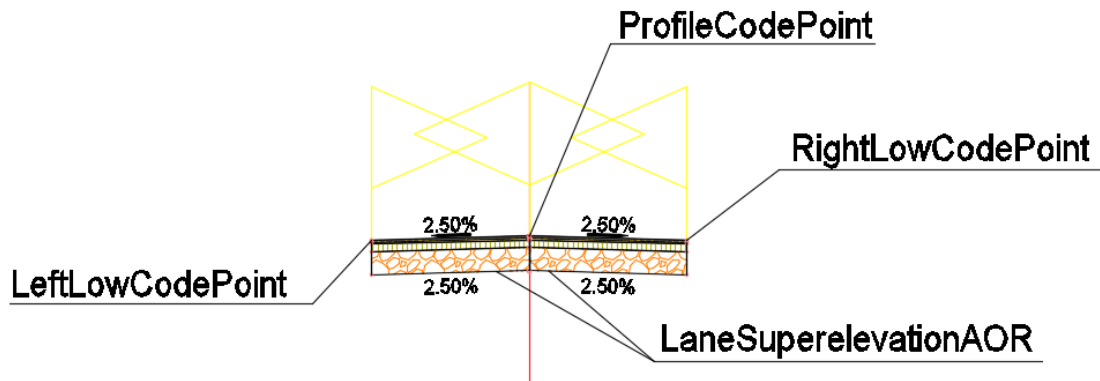
Now you can let Civil 3D create your corridor model.
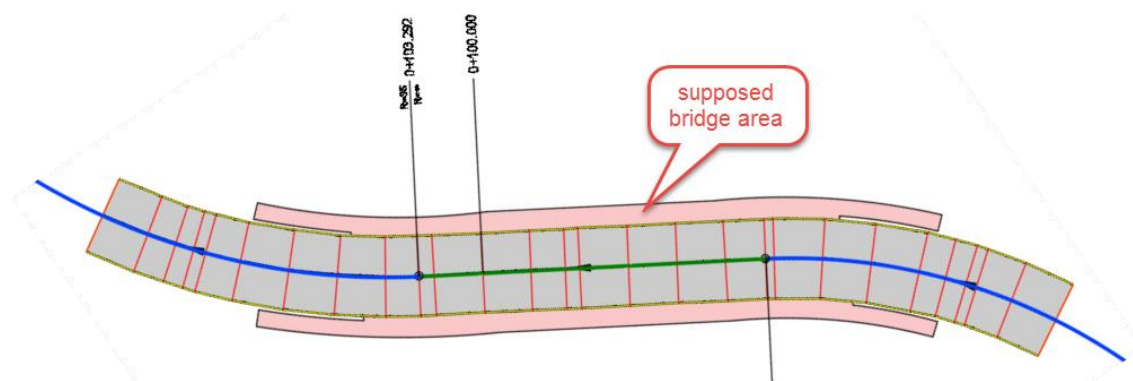
Note: The smaller the steps of your corridor interval the closer you approximate to the original alignment! Let´s use 2.5 meters as an interval. Make also sure your corridor covers the full length of the bridge. Extend it on the start and end of the bridge.

The next step is to create points along our coded corridor edges. You might use Civil 3D *Points* tools to *Create COGO Points from Corridor*. After that you could manage them in point groups and export them to Excel for instance. There´s also a point tool called *Measure Alignment* to place points along your alignment.

During this class however I´d like to introduce a feature from our latest *AutoCAD Civil 3D 2016 Transportation Extension* available as a Subscription benefit on Autodesk Account. It can be found under the *Productivity Tools for AutoCAD Civil 3D 2016*.

Productivity Tools for AutoCAD Civil 3D 2016

Global - Autodesk® AutoCAD® Civil 3D® 2016 Transportation Extension
(Readme) - English *(html - 8Kb)*

Global - Autodesk® AutoCAD® Civil 3D® 2016 Transportation Extension
64-bit - English *(exe - 3382Kb)*

Global - Autodesk® AutoCAD® Civil 3D® 2016 Transportation Extension
64-bit - English for Deployments *(msi - 4204Kb)*

Leveraging this great Extension you can use the *Corridor Points Report* to let Civil 3D create you an **Excel file** including all your points. By just ticking the checkboxes next to your point codes you´ve created before it´s extremely easy to write a file for your appropriate profile and left / right low points.
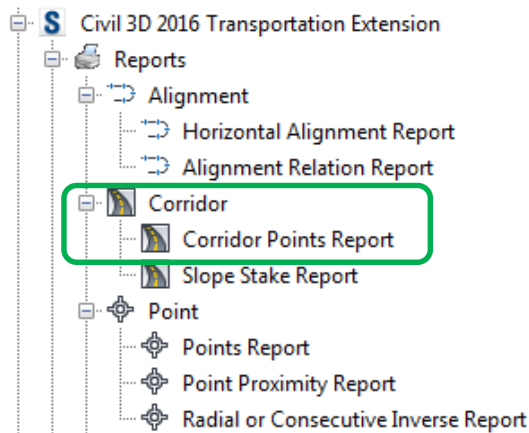
Another benefit of using this report is that it provides exactly the information we need in a structured order.
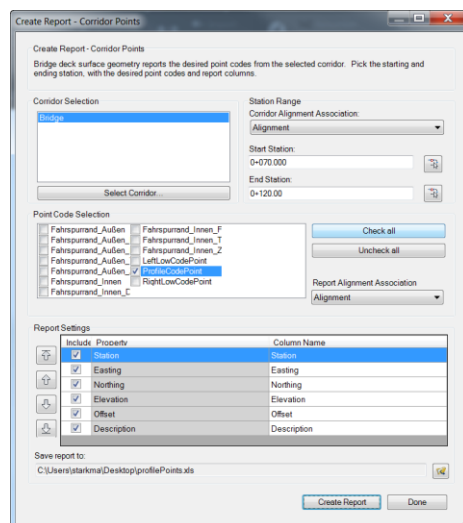
Corridor Points Report

Client:	Prepared by:
Client	Preparer
	Your Company
Client Company	Name
Address 1	123 Main Street

Date: 30.10.2015 15:53:07

Corridor Name: Bridge

Reference Alignment Name: Alignment

Station	Easting	Northing	Elevation	Offset	Description
0+070.000	4505862.033	5299893.224	469.289	0.000	ProfileCodePoint
0+072.500	4505860.718	5299895.349	469.398	0.000	ProfileCodePoint
0+074.438	4505859.580	5299896.917	469.483	0.000	ProfileCodePoint
0+075.000	4505859.231	5299897.358	469.507	0.000	ProfileCodePoint
0+076.105	4505858.521	5299898.205	469.556	0.000	ProfileCodePoint

Note: As mentioned in the beginning of this chapter it is possible to drive also variable behavior of our bridge. When having variable width like a widening for instance you can draw a polyline representing your widening and let your corridor target that polyline. In terms of variable cross-fall the chosen subassemblies *LaneSuperelevationAOR* can handle superelevation as well. In fact all this variable parameters will affect your corridor and your points included in your report accordingly.

A sample file of the AutoCAD Civil 3D DWG will be provided on an AU webpage dealing with this class.

Microsoft Excel 2013

Take your recently exported Excel files and merge it to one single file. Make sure to add a sheet for each "point group". The schema might look like this:

	Station	Easting	Northing	Elevation
13				
14	**Station**	**Easting**	**Northing**	**Elevation**
15	0+070.000	4505862.033	5299893.224	469.289
16	0+072.500	4505860.718	5299895.349	469.398
17	0+074.438	4505859.580	5299896.917	469.483

Profile | Alignment | LeftLowPoint | RightLowPoint

Note: There´s no need to export points along your alignment. The values for Station, Easting and Northing are already there inside your Profile sheet. The only difference is the Elevation – just set it to zero and you got your Alignment!

Moving on with the next step. We have to **transform our values**. As you can see by focusing on an Easting value for instance the numbers are very big since they´re including real coordinates. Certainly you are also aware of the fact that actually Revit doesn´t like big coordinates – same for Dynamo. By creating three transformation factors called "TransformX", "TransformY" and "TransformZ" for instance we will do a transformation of our whole alignment from the beginning of the profile into zero (0|0|0).

Transformation happens with the first point of the profile (Station 0+070.000)	
TransformX	4505862.033
TransformY	5299893.224
TransformZ	460.000

Station	Easting	Northing	Elevation
0+070.000	0.000	0.000	9.289
0+072.500	-1.315	2.125	9.398
0+074.438	-2.453	3.693	9.483
0+075.000	-2.802	4.134	9.507

BTW – no worries in terms of transformation! By using shared coordinates in Revit´s project environment we will get our bridge back to the desired location!

As a final step we have to create two additional sheets in Excel. The first will be called PROF, the second will get ALIG. Copy (Paste as Link) your transformed values of your profile as well as alignment on these sheets. To see the numeric order add also the station information. Don´t forget to add captions as well.
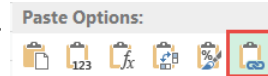
Note: this type of formatting is extremely important since the Dynamo scripts will need it exactly this way! Focusing again optional variable behavior: On your PROF sheet add four columns for your optional variable parameters of this bridge:

- **Cross-fall_left**
- **Cross-fall_right**
- **Width_left**
- **Width_right**

The values for those columns are already there as well actually. Cross-falls can be expressed by ProfileElevation minus Left/RightLowPointElevation, Widths can be found in the offset column of the *Corridor Points Report*.

	A	B	C	D	E	F	G	H
1	Station	Easting	Northing	Elevation	Cross-fall_left	Cross-fall_right	Width_left	Width_right
2	0+070.000	0.000	0.000	9.289	0.051	0.051	2.05	2.05
3	0+072.500	-1.315	2.125	9.398	0.051	0.051	2.05	2.05
4	0+074.438	-2.453	3.693	9.483	0.051	0.051	2.05	2.05
5	0+075.000	-2.802	4.134	9.507	0.051	0.051	2.05	2.05
6	0+076.105	-3.512	4.981	9.556	0.051	0.051	2.05	2.05
7	0+077.500	-4.451	6.012	9.615	0.052	0.052	2.05	2.05
8	0+080.000	-6.251	7.746	9.709	0.051	0.051	2.05	2.05

Profile | Alignment | LeftLowPoint | RightLowPoint | **PROF** | ALIG | (+)

You will find a sample file of this Excel file within the extra files of the Dynamo Bridge Package; see last chapter for further instructions.

Cross sections

The last step before we start doing really the cool stuff is just a kind of brainteaser. Think of your bridge – what cross sections do you need to fully represent it? Take this abutment as an example: there are 4 cross sections needed to describe its form. Also note that all of these cross sections are dependent on your profile and variable behavior of your bridge. For me it´s like playing with Lego blocks – it´s all about a modular design principle…
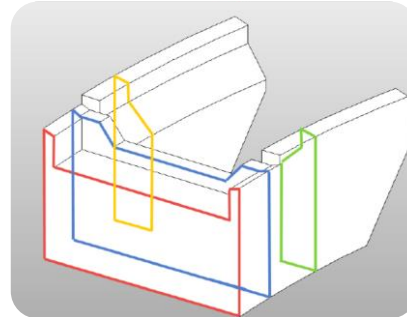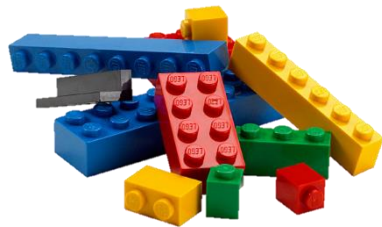
Note: there might be objects / geometry which isn´t dependent on our profile – foundations or some piers for instance. In that case there´s no need for this approach. It will be sufficient to model them by extruding just layout sketches to a certain elevation.

Within the next chapter I will introduce two different modeling concepts where those cross sections are utilized. The first concept will use adaptive components, the second one simple mass families. **You can have a look into those families and see how they have been created – just move to the last page of this document and check where you can find them! If you have variable behavior with your bridge make sure your families include parameters for it. To steer those through Excel their names need to be correspond to each other (Parameter names in Revit = Parameter names in Excel columns)**
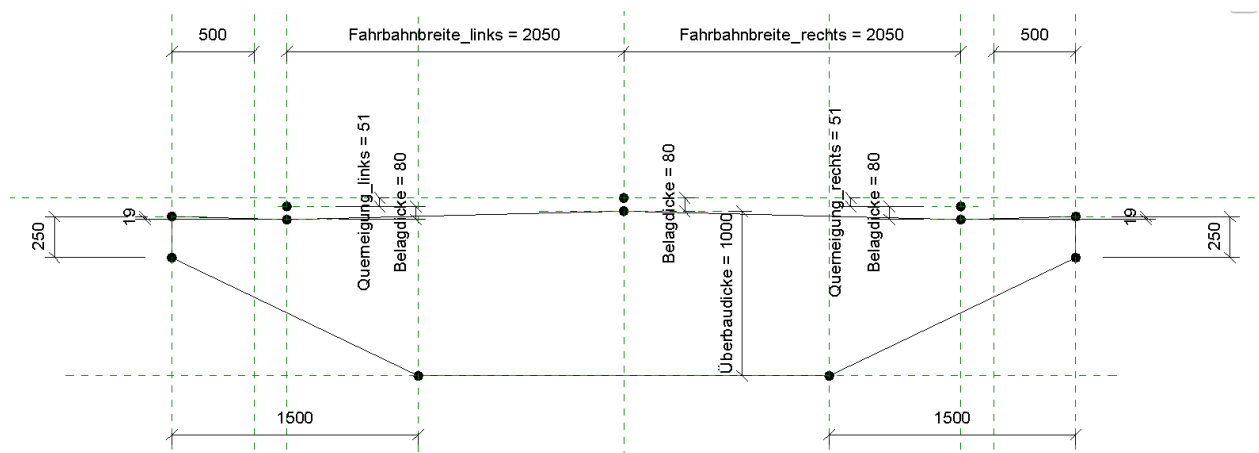
Picture shows a mass family

Modeling concept 1 – adaptive components

Revit 2016 / Dynamo Release 0.8.2.2392 / Bridge package
Starting in adaptive family template "Metric Generic Model Adaptive BRIDGE.rft" where all **adaptive families** have already been included

Great – all preparation is done! Let´s start modeling! In this first concept we will leverage Dynamo to read the Excel file, extract the points of our alignment and profile, create appropriate points and splines trough these points and push the whole stuff to Revit. In Revit adaptive families will be used for representing the different cross sections we thought about before. You might ask: Why adaptive families? Well – you can force them to be always vertical! This is exactly what we want!

Some general notes to the input schema of the Bridge package´s nodes:

LIB …	Indicates that you have to search for a node in the library
LIB Select Edge	Search for *Select Edge* in the library
CB …	Code Block (double-click on canvas)
CB Offset	Mandatory: Provide a value for *Offset*
CBOffset	Optional: a common default value is already set; can be overridden
	(No space between CB and input)
CB "Worksheet"	Provide a text with quotation marks

First of all let´s import our profile:

Note: Why a Boolean? Imagine there are changes within the Excel file and you want to update the results in Dynamo just switch the Boolean to True instead of False or the other way around. To let the 01_SplineFromExcel node update itself there needs to be a change with the inputs.

Same can be done with the alignment:

If you take a look into Revit you will realize that nothing has happened yet. To push our alignment into Revit we need some more nodes:
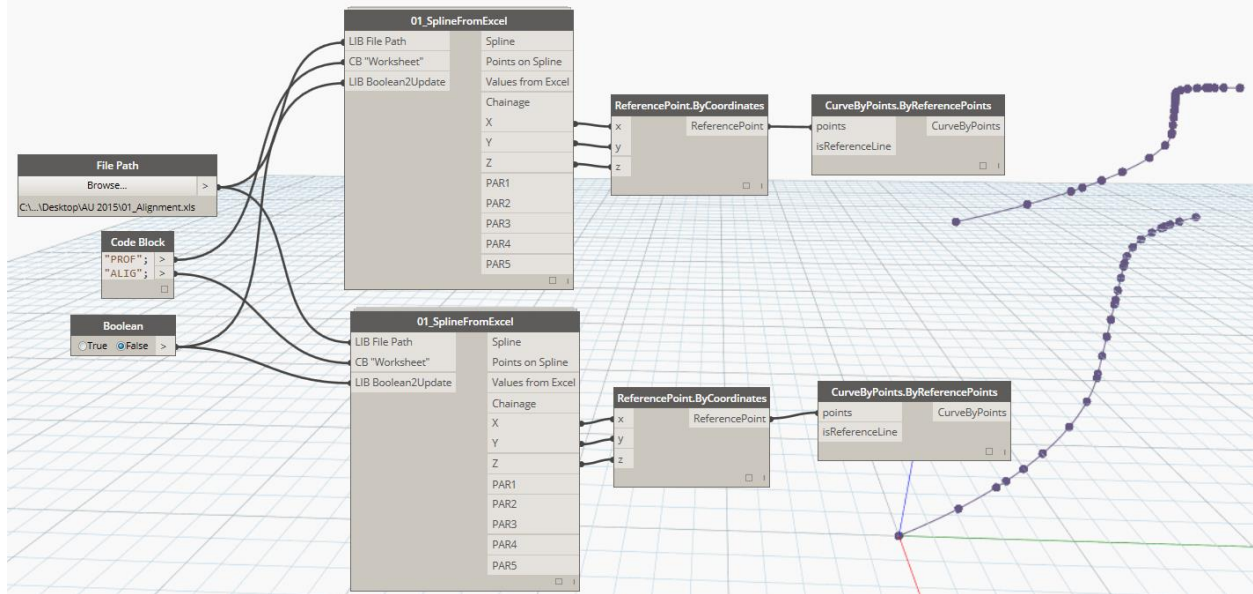
Those will show up in Revit immediately:
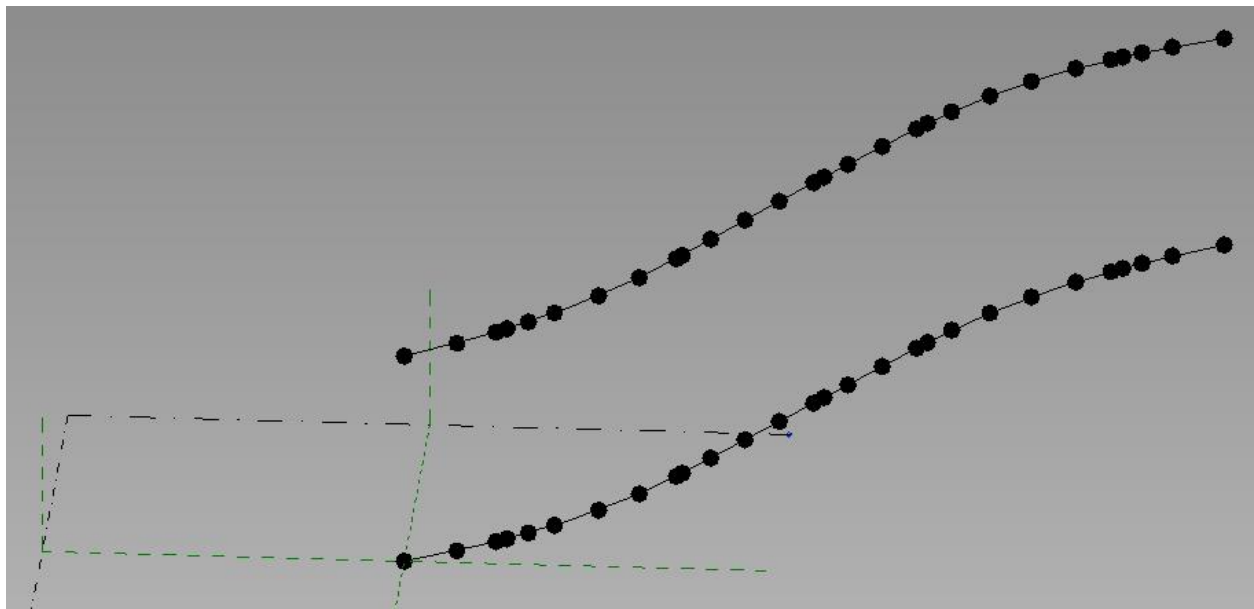
To have a better view just set the visibility of the reference points to invisible.

In a second step you can create a *divided path* out of your profile spline in Revit:
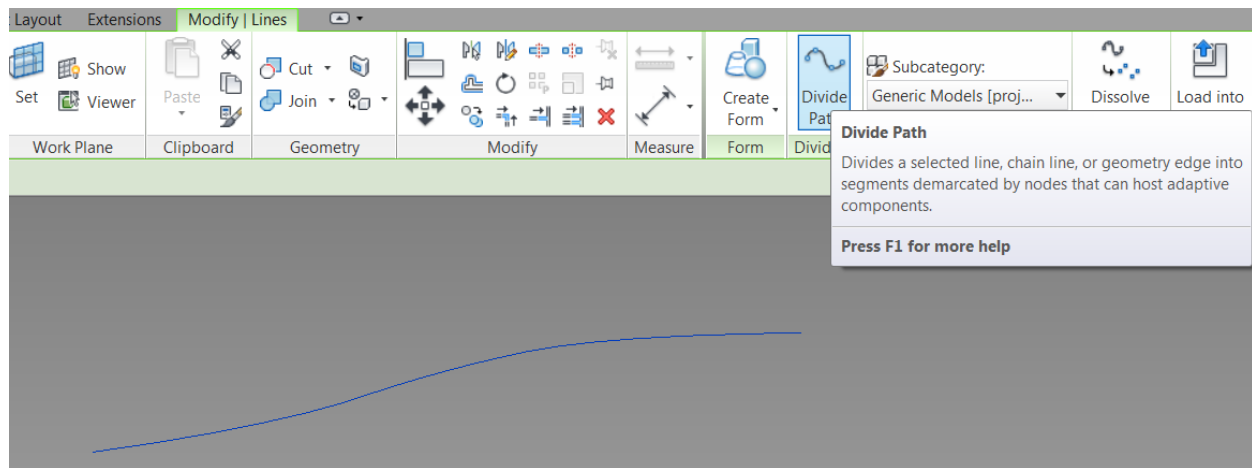
Let Revit divide your path into 20 segments for instance:
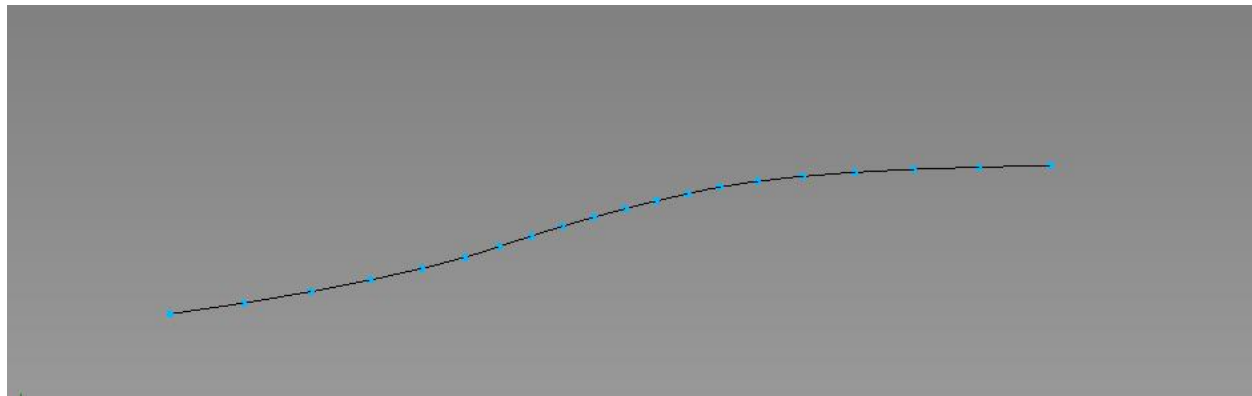
Those segment points will act as kind of anchors for our adaptive families – just drag and drop them on the canvas:
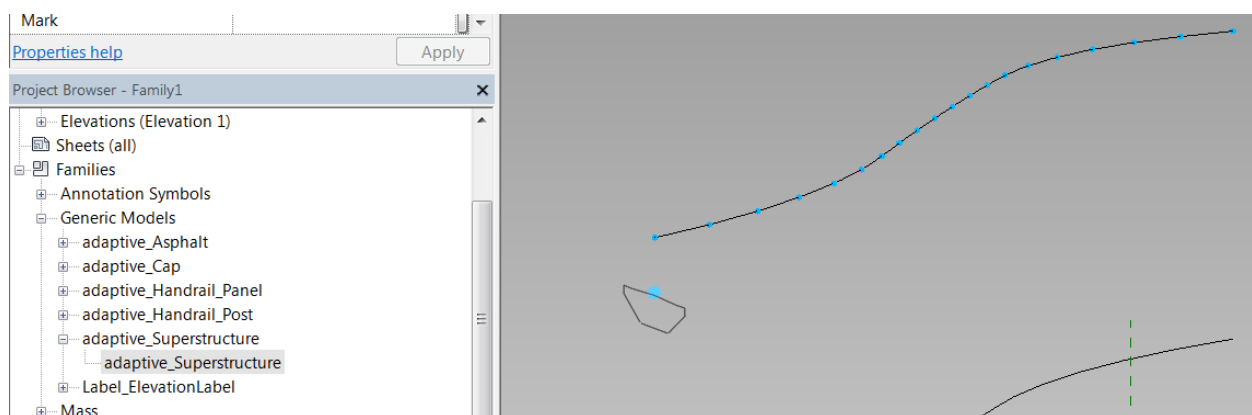
Once the adaptive family snaps to one of those 20 segment points it will adjust vertically and perpendicular to it:
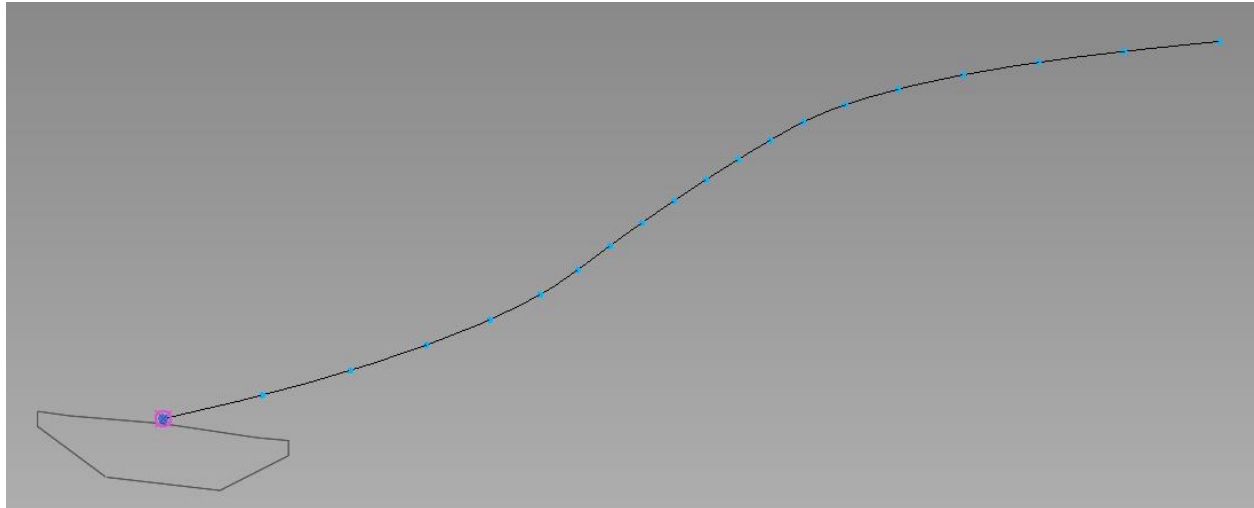
Now let´s do this 19 times more. Since we´re lazy let´s use Revit functionality. There´s a function called *Repeat*:
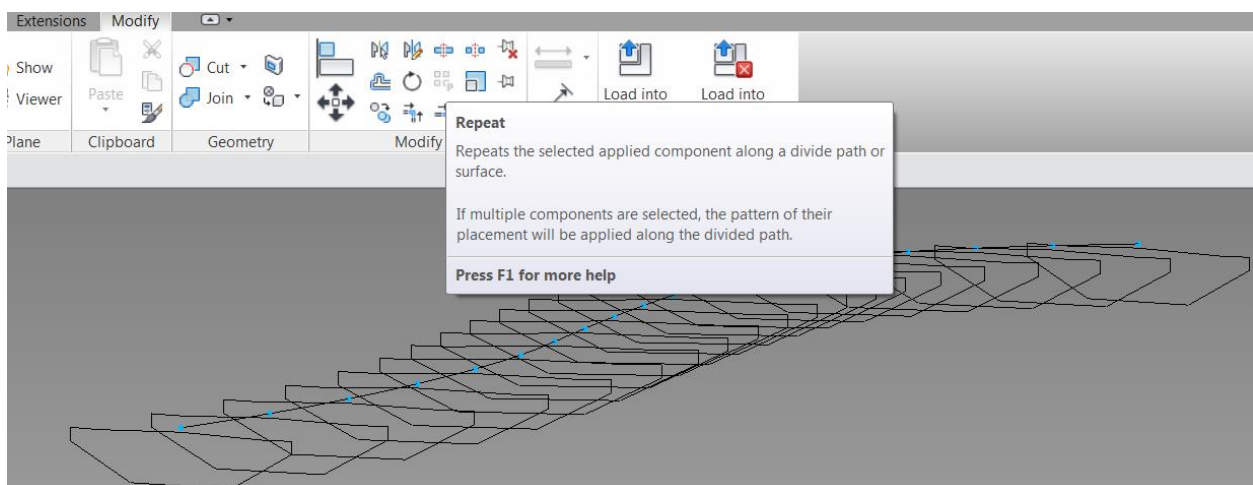
Having finished this you can click on one of your cross-sections, *remove the Repeater* and *create a Form* out of it – see next pictures:
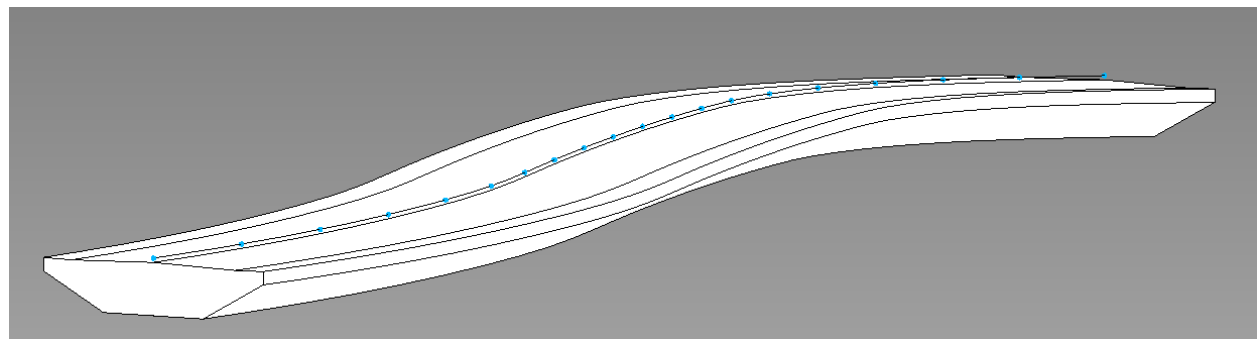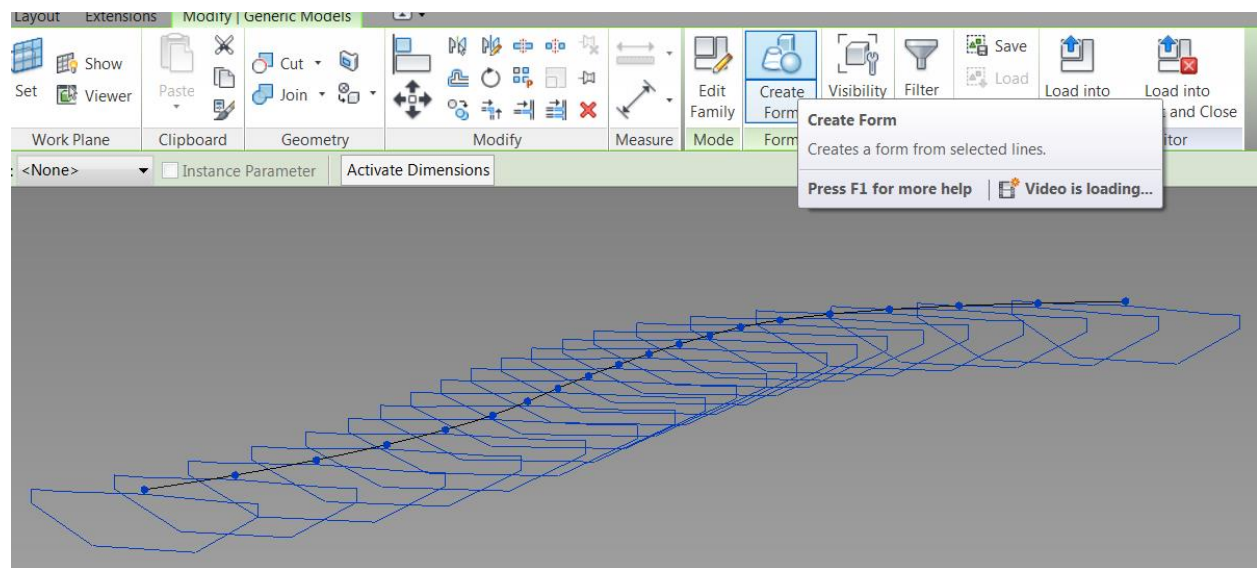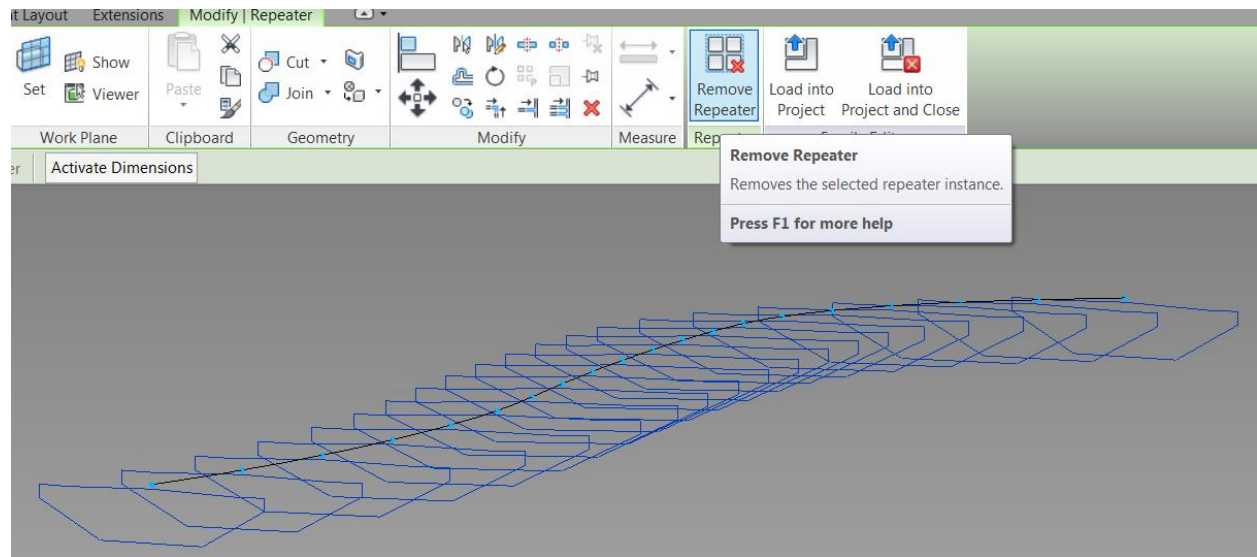
(Cross-sections are set to invisible)

Now you can do the same for the asphalt layer for instance:
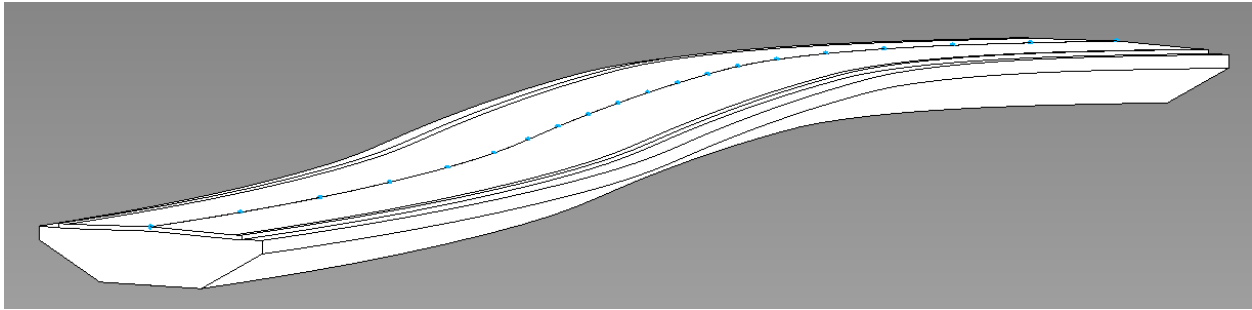
You can also create a *divided path* out of existing edges of your generic model body. Just select the desired edge and create the division:
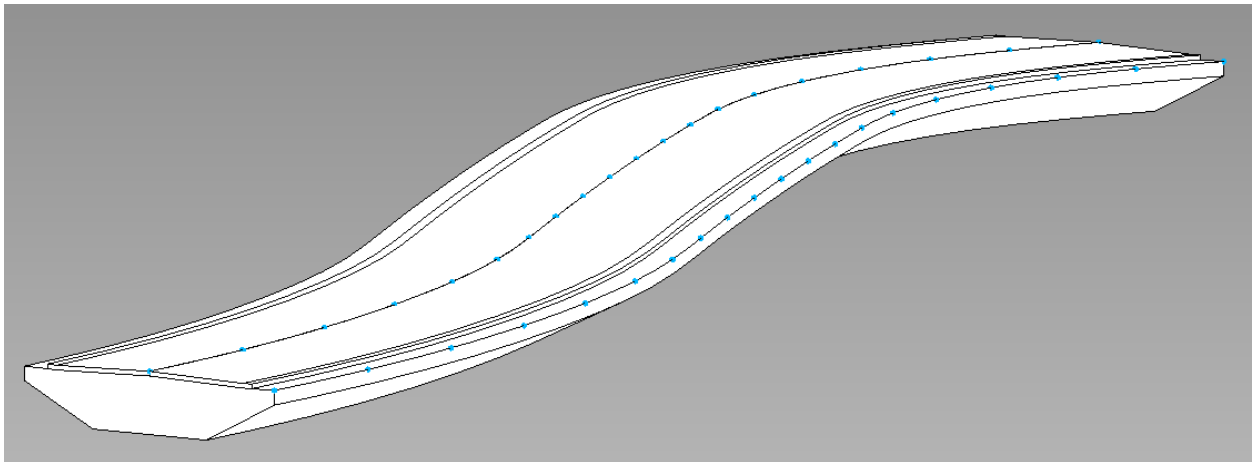
Now we can use our adaptive family for the caps:
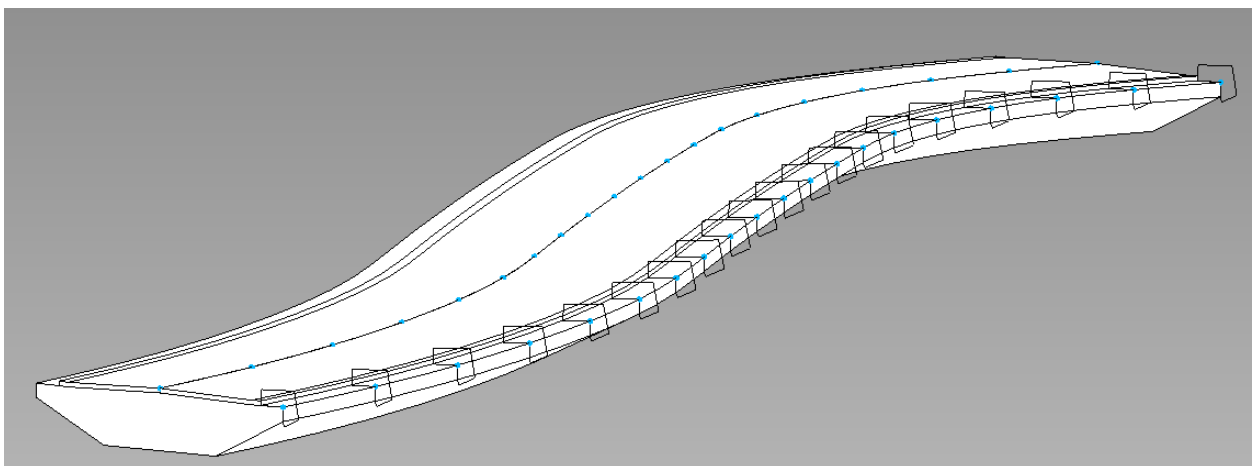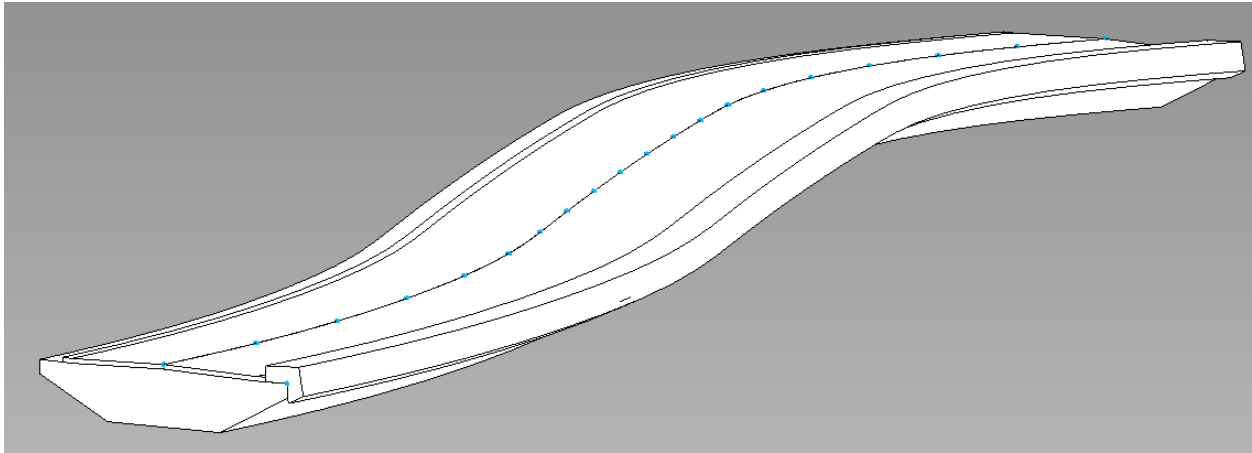
Of course – our generic models seem to be too long. Now you can use traditional Revit technology to subtract voids to shorten it to the desired length and shape.

Modeling concept 2 – modeling in Dynamo

Revit 2016 / Dynamo Release 0.8.2.2392 / Bridge package
*Starting in adaptive family template "Metric Generic Model Adaptive BRIDGE.rft" where all **mass***
***families** have already been included*

Let´s have a look into the second concept. The second concept concentrates more on modeling in Dynamo itself and using Revit just for the output, little adjustments of the model and further drawing production. Another difference compared to the first concept is that it´s using simple mass families (instead of adaptive families) as cross sections. In the following steps the Bridge package will be utilized – please navigate to the end of this script to see where you can download the package.

Some general notes to the input schema of the Bridge package´s nodes:

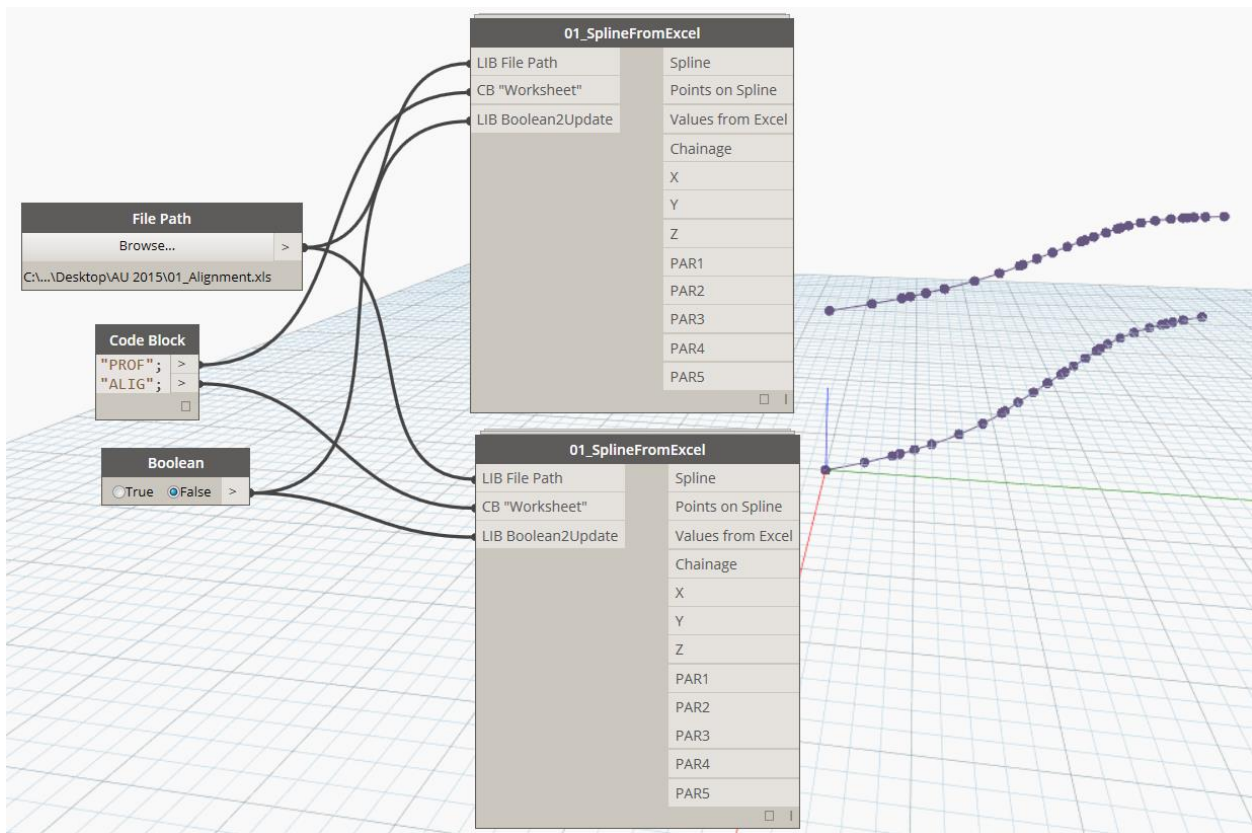| LIB …	Indicates that you have to search for a node in the library
LIB Select Edge	Search for *Select Edge* in the library
CB …	Code Block (double-click on canvas)
CB Offset	Mandatory: Provide a value for *Offset*
CBOffset	Optional: a common default value is already set; can be overridden
	(No space between CB and input)
CB "Worksheet"	Provide a text with quotation marks

First of all let´s import our profile:

Note: Why a Boolean? Imagine there are changes within the Excel file and you want to update the results in Dynamo just switch the Boolean to True instead of False or the other way around. To let the 01_SplineFromExcel node update itself there needs to be a change with the inputs.

Same can be done with the alignment:

Well – that was the same like in the first modeling concept. But now let´s stay in Dynamo. We have to create coordinate systems in each and every point of the profile (perpendicular to the profile / absolutely vertical):
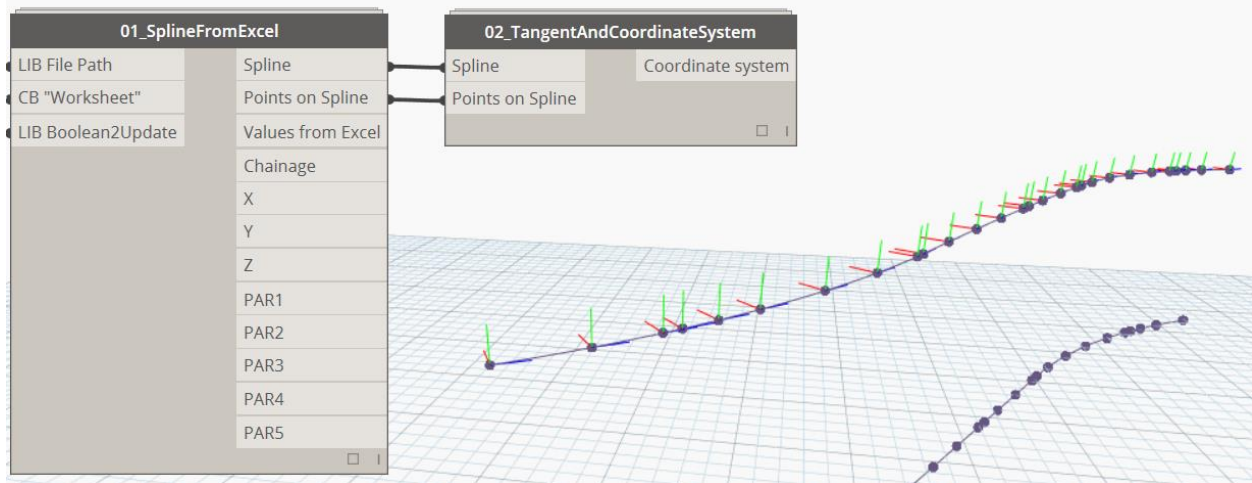
Let Dynamo access the mass family's we´ve prepared – for instance the superstructure cross section – read the variable parameters from Excel and loft it:
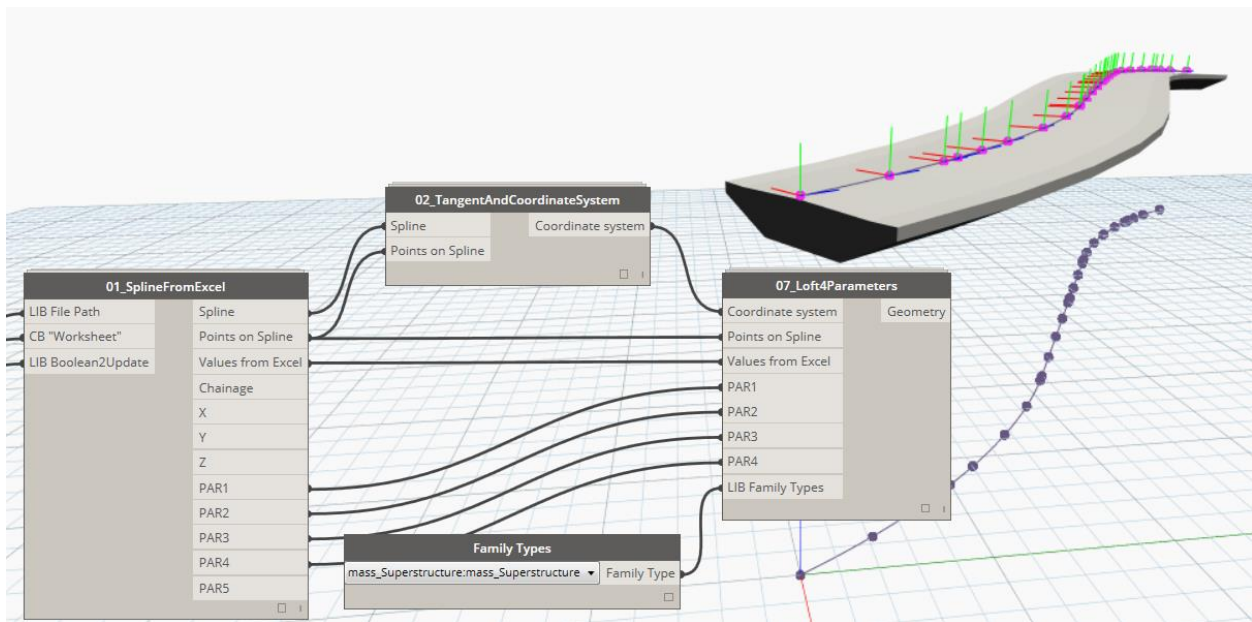
Note: Do this as long as needed to let Dynamo create all your solids you want to insert into Revit later on. I usually create all solids needed for my superstructure for instance. Then I run another script within a new family template for my first abutment / my second abutment / my pier / my caps / … As an result I will get a family for each and every part of my bridge which I finally will bring into my project environment. In terms of plan production you want to be able to steer the visibility / display / color / … of your certain parts differently.

Since the solid created just before is too long we have to shorten / trim it at a specific station. Therefore let´s create a station plane along our alignment. We need to specify the station; the default angle is 90°; let´s imagine there´s a skewed angle of 110°:
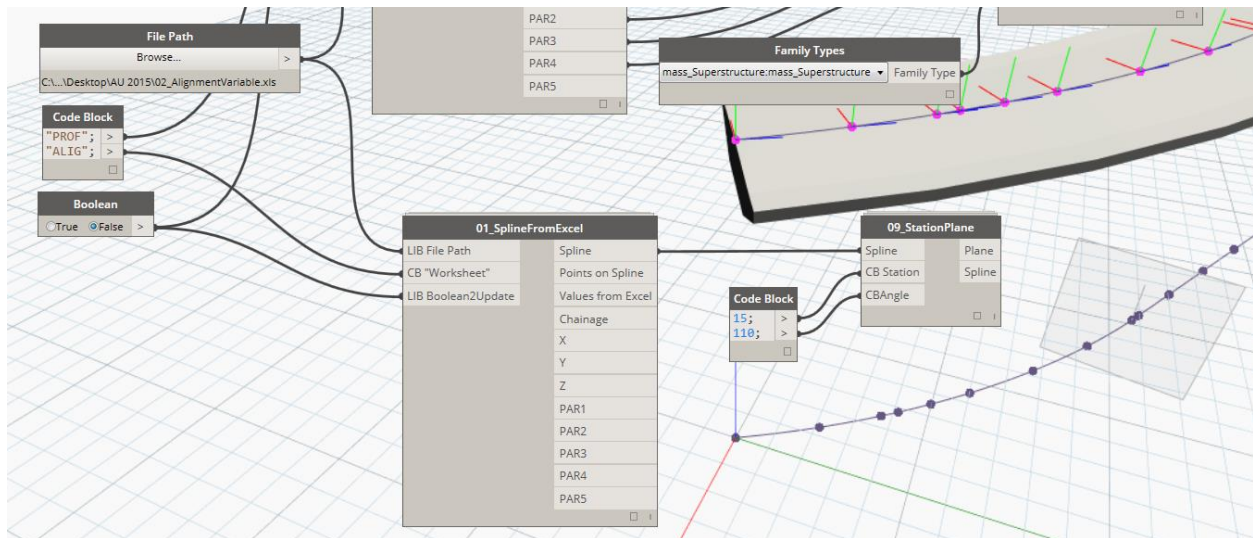

In a second step let´s trim the superstructure at our station plane:
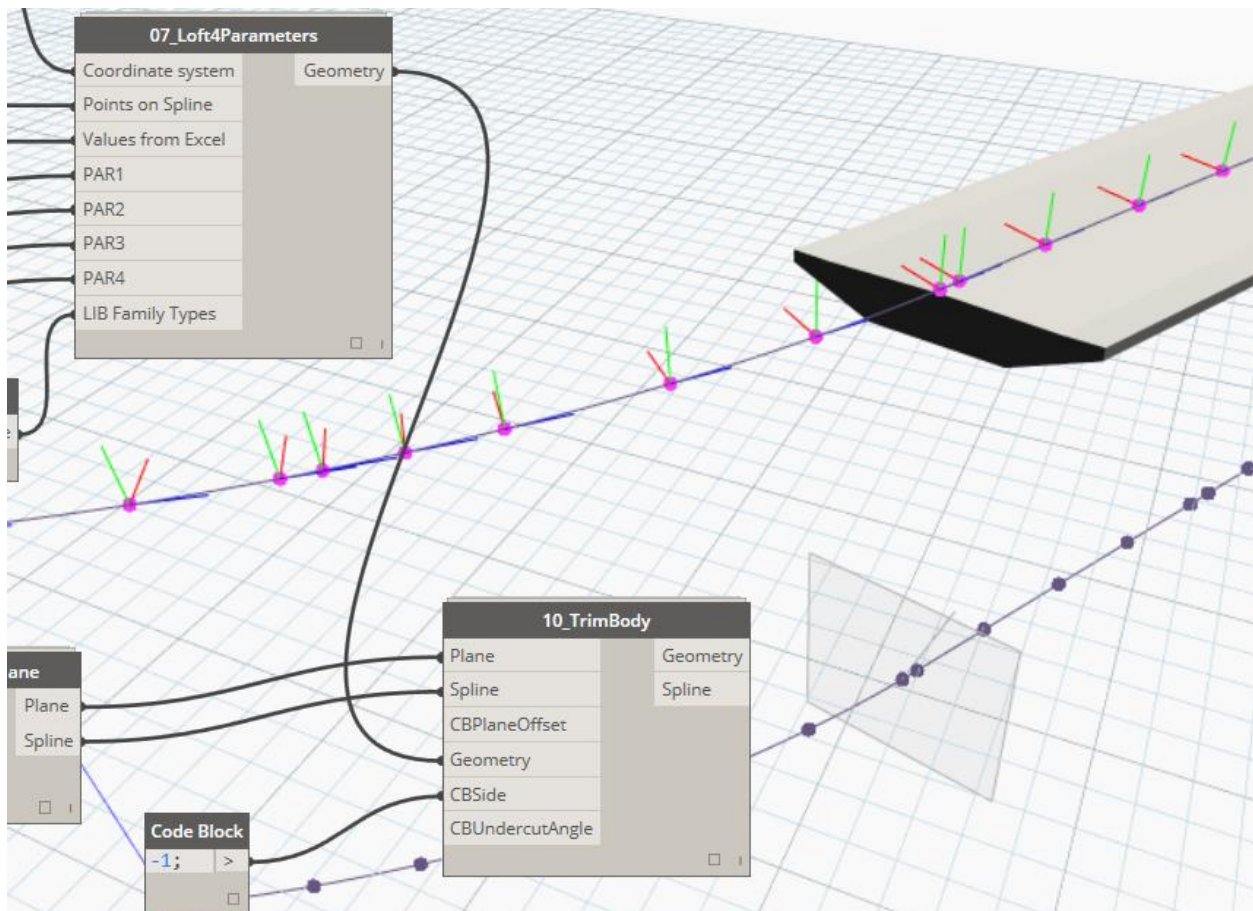
Note: Basically Dynamo displays all modeling steps. The trimmed geometry as well as the geometry from our loft will still be visible / superpose each other. Do a right-click on the loft node and uncheck it´s preview.

If you want to import your solid / geometry into Revit just search for a node called *ImportInstance.ByGeometry.* After that your geometry will show up in Revit for the first time:
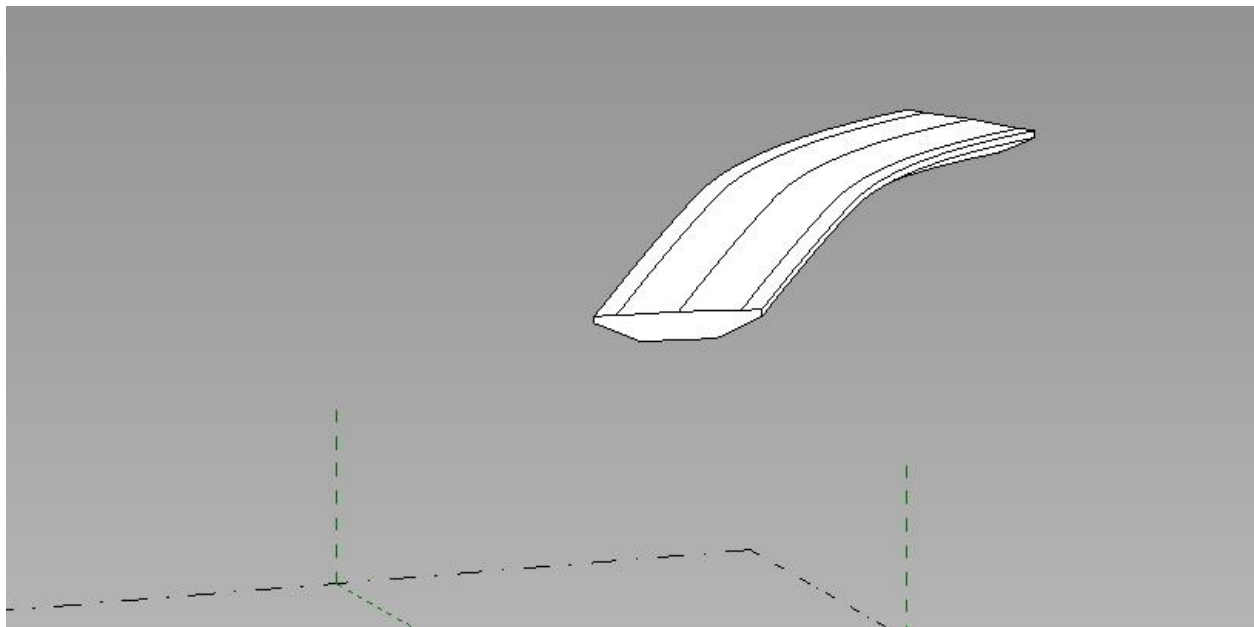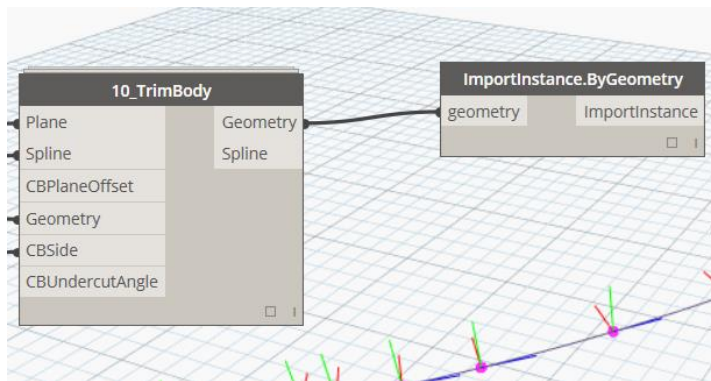
Basically planers and designers are always interested in certain elevations of the bridge´s edges at a specific station / under a specific angle. Normally this often is really manual and time consuming work to calculate those values by using a pocket calculator for instance.

To make this much easier there´s another node which displays all elevation values. Under the hood Dynamo will create an invisible station plane which intersects with the geometry. On each intersection point the appropriate elevation will be determined and displayed with a text object.

Let´s say we are interested in all elevations at station 25 and an angle of 90° (default):
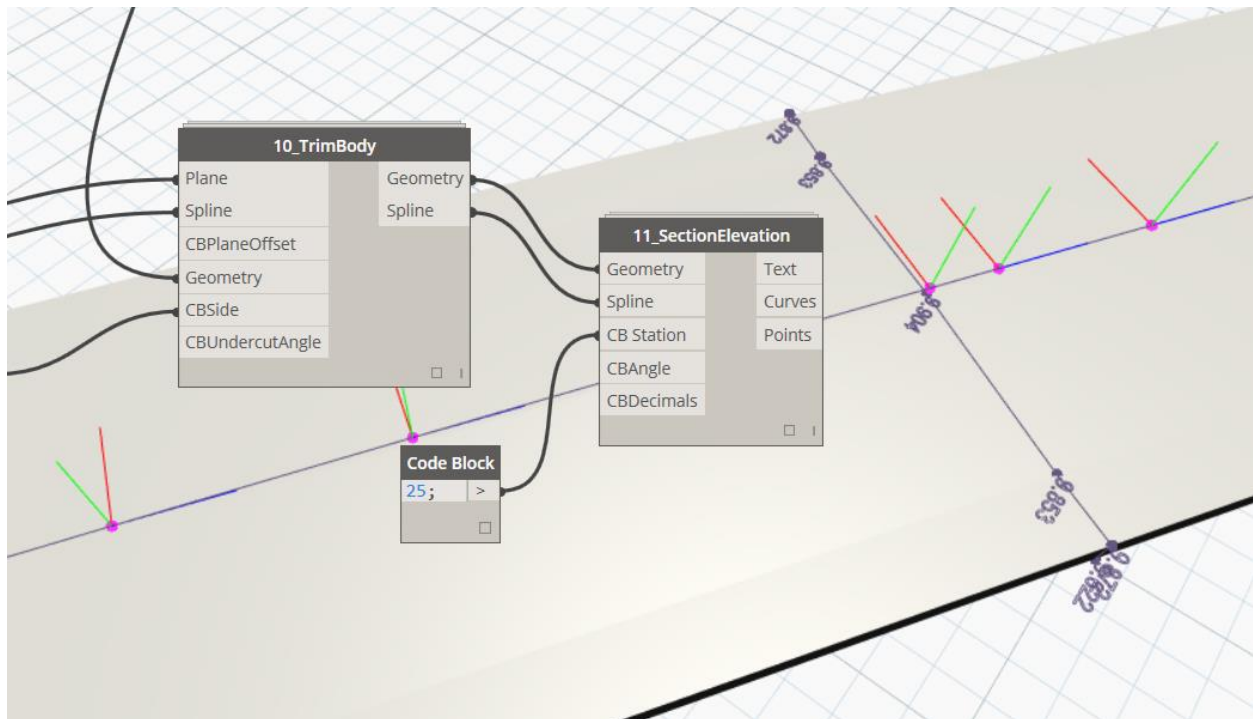
Wouldn´t it be cool to not just have those elevations in Dynamo but also in Revit in terms of plan production?! There´s another node which does the same like the one above but additionally adds a labeling family into Revit. The labeling family has a parameter called "Elevation" which finally will be displayed in Revit:
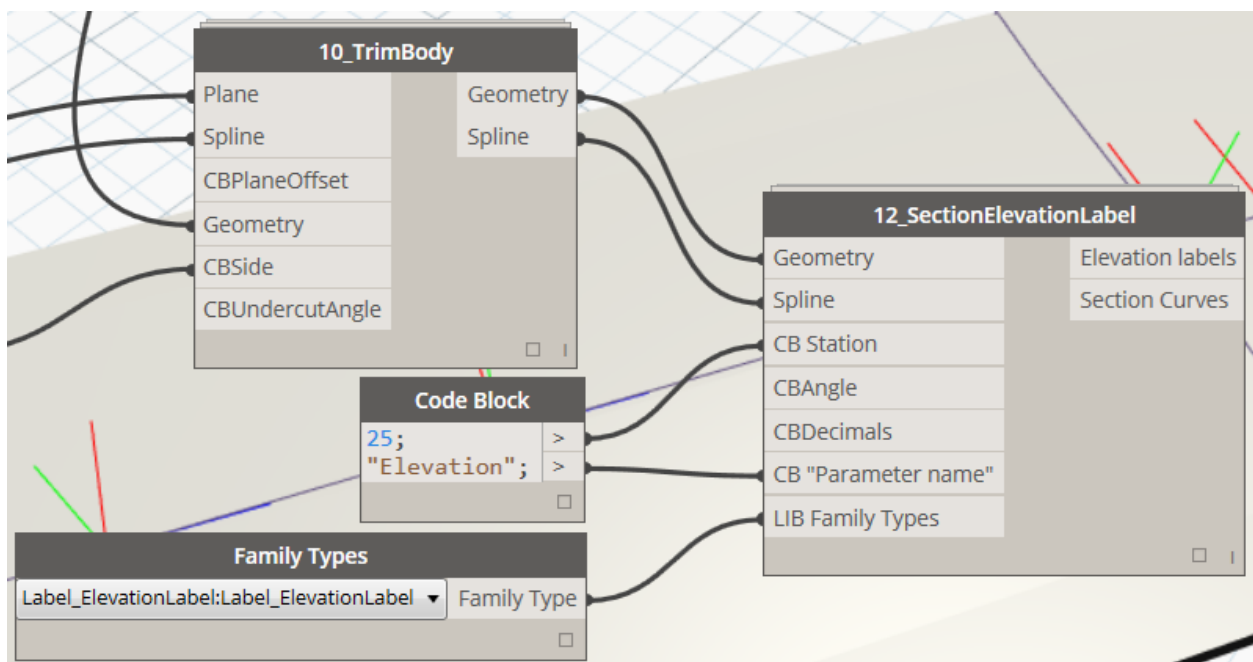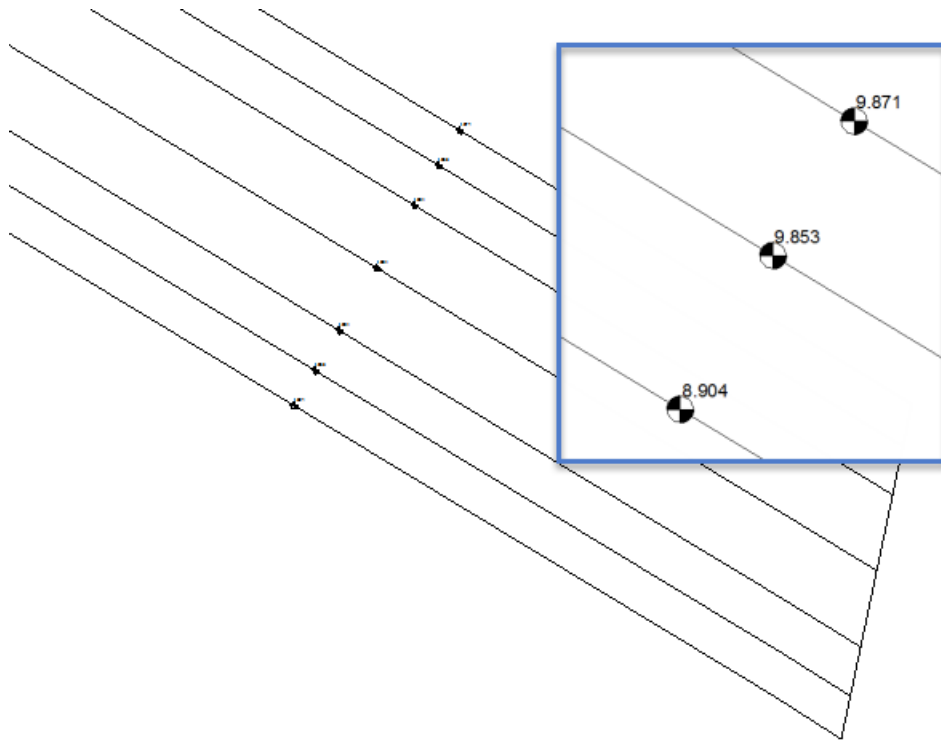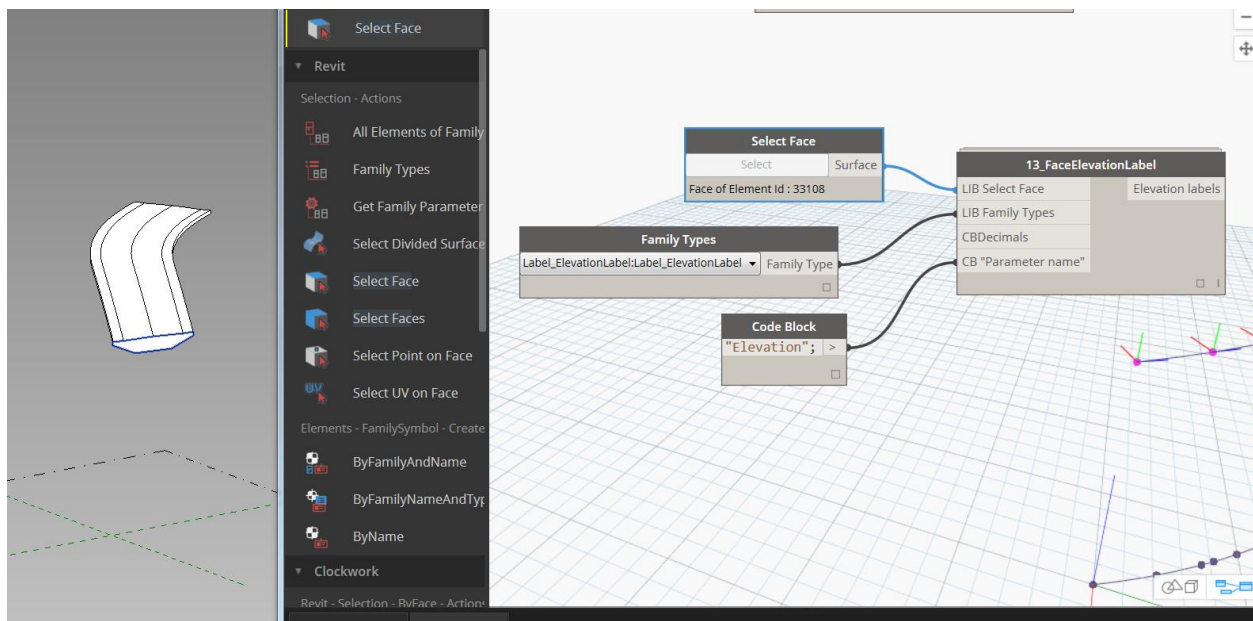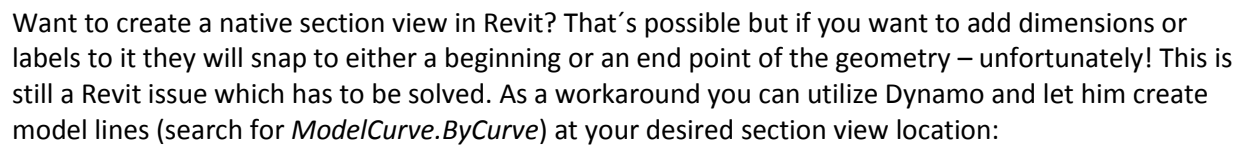
Not too bad! But guess what – you can also define an increment for your station value. For instance let´s create those labels from station 25 to station 60 every 2.5 meters:
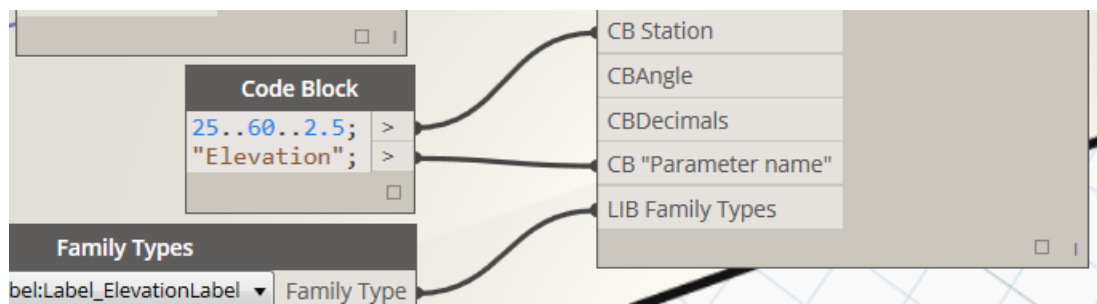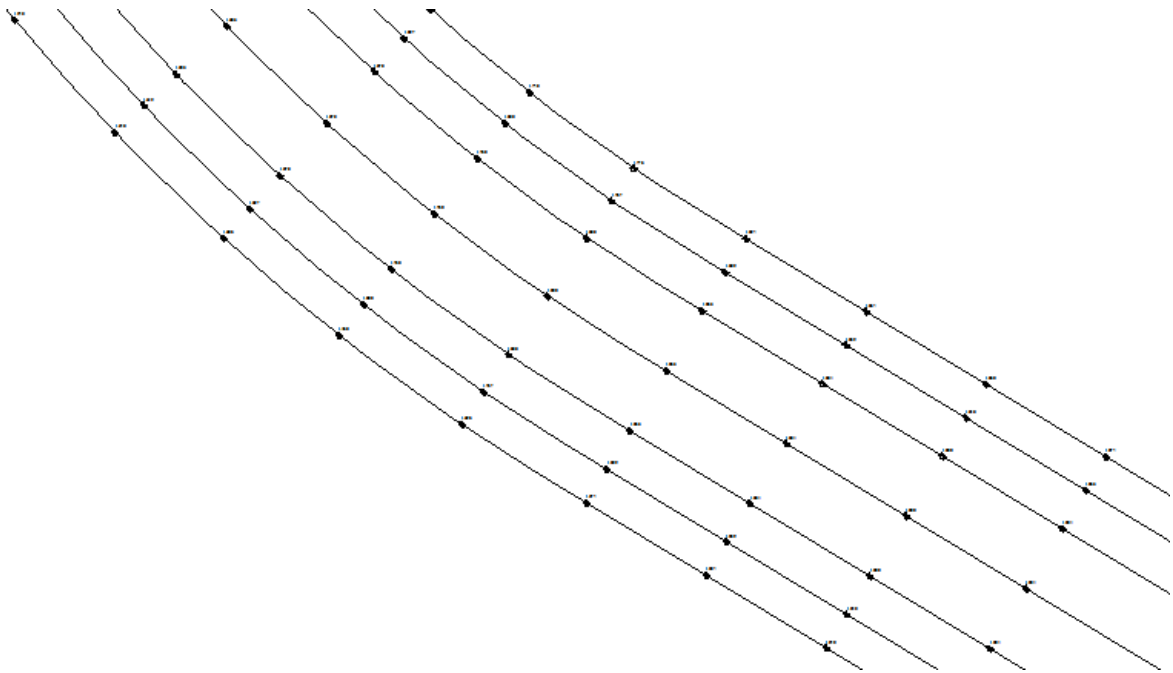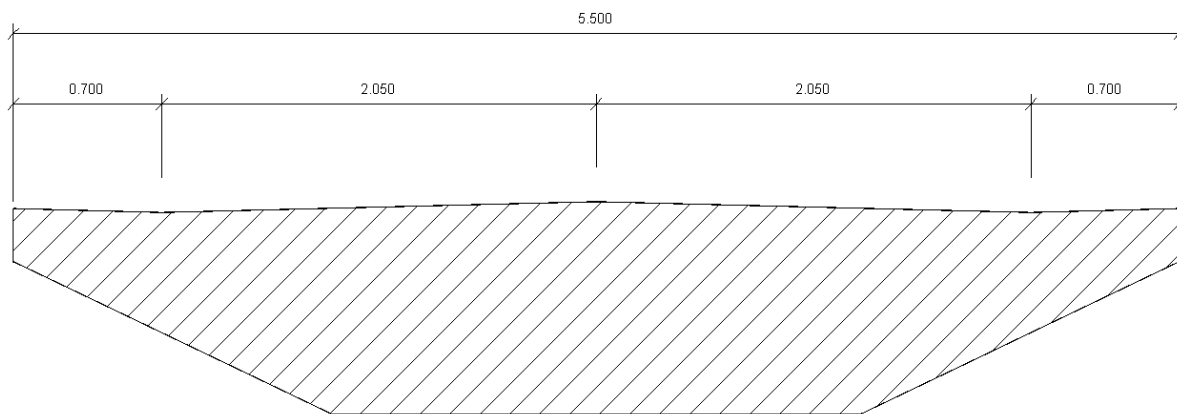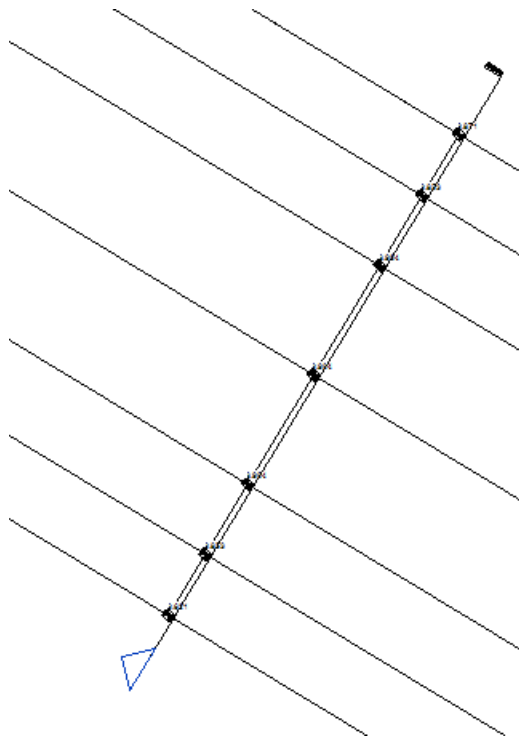
Remember our trimmed end face of our superstructure? It doesn't fit into the increment´s range because of the skewed angle. To be also able to label all types of faces there´s another node. We just need to live select the face we´re interested in within Revit. After that Dynamo will determine the vertices of that face and will bring labels back into Revit:

Want to create a native section view in Revit? That´s possible but if you want to add dimensions or labels to it they will snap to either a beginning or an end point of the geometry – unfortunately! This is still a Revit issue which has to be solved. As a workaround you can utilize Dynamo and let him create model lines (search for *ModelCurve.ByCurve*) at your desired section view location:

Note: Basically the imported geometry is an *imported symbol* at the moment. You can explode it and it will get a generic model which can host rebar / can have a material / can be cut in terms of section views / … In current available Dynamo builds there is another option available where you can import Dynamo geometry right into generic models.


In a last step I´d like to introduce an option how to create standardized bridge equipment and decorations like handrails / noise protections barriers / guard rails / built in parts / … In this case it will be about a handrail utilizing two adaptive families. For these types of actions Dynamo really reduces the modeling time to a minimum.
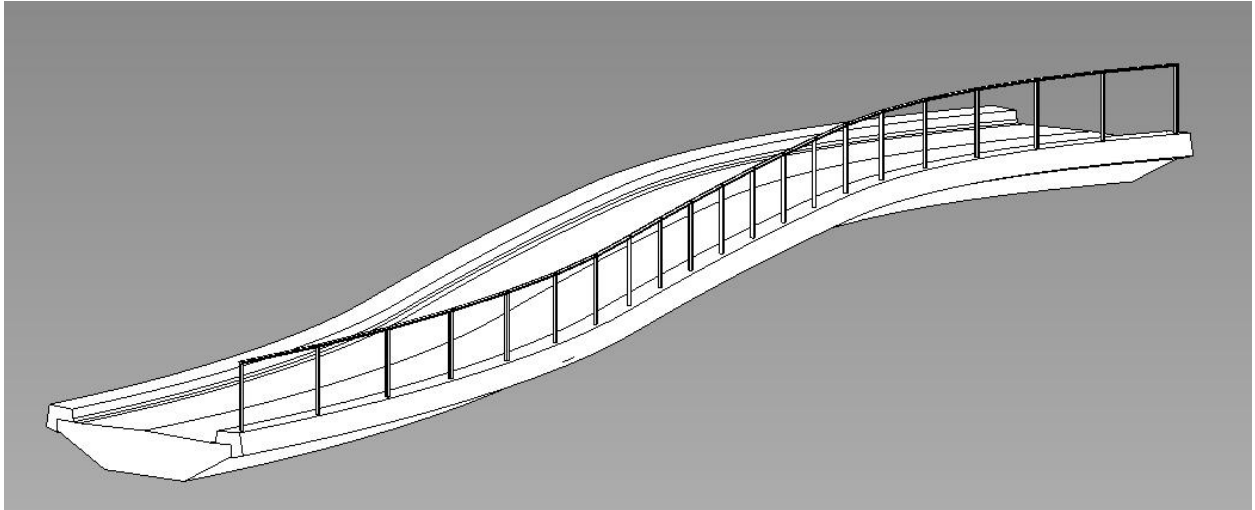
In this example I´d like to create a handrail automatically by using Dynamo. Handrail design in Germany for instance is highly standardized and driven by norm drawings. Those standards are built into the following node:
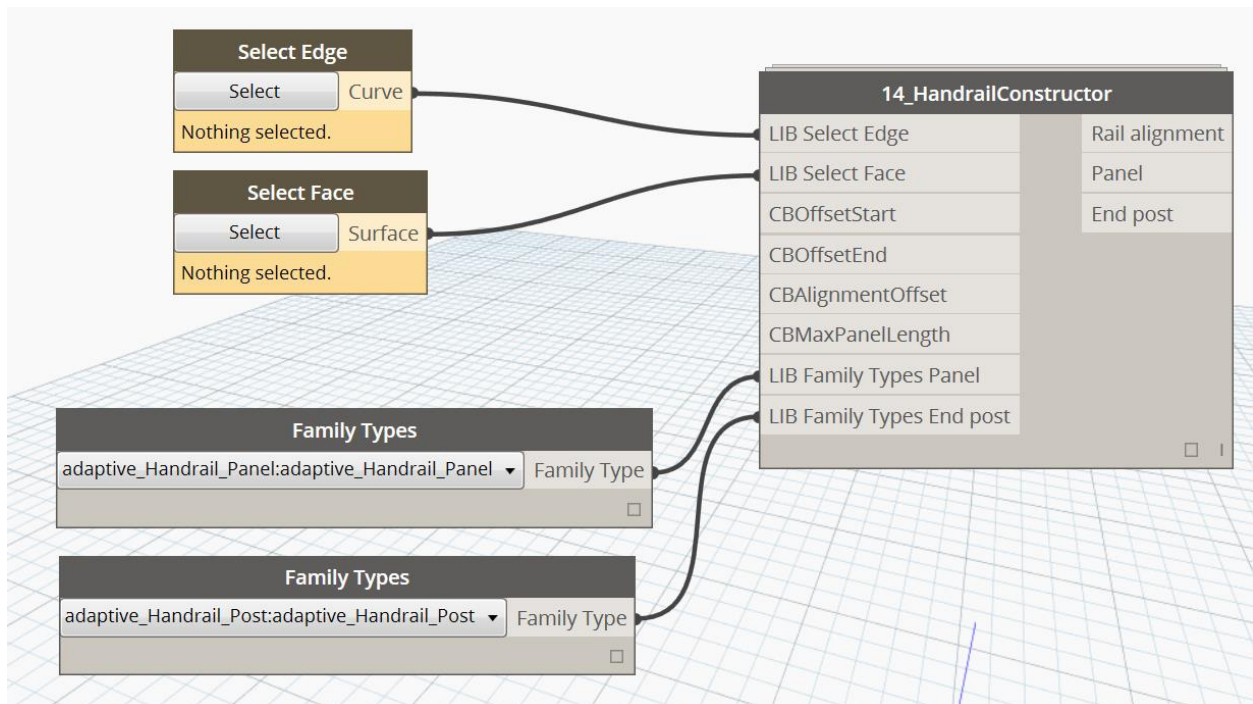
You need to live select an edge and a face of the object which hosts your handrail – in this example it is hosted by the right cap:
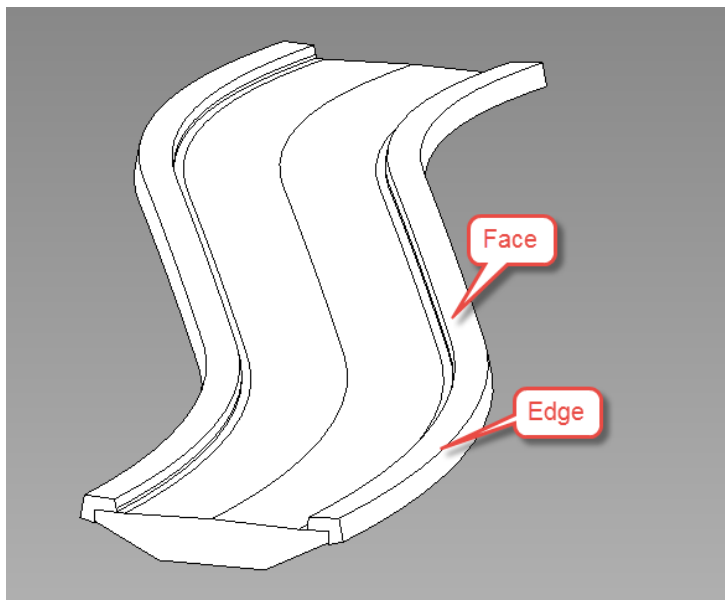
Here we go!!!

Summary

The workflow you have seen in this class respectively document isn´t fully developed so far. There are some questions which still needs to be answered by either spending more time on testing or thinking about other Dynamo scripts / workflows / … . There might also be some open tasks in terms of Revit´s and Dynamo´s development.

Nevertheless the current results were focused on geometric modeling and are very promising from my point of view! Dynamo really acts like a door-opener for the bridge industry today!

In the past we showed this workflow to a bunch of customers in EMEA with extremely big success (even it hadn´t that level of development)! Being able to model their bridges in 3D, getting exact volumes, creating sections wherever they want, getting elevation information, doing photorealistic renderings, lowering their errors almost to zero during design, better communicating with their stakeholders and utilizing their BIM models for further phases and tasks brings their productivity and reputation to a new level!

During discussions with customers, Autodesk resellers and peers there are a lot´s of ideas waiting to be implemented:

- Automatic section creation
- Unfolded curved section creation
- Rebar
- Driving inputs (alignment and cross section) by structural analysis
- …

Having said this, …

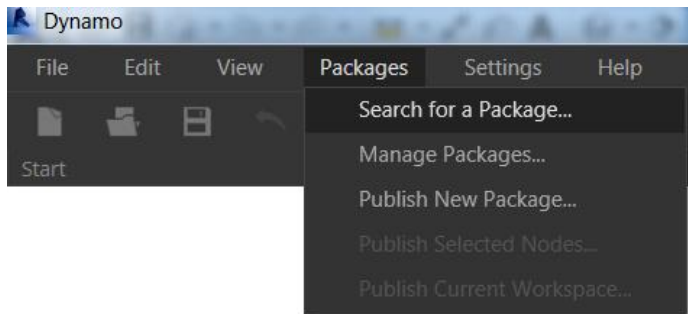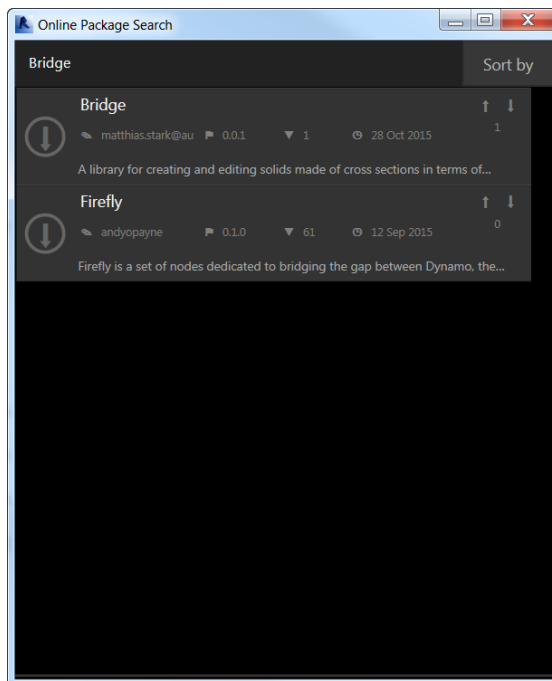**Stay tuned | Get inspired | Test it**

Test it - Download the Bridge package

1. Download and install the package

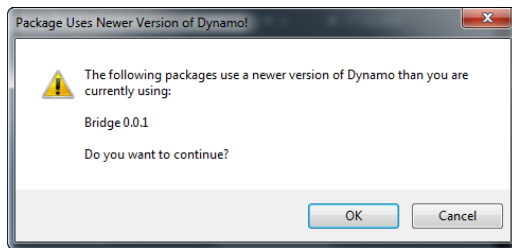- Start Dynamo and click on *Packages / Search for a Package*…


- Search for *Bridge*

- Click on the arrow within the circle to download the package
- You will be asked if you want to install the current version of Bridge
- Hit *OK*
- There might be a message telling you that the nodes were created with an older or newer version of Dynamo
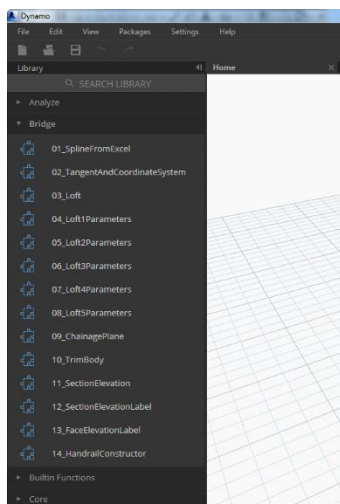- Hit *OK* to continue

- The Bridge package as well as the Dynamo Text package will be installed. The Dynamo Text package is utilized within a custom node of the Bridge package – that´s the reason why
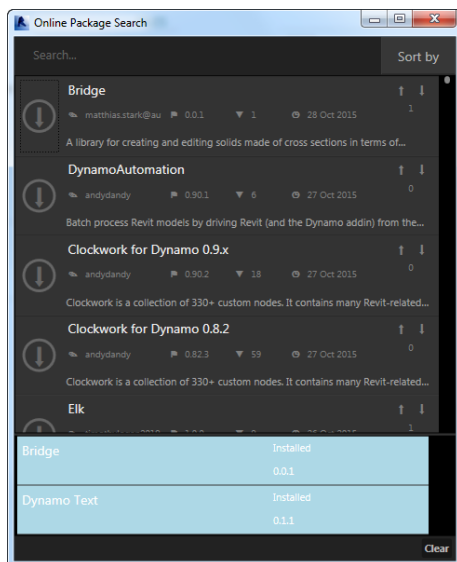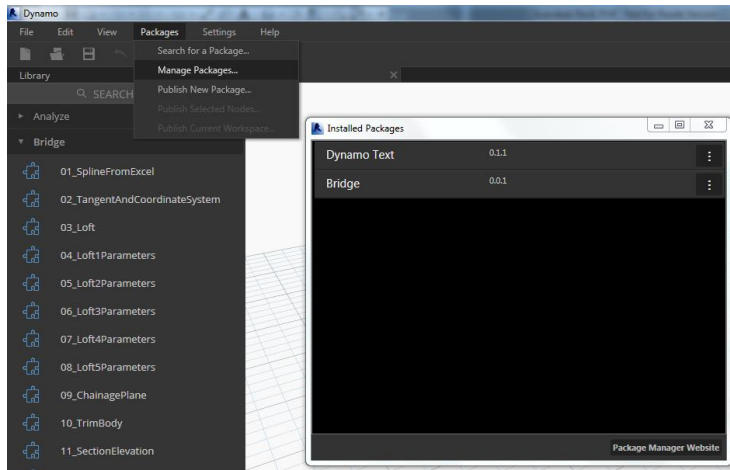

- Start a new project in Dynamo
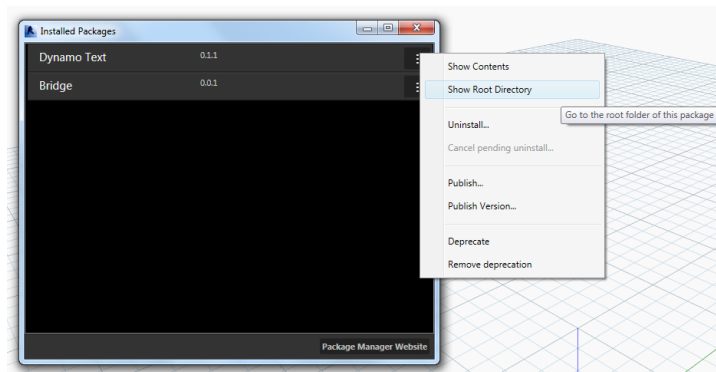- There´s a new category in the library window showing up: *Bridge*

2. Access additional resources

- Click on *Packages / Manage Packages*...

- Your installed packages will show up
- Click on the button next to bridge
- Click on *Show Root Directory*

- The Bridge package folder will be opened showing you additional files for testing
  (for instance the family template, cross section families, Excel file and examples…)