ES17397:
Taking BIM for Structural Engineering to the Limits and Beyond

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Class summary

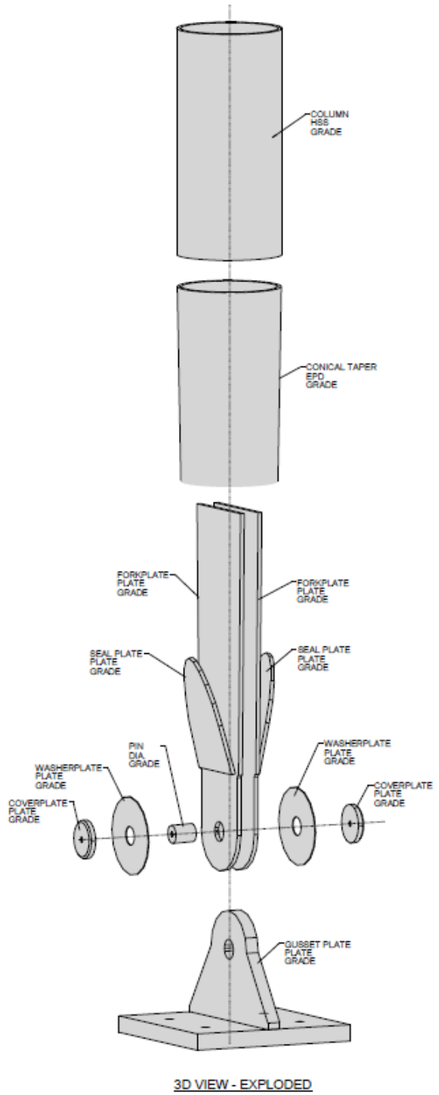
This class will examine new workflows to ***increase productivity*** and ***minimize*** the ***waste*** caused in the design and documentation of structural solutions. The class will explore ***interoperability*** between analysis software and Building Information Modelling (BIM) tools, with a focus on ***Revit*** as the primary documentation model. By making the most of ***parametric*** tools such as ***Dynamo*** and ***Grasshopper/Rhino***, we will demonstrate how "***Open BIM***" can provide the foundation to successful ***collaboration***. Using real-world examples of ***complex*** and ***simple*** structures to demonstrate techniques and processes that will ***maximise*** your ***efficiency*** and make the most of your team's skill set, and examine what ***future skills*** your team might need to develop

Key learning objectives

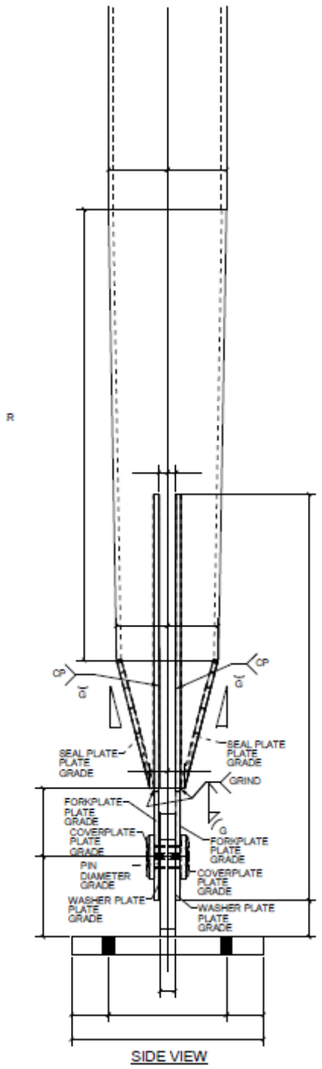
At the end of this class, you will be able to:

- Learn how to make the most of ***collaborative workflows*** between the ***Architect*** and ***Engineer*** to maximize efficiency and minimize waste in the design and delivery of structural engineering solutions
- Learn how to ***optimize structural solutions*** to provide sustainable design choices that are buildable and cost-effective
- Gain insight into the ***training opportunities*** and skill set your team will need to stay ahead of your competitors
- Gain a better understanding of the needs of ***all stakeholders*** in the lifecycle of a project through design, construction, and operation of a facility, and learn how your design can be ***flexible to accommodate future changes***

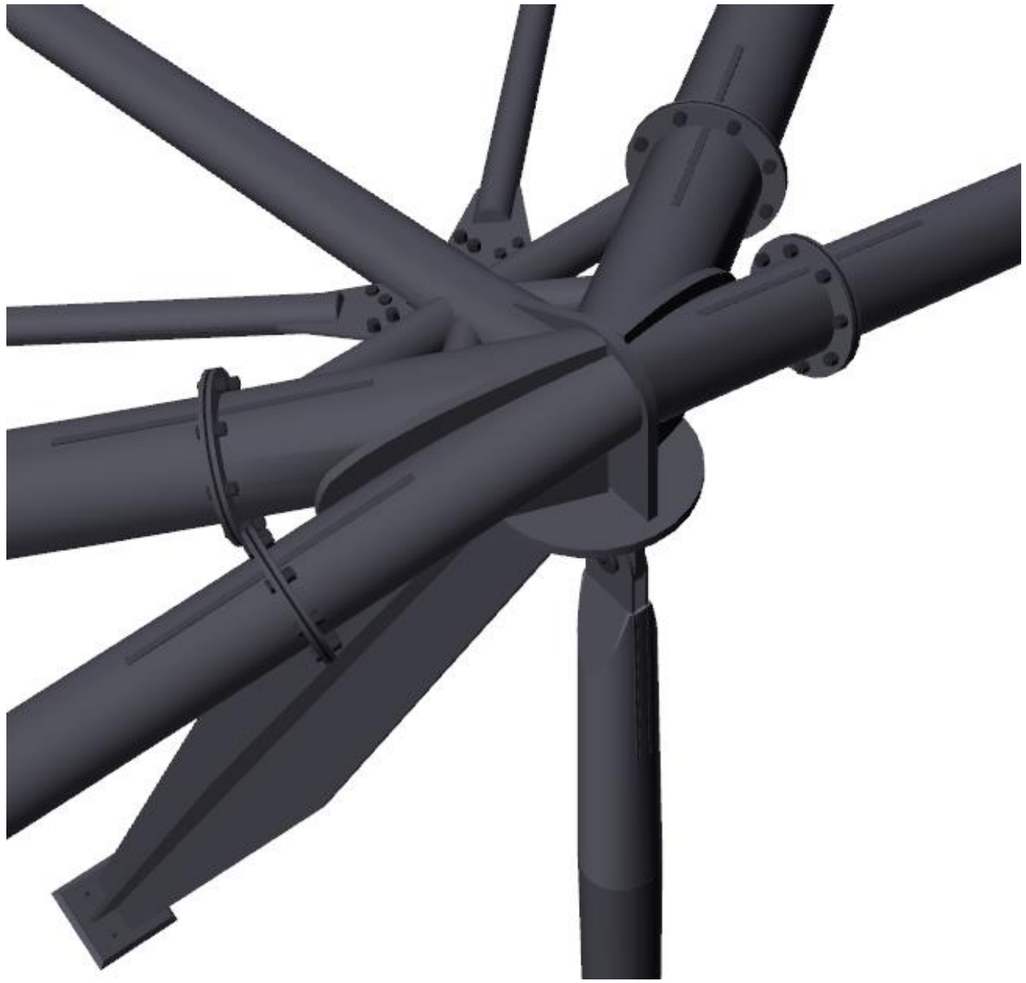
How could you detail these steel connections?



3D VIEW - EXPLODED



SIDE VIEW



- 3D ***Exploded*** View with ***2D*** details
- ***3D Interactive*** View

Modelling Study Goals

- Minimise duplication of effort, create ***flow of data***, encourage ***open BIM***, applicable to ***simple*** and ***complex*** connections, ***flexible*** to change for ***external stakeholder*** requests

- Scope of work – Provide ***LOD300 details*** from which a shop detailer can produce LOD400 model/drawings

- Current workflow for ***geometry*** and ***section sizes***– ***Rhino/Grasshopper/Analysis(GSA)/Revit***

Considerations

- How many ***variations*** of the connections are there?
- Checking of ***shop detailers model/drawings***
- ***Resources*** and ***training*** required
- Time to build ***fully parametric*** solution ‘v’ in place 3d connection ***modelling within Revit***
- ***Architectural impacts, constructability*** and ***shop detailers preferences*** downstream

Possible Solutions

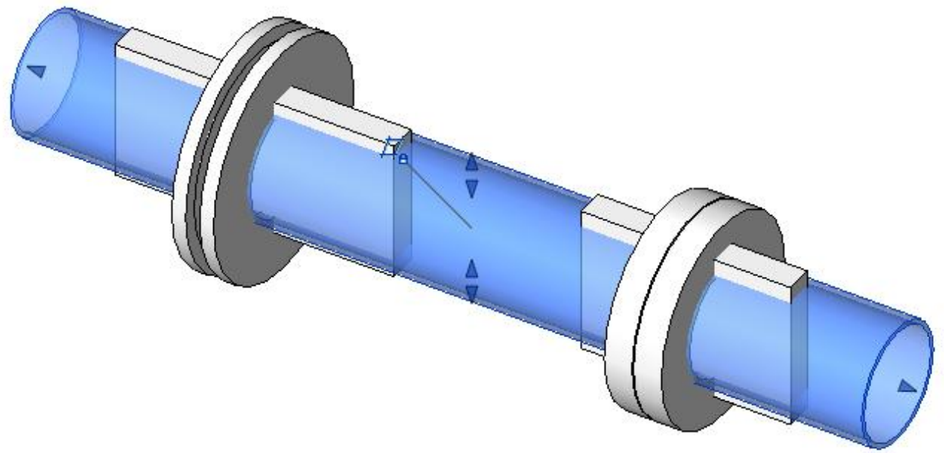
- Embed parametric connection components within individual ***Revit framing and column families***

- Use generic parametric ***Revit connection components*** for plates and bolts and model ***“in place”*** connections which rely on parametric relationships to one another

- Build parametric script in ***Grasshopper/Tekla/Dynamo*** to create ***relationships between node connection members***

Embed parametric connection components within individual Revit framing and column families

Dimensions		
End 1 Splice Cap Dia Ext (default)	80.0	=
End 1 Splice Cap T (default)	20.0	=
End 1 Splice Cut Back (default)	300.0	=
End 1 Splice Cut Back Working (default)	400.0	=if(End 1 Splice OnOff, End 1 Splice Cut
End 1 Splice Gap (default)	20.0	=
End 1 Splice Gap Half (default)	10.0	=End 1 Splice Gap / 2
End 1 Splice Slot L (default)	400.0	=
End 1 Splice Slot L Half (default)	200.0	=End 1 Splice Slot L / 2
End 1 Splice Slot T (default)	40.0	=
End 1 Splice Slot W Ext (default)	15.0	=
End 2 Splice Cap Dia Ext (default)	60.0	=
End 2 Splice Cap T (default)	40.0	=
End 2 Splice Cut Back (default)	250.0	=
End 2 Splice Cut Back Working (default)	350.0	=if(End 2 Splice OnOff, End 2 Splice Cut
End 2 Splice Gap (default)	2.0	=
End 2 Splice Gap Half (default)	1.0	=End 2 Splice Gap / 2
End 2 Splice Slot L (default)	300.0	=
End 2 Splice Slot L Half (default)	150.0	=End 2 Splice Slot L / 2
End 2 Splice Slot T (default)	40.0	=
End 2 Splice Slot W Ext (default)	20.0	=
End Splice Cap Dia Extension (default)	60.0	=

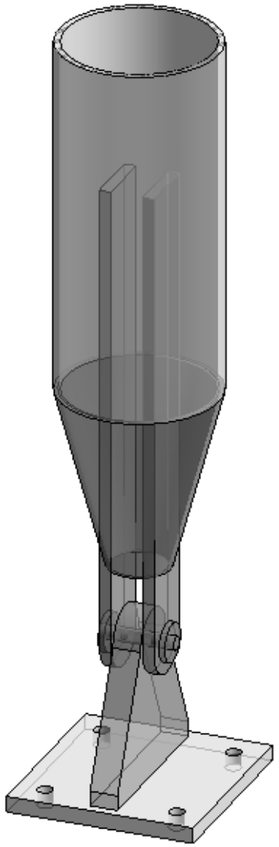


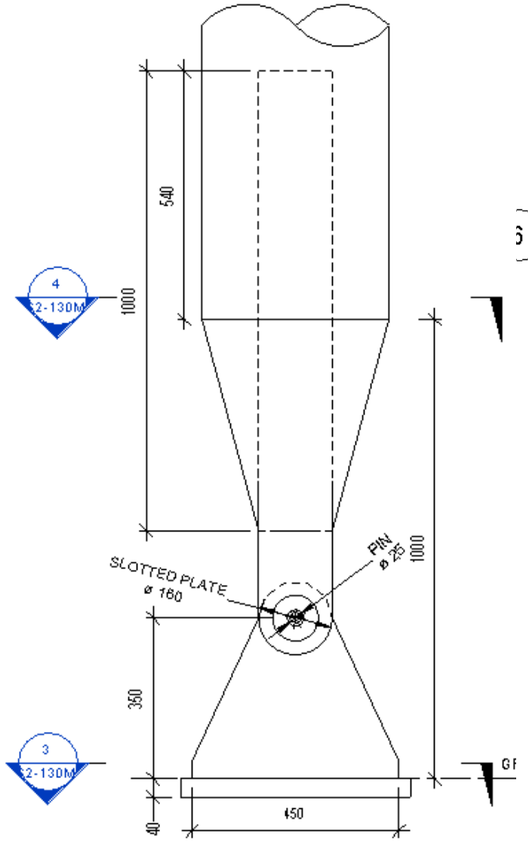
Parameter	Value
Graphics	
End 1 Splice OnOff (default)	☑
End 2 Splice OnOff (default)	☑

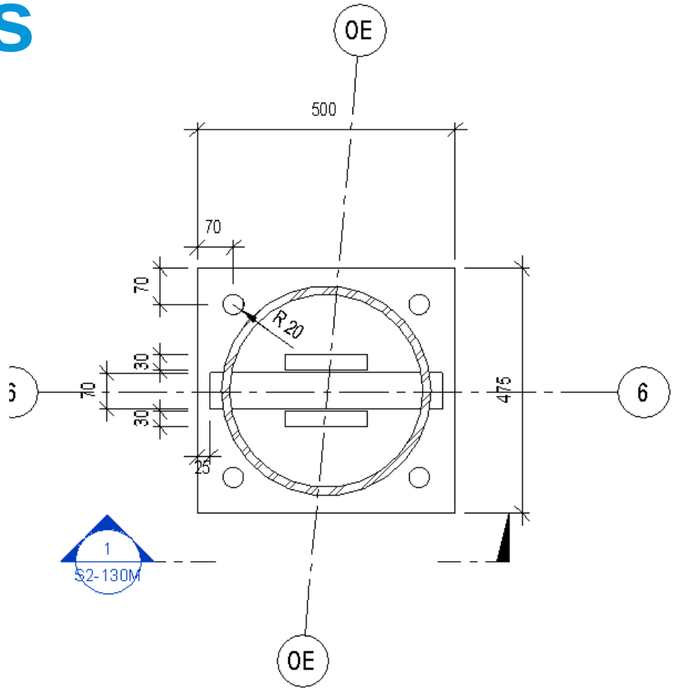
- Approx. ***20 new parameters*** required for this connection

Embed parametric connection components within individual Revit framing and column families

Dimensions		
Baseplate Edge Dist (default)	35.4	=
Baseplate Hole Dia (default)	59.2	=
Baseplate Length (default)	495.6	=
Baseplate Pin Cap Dia (default)	99.8	=
Baseplate Pin Cap T (default)	15.0	=
Baseplate Pin Dia (default)	35.0	=
Baseplate Pin Extension (defaul	25.0	=
Baseplate T (default)	41.2	=
Baseplate V Plate to Taper V Pl	5.0	=
Baseplate Vert Dist to Pin CL (d	350.0	=
Baseplate Vertical Dia Inner (de	150.0	=
Baseplate Vertical H1 (default)	500.0	=
Baseplate Vertical H2 (default)	183.6	=
Baseplate Vertical Radius (defa	91.8	=Baseplate Vertical H2 / 2
Baseplate Vertical T (default)	65.4	=
Baseplate Width (default)	548.5	=
End 1 Cut Back (default)	1500.0	=
End 1 Cut Back Working (defaul	1600.0	=if(End 1 Cut Back OnOff, End 1
End 2 Cut Back (default)	500.0	=
End 2 Cut Back Working (defaul	600.0	=if(End 2 Cut Back OnOff, End 2
OD	273.1	=
Seal Plate Angle (default)	61.201°	=
Taper CHS OD2 (default)	183.6	=Baseplate Vertical H2
Taper CHS Vertical Slot L (defa	280.0	=
Taper CHS Vertical T (default)	68.6	=





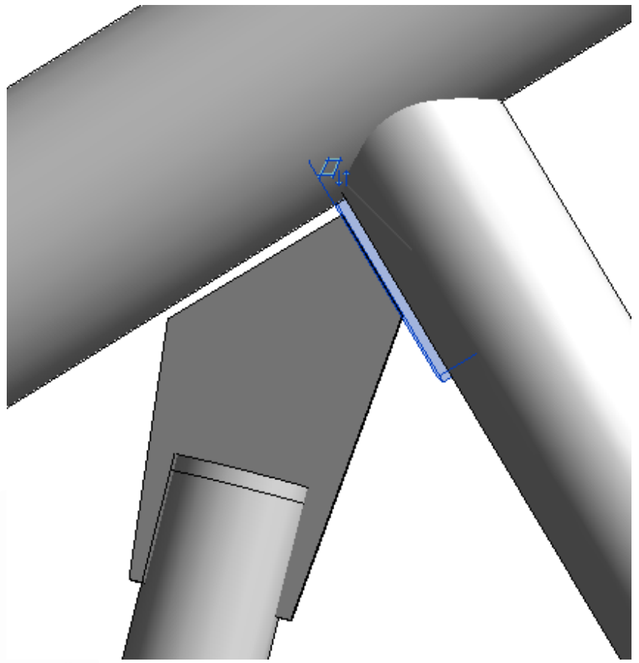


Parameter	Value
Graphics	
Baseplate OnOff (default)	☑
Baseplate Vertical OnOff (defau	☑
End 1 Cut Back OnOff (default)	☑
End 2 Cut Back OnOff (default)	☑
Taper CHS OnOff (default)	☑
Taper CHS Vertical Plates OnOff	☑

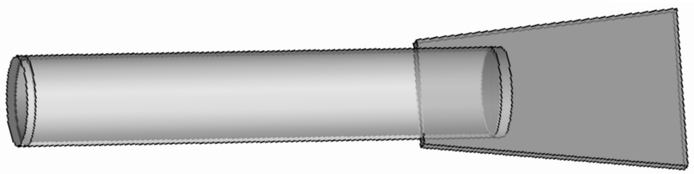
- Approx. ***20 new parameters*** required for this connection

Embed parametric connection components within individual Revit framing and column families

Dimensions		
End 1 Splice Cap Dia Ext (default)	80.0	=
End 1 Splice Cap T (default)	20.0	=
End 1 Splice Cut Back (default)	300.0	=
End 1 Splice Cut Back Working (default)	400.0	=if(End 1 Splice OnOff, End 1 Splice Cut
End 1 Splice Gap (default)	20.0	=
End 1 Splice Gap Half (default)	10.0	=End 1 Splice Gap / 2
End 1 Splice Slot L (default)	400.0	=
End 1 Splice Slot L Half (default)	200.0	=End 1 Splice Slot L / 2
End 1 Splice Slot T (default)	40.0	=
End 1 Splice Slot W Ext (default)	15.0	=
End 2 Splice Cap Dia Ext (default)	60.0	=
End 2 Splice Cap T (default)	40.0	=
End 2 Splice Cut Back (default)	250.0	=
End 2 Splice Cut Back Working (default)	350.0	=if(End 2 Splice OnOff, End 2 Splice Cut
End 2 Splice Gap (default)	2.0	=
End 2 Splice Gap Half (default)	1.0	=End 2 Splice Gap / 2
End 2 Splice Slot L (default)	300.0	=
End 2 Splice Slot L Half (default)	150.0	=End 2 Splice Slot L / 2
End 2 Splice Slot T (default)	40.0	=
End 2 Splice Slot W Ext (default)	20.0	=
End Splice Cap Dia Extension (default)	60.0	=



Parameter	Value
Graphics	
End 1 Cap Plate (default)	☑
End 1 Cap Plate OnOff (default)	☑
End 1 Cut Back OnOff (default)	☑
End 1 Slotted Plate OnOff (defa	☑
End 2 Cap Plate OnOff (default)	☑
End 2 Cut Back OnOff (default)	☑



Properties

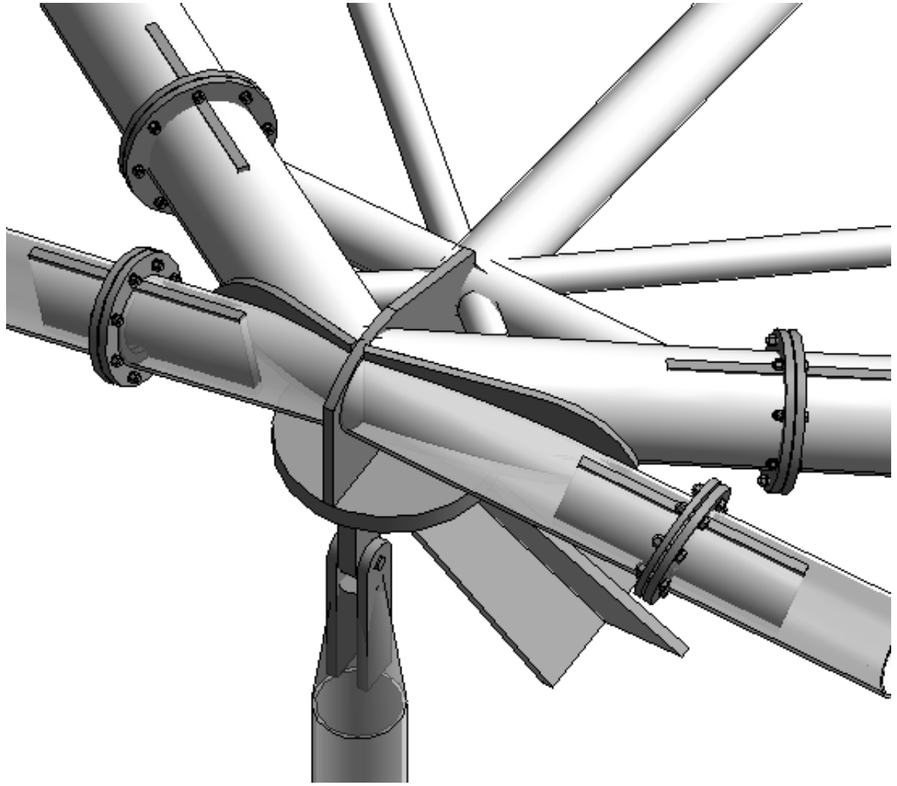
Rectangular Void - Face Based

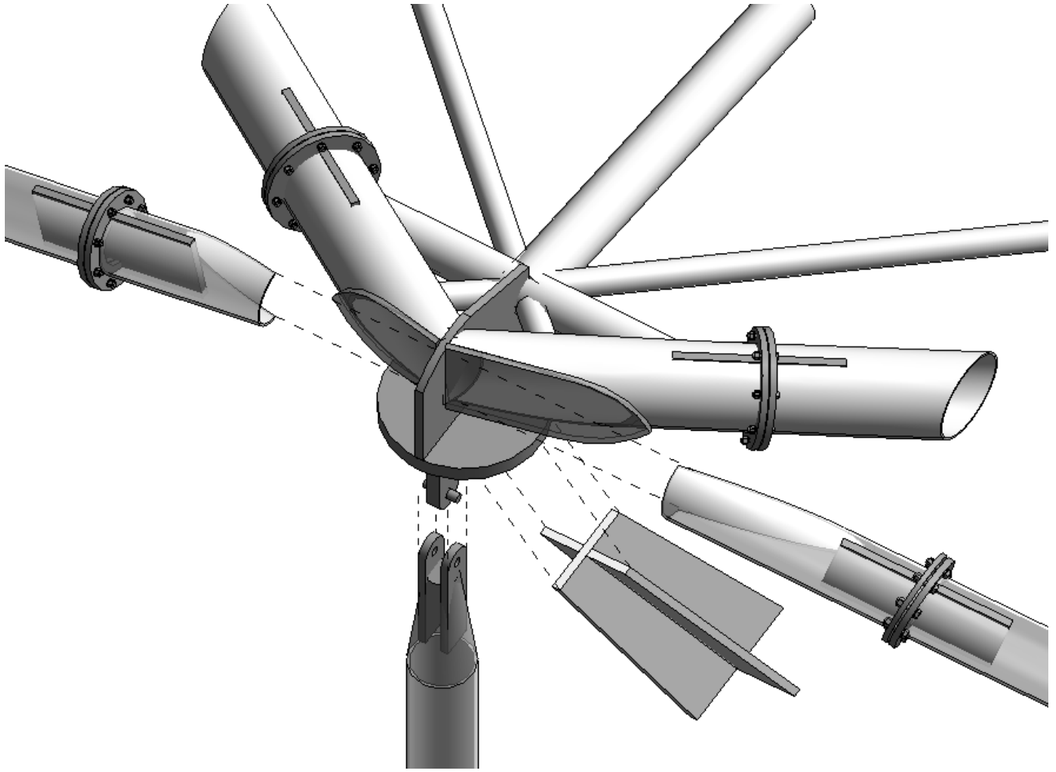
Generic Models (1) Edit Ty

Constraints	
Host	<not associated>
Elevation	17266.8
Dimensions	
Void Width	300.0
Void Depth above P...	100.0
Void Depth below P...	100.0
Void Breadth	100.0

- Parametric Relationship between members, ***manual adjustment required***

Use generic parametric Revit connection components for plates and bolts and model “in place” connections which rely on parametric relationships to one another





- ***No new parameter*** or families required
- Flexible exploded views ***simple to create***

Controlling parameter within Revit families/components

- Directly in ***Revit***
- Within a link through ***Excel***
- Within a link through ***Dynamo***

Directly in Revit project environment

Structural Columns (1)	
Baseplate Pin Cap T	15.0
Baseplate Pin Dia	35.0
Baseplate Pin Extension	25.0
Baseplate T	40.0
Baseplate V Plate to Taper V Plate Tol	5.0
Baseplate Vert Dist to Pin CL	350.0
Baseplate Vertical Dia Inner	25.0
Baseplate Vertical H1	450.0
Baseplate Vertical H2	160.0
Baseplate Vertical Radius	80.0
Baseplate Vertical T	70.0
Baseplate Width	475.0
End 1 Cut Back	1000.0
End 1 Cut Back Working	1100.0
End 2 Cut Back	0.0
End 2 Cut Back Working	100.0
Seal Plate Angle	61.201°
Taper CHS OD2	160.0
Taper CHS Vertical Slot L	1000.0
Taper CHS Vertical T	30.0

Advantages

- ***Quick*** to make small changes to a few parameters
- ***Little training*** of team required

Disadvantages

- ***Not linked*** to a calculation, therefore double handled
- ***Hard to distinguish parameter function***

Within a link through Excel

Structural Column Tapered Baseplate Schedule									
Type	Length	Width	BP Thickness	Bolt Edge Dist	Hole Dia	Pin Cap Dia	Pin Cap Thickness	Pin Dia	Pin Extension
HSS10.750X0.375	500	550	40	70	30	100	15	35	25
HSS16X0.625	500	500	20	50	30	100	15	35	25

	F	G	H	I	J	K	L	M	N	O
	Instance:Type	Instance:Baseplate Length	Instance:Baseplate Width	Instance:Baseplate T	Instance:Baseplate Edge Dist	Instance:Baseplate Hole Dia	plate Pin Cap Dia	Instance:Baseplate Pin Cap T	Instance:Baseplate Pin Dia	Instance:Baseplate Pin Extension
1	HSS10.750X0.375	500.0	550.0	40.0	70.0	30.0	100.0	15.0	35.0	25.0
1	HSS16X0.625	500.0	500.0	20.0	50.0	30.0	100.0	15.0	35.0	25.0

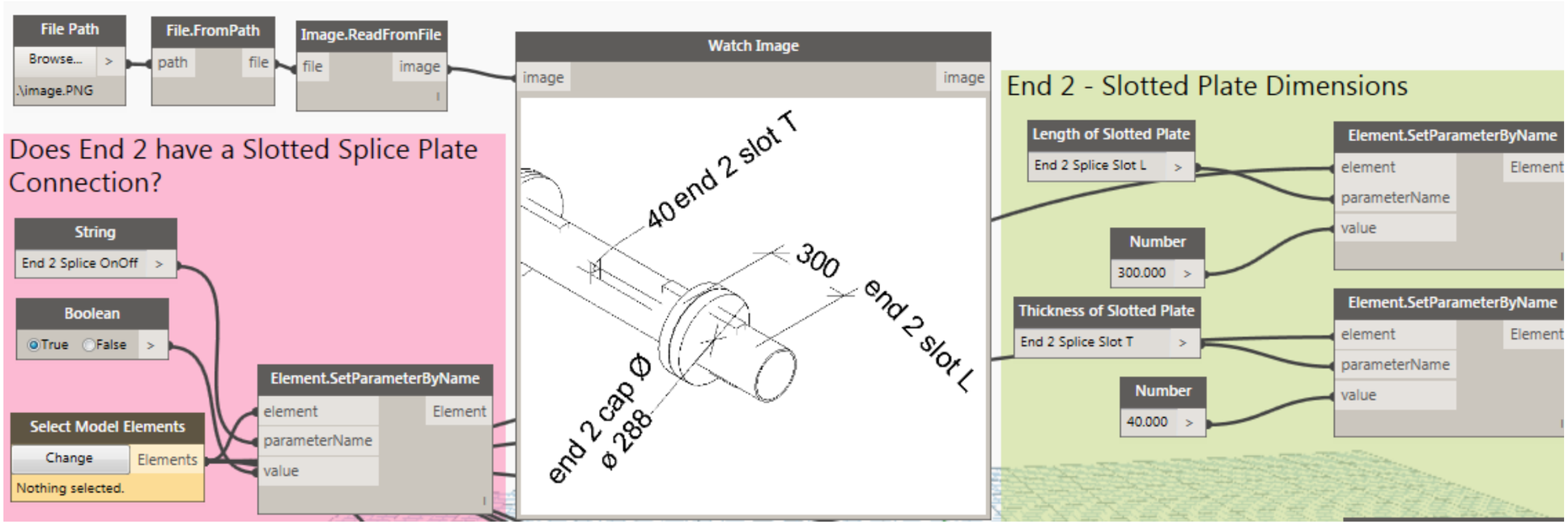
Advantages

- Can be ***linked to an engineering spreadsheet***, therefore no double handling
- ***Little training*** of team required

Disadvantages

- ***No visual preview*** of updates
- ***Not as quick*** as modifying in the project for ***small changes***
- Need to ***ensure Excel and Revit are in sync***

Within a link through Dynamo



Advantages

- Can ***add images*** to explain parameters
- ***Quick*** to make small changes
- ***Quick*** to generate new members/geometry

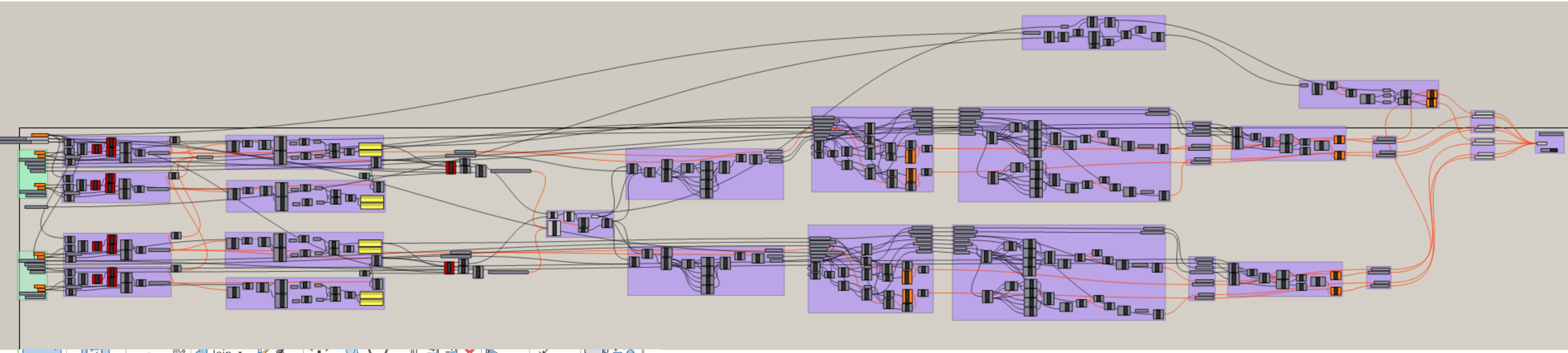
Disadvantages

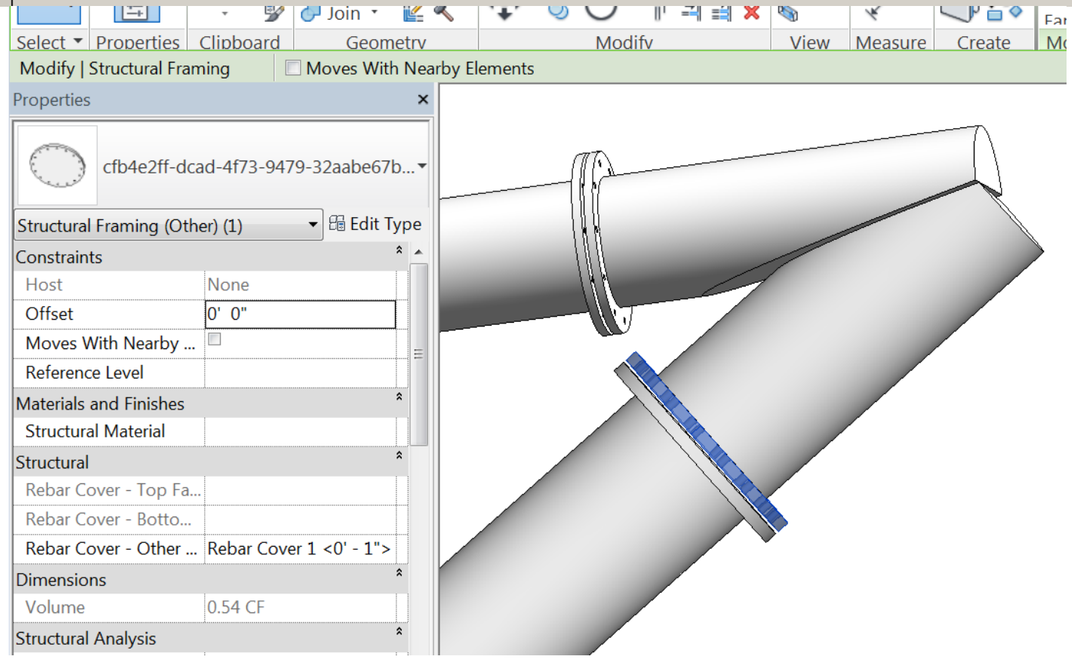
- Basic ***dynamo training required***
- Only controlling parameters within each member, ***no relationship between adjacent members***

Grasshopper & Dynamo

- Bespoke connections with ***parametric relationships to one another*** have to be ***created*** in either Grasshopper or Dynamo

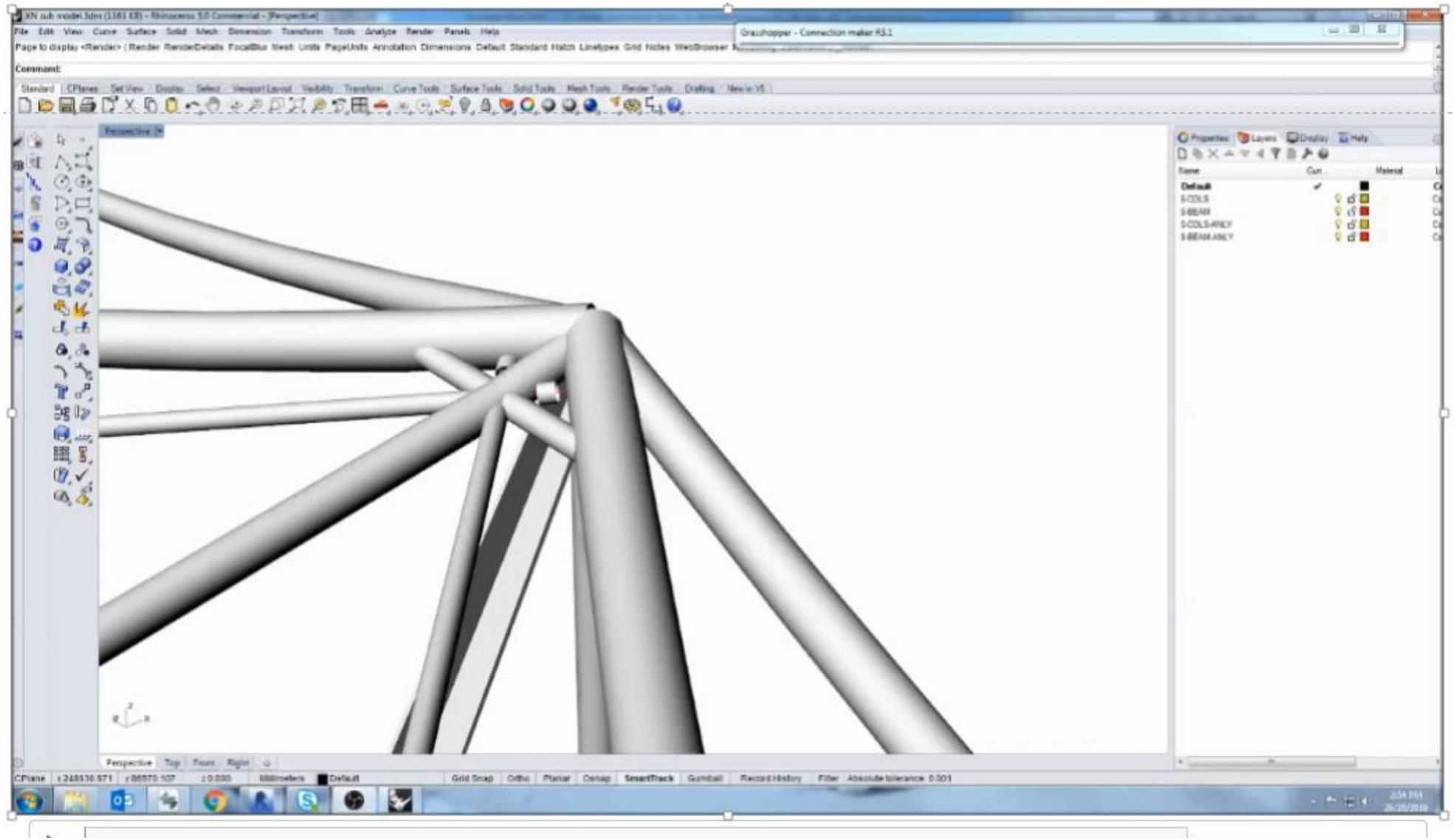
Grasshopper / Revit via Geometry Gym



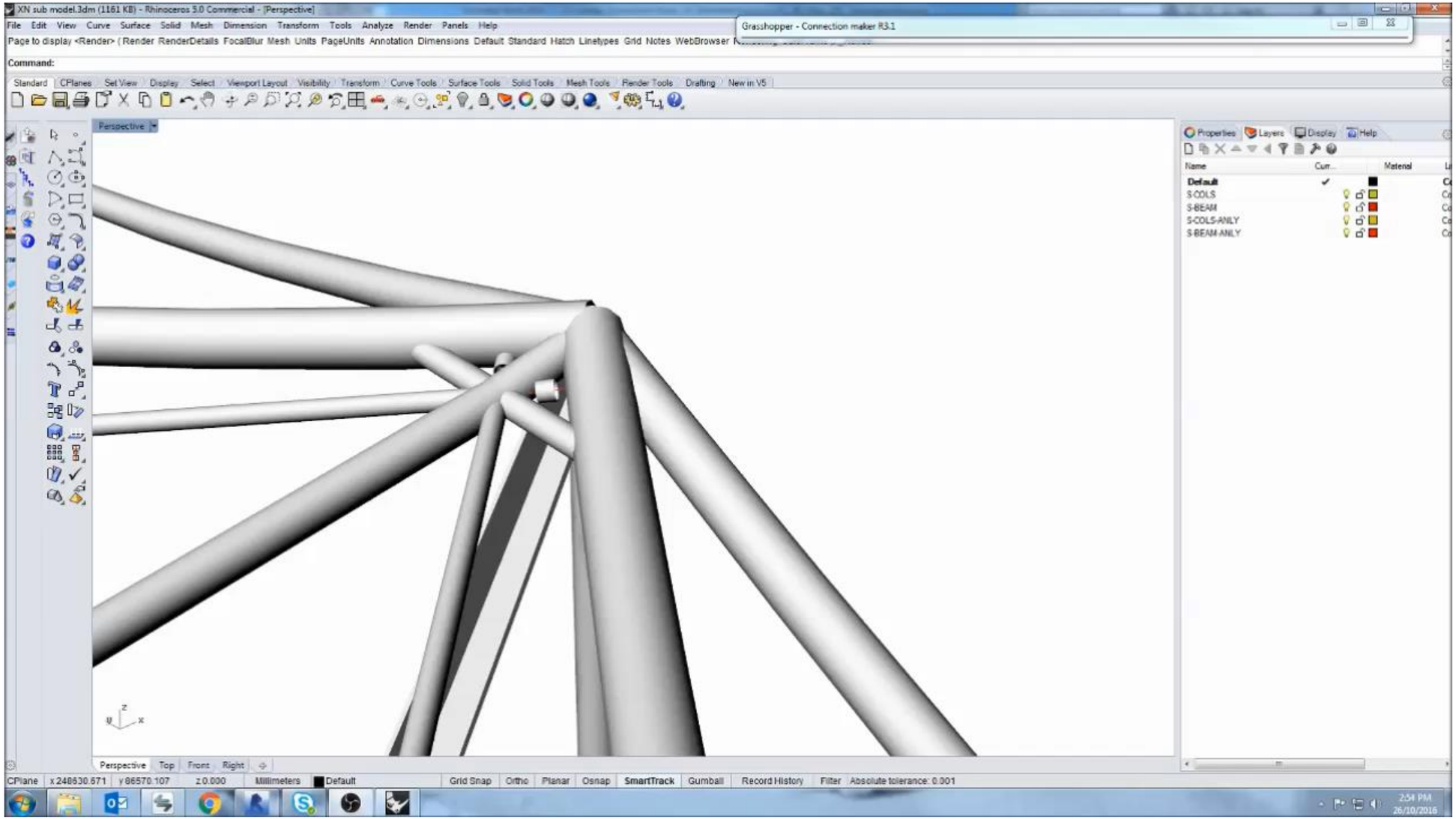


- Parametric relationship between members, automated back into Revit, however ***relies on IFC exchange for functionality*** of connection in Revit
- ***Real-time preview in Rhino***

Grasshopper / Revit via Geometry Gym

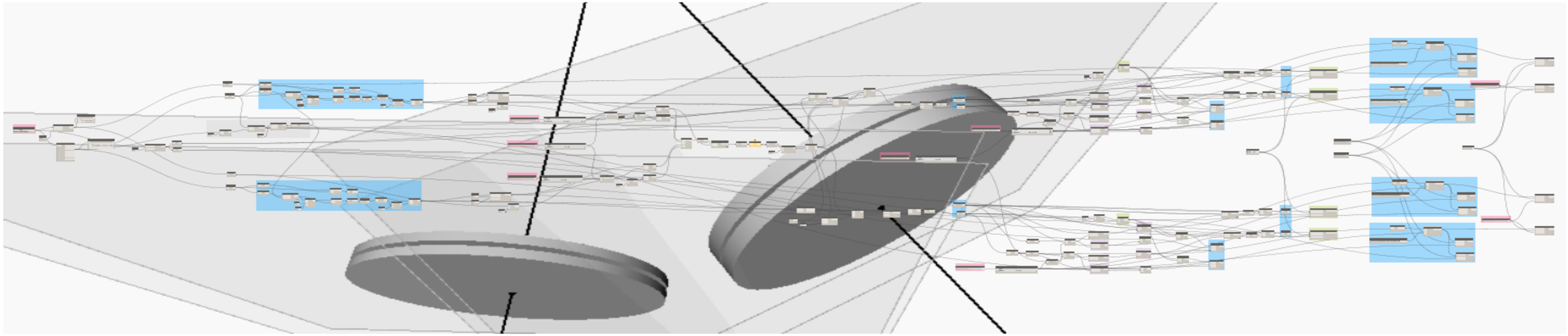


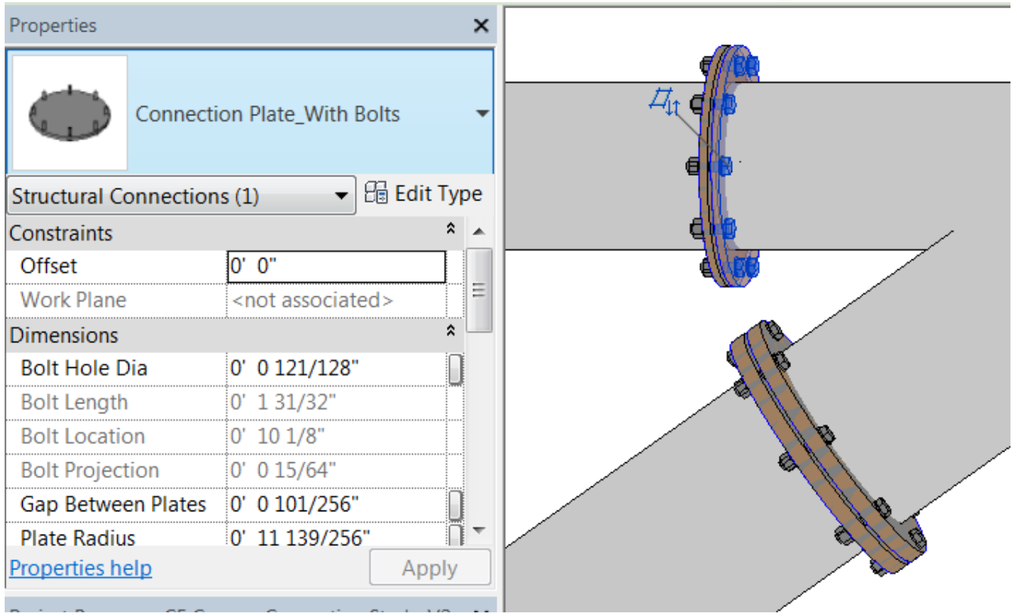
Grasshopper / Revit via Geometry Gym



Dynamo / Revit

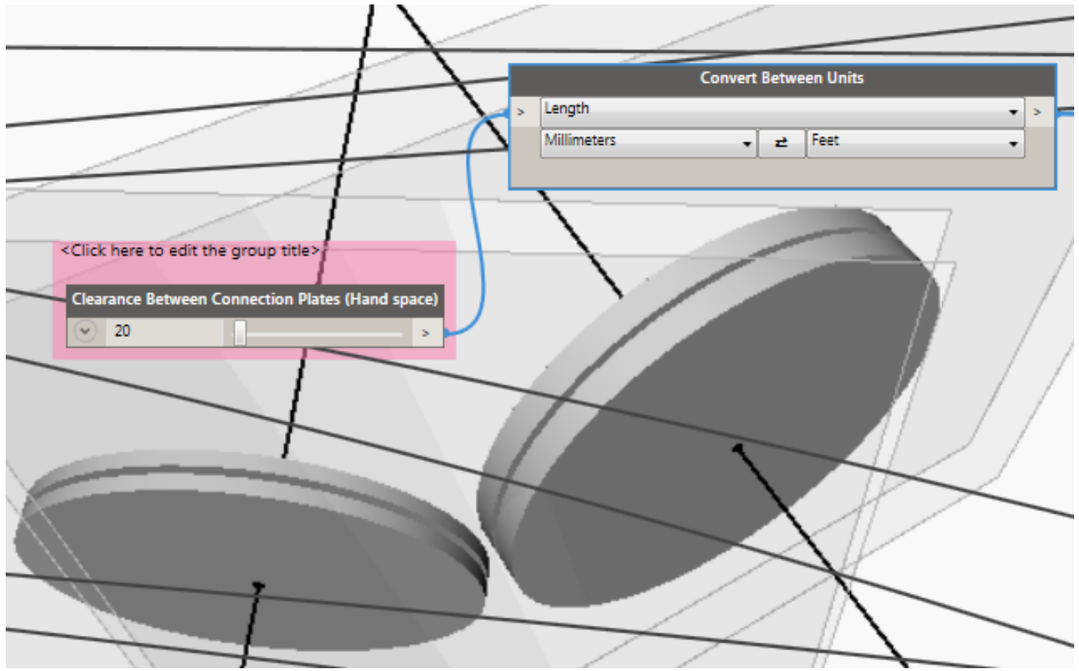
- Recreate previous Grasshopper script using Dynamo

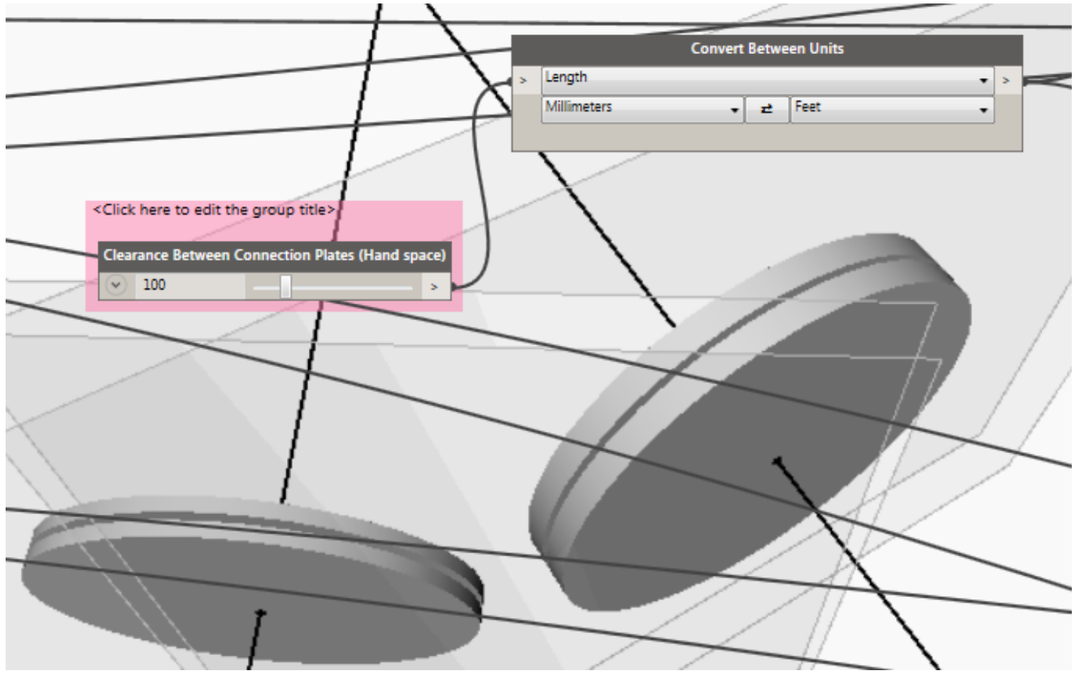




- No loss of information during the data exchange and ***full Revit functionality*** achieved including scheduling
- ***Additional nodes*** required ***for Real-Time preview***

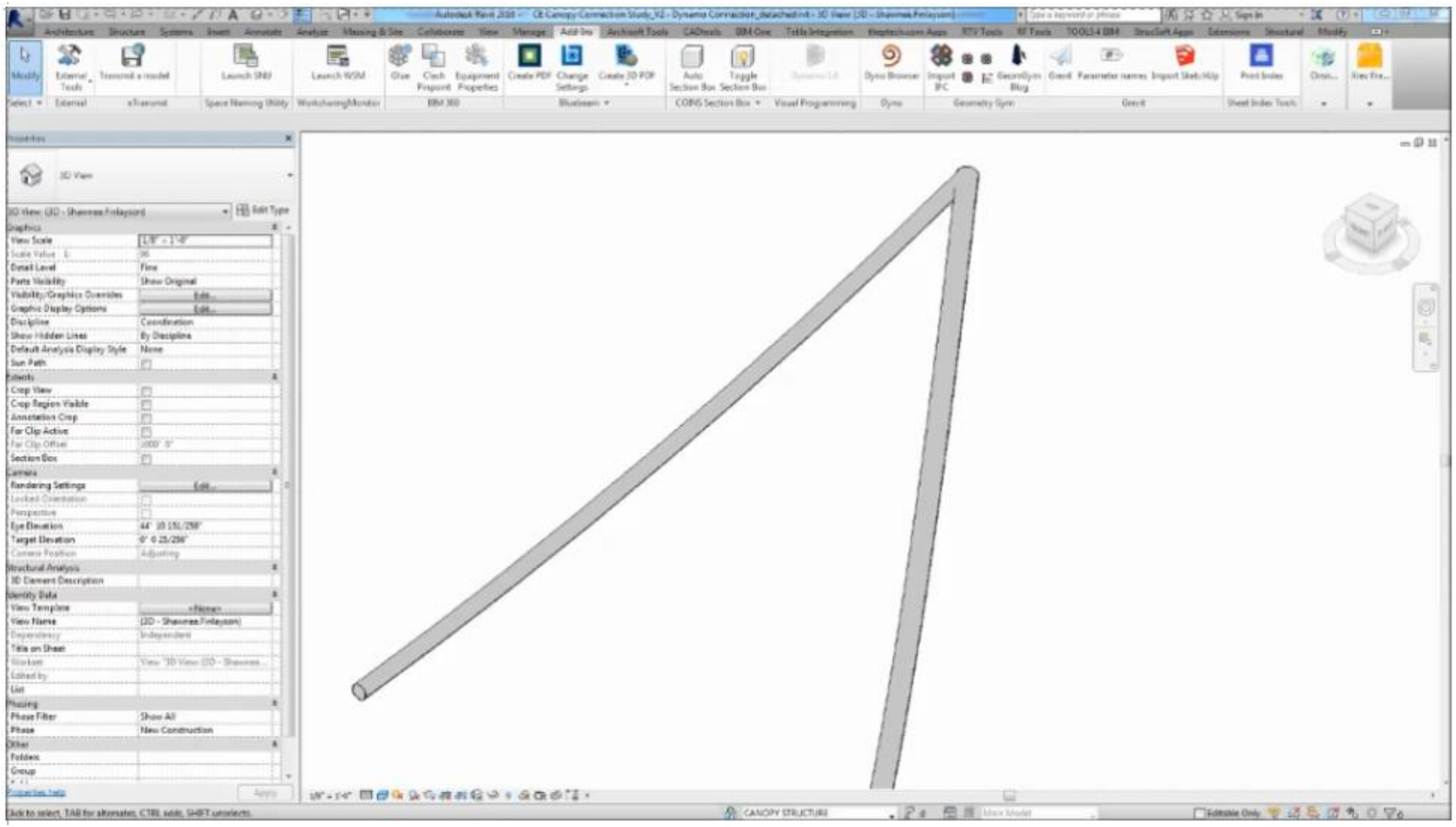
Dynamo / Revit



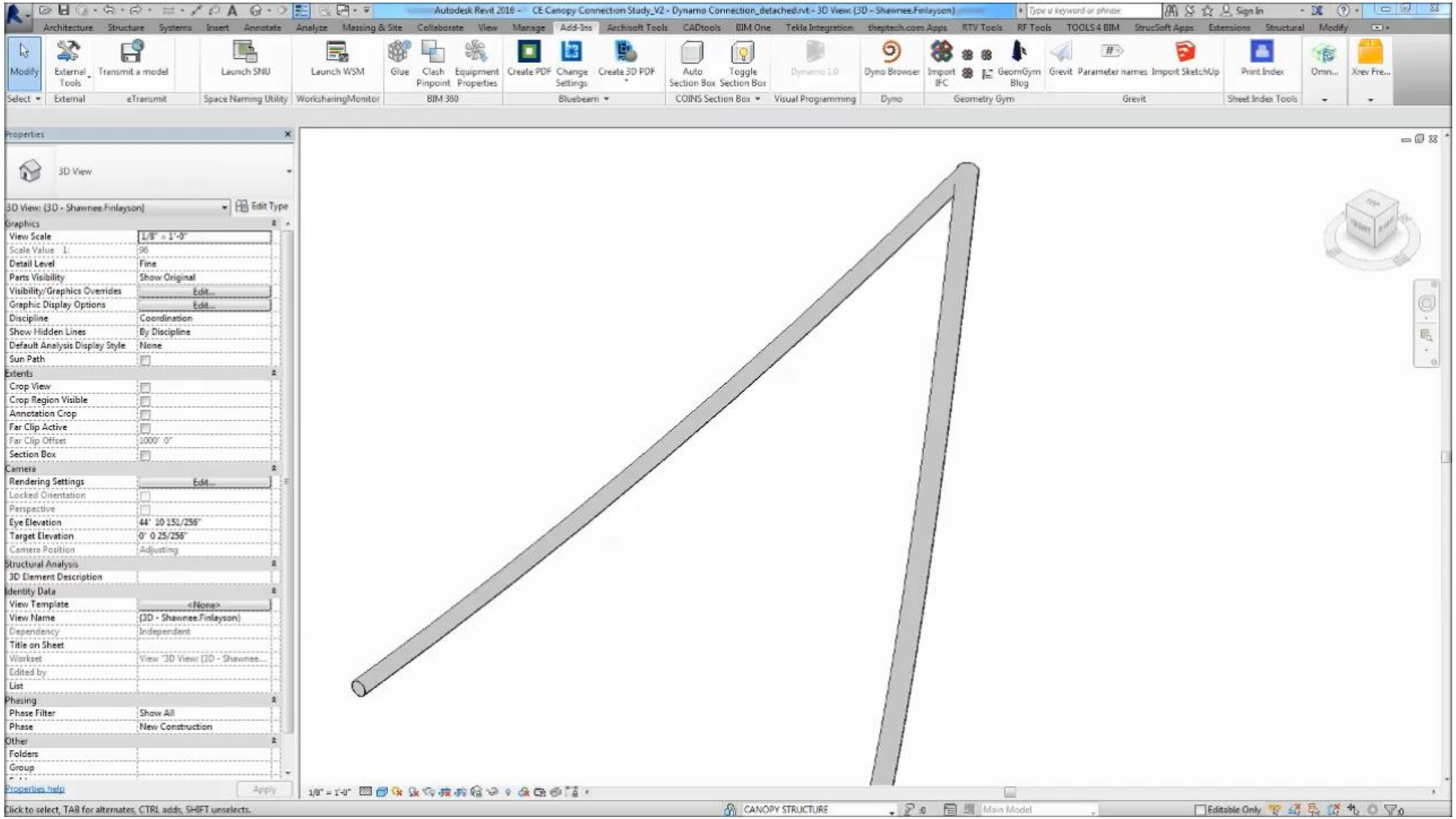


- ***Dynamo / Revit*** gives the ability to have ***parametric relationships between members***. i.e. an allowable gap between the cap plates which is much harder directly in Revit
- Updating changes to these type of variables are fast using this workflow but requires ***careful planning***

Dynamo / Revit

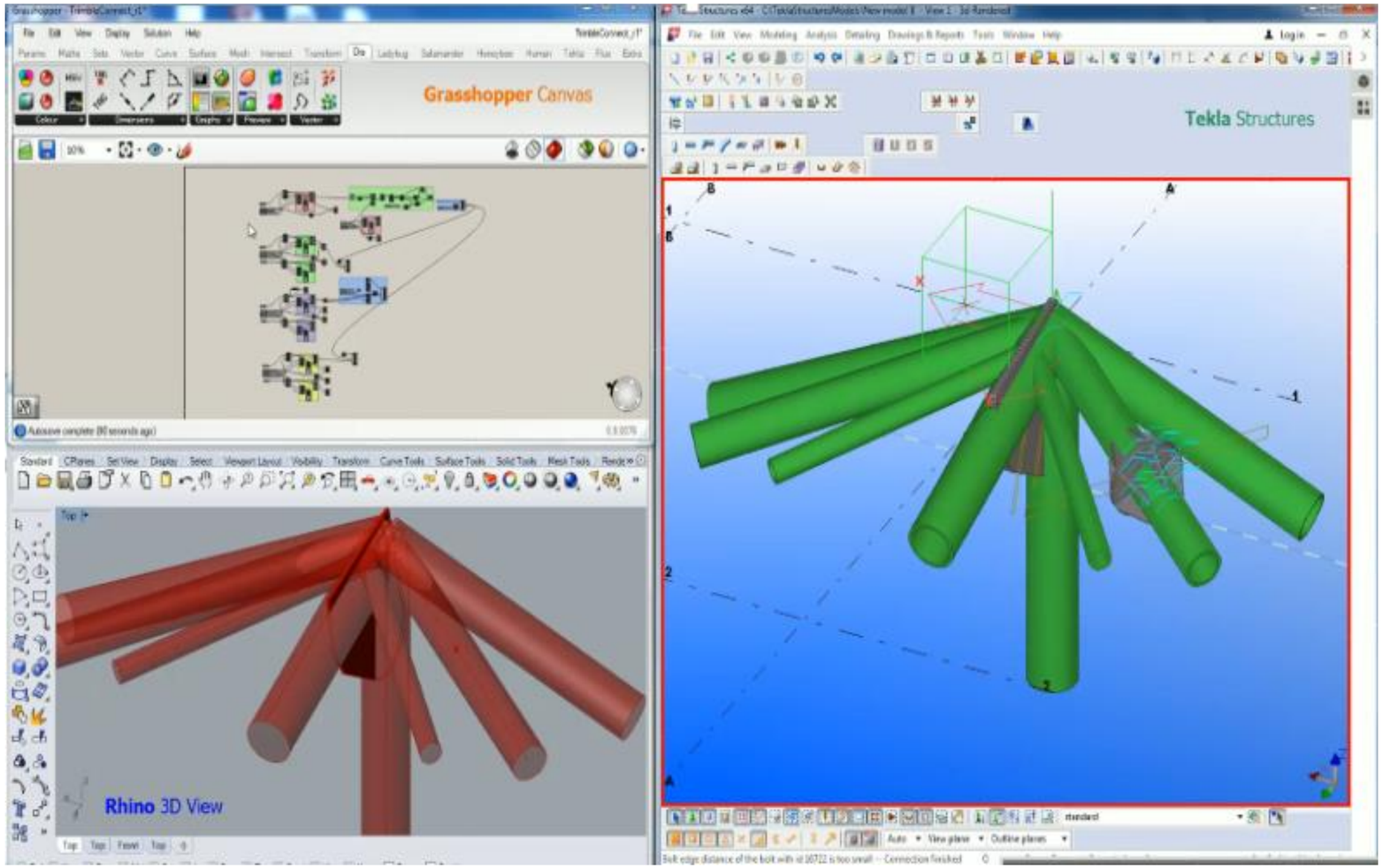


Dynamo / Revit

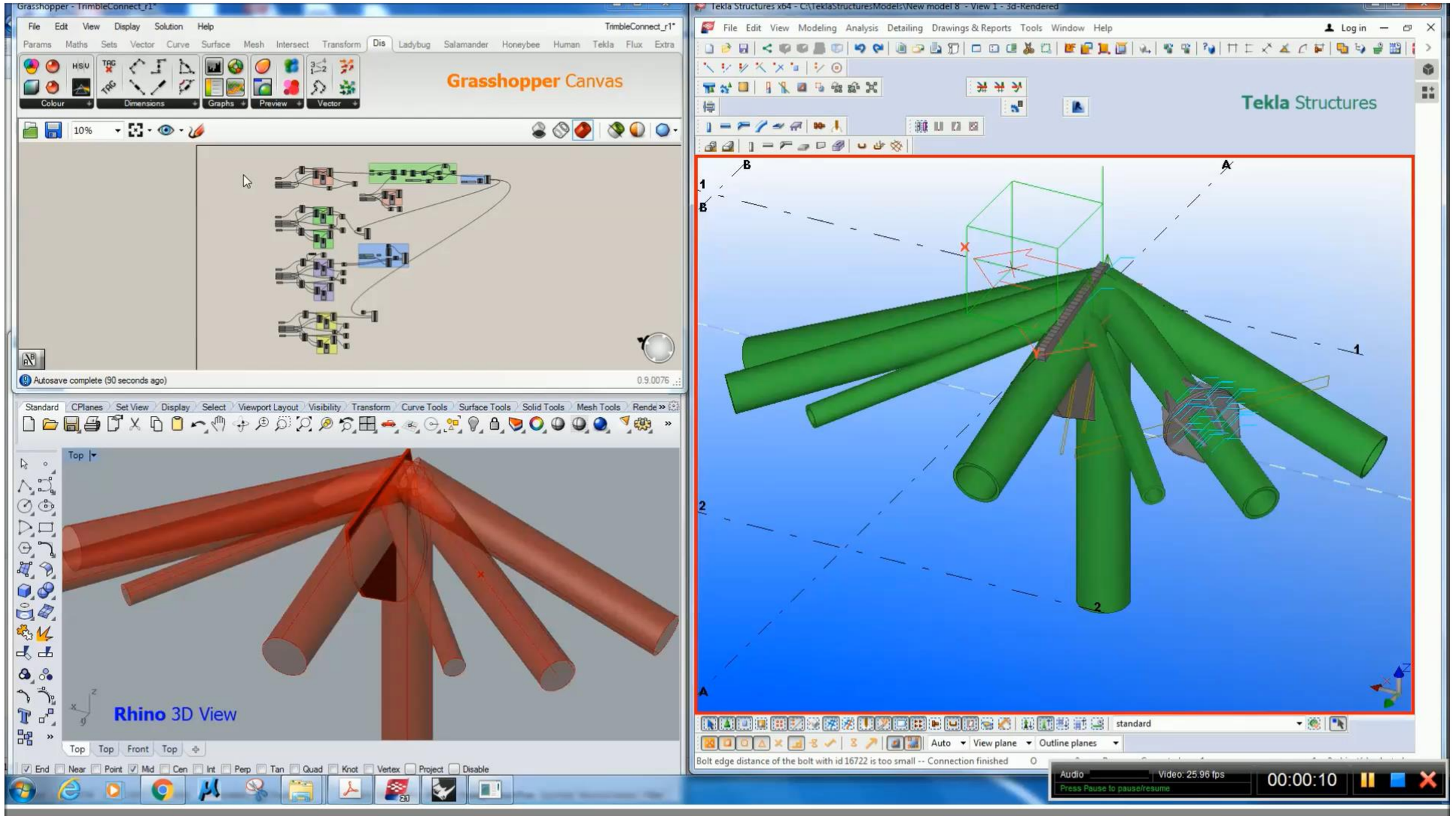


Grasshopper Bisector Plate Script

- ***Curves*** and ***tube diameters*** as ***inputs***
- Define ***planes***
- Define ***plates***
- Responds to ***geometry or tube size changes***



Grasshopper/Tekla



Grasshopper/Tekla

Advantages

- Produce ***LOD350 level detailing*** out of the box
- ***Real-time updates***
- Link to ***design spreadsheets***
- Link to ***FE analysis***

Disadvantages

- ***Training*** of existing Revit team
- The rest of the project ***LOD300 documentation is in Revit***

Summary of findings - Overall

- Parametric components within a ***single member*** are relatively ***simple*** to create in any software. i.e. ***baseplate connection*** and can be updated to suit new geometry with little effort
- Parametric components which are ***dependent on other members*** are ***hard*** and ***time consuming*** to create within ***Revit***, independent parametric tools are better suited i.e. ***Grasshopper/Dynamo***
- ***Effort 'v' Reward*** needs to be assessed for each connection type. A single one off connection may be better modelled in place within Revit if geometry is fixed and the deliverable is design intent

Conclusions

		Software/Workflow Option						
		Revit - Column and Framing with in-built connections	Revit - Parametric Connection	Revit - In Place Families	Grasshopper to Tekla	Grasshopper to Revit	Dynamo to Revit	Revit / Advanced Steel / Statica
Judging Criteria	Upfront time/resource to build script/family	☺	☺☺	☺☺☺	☹☹☹	☹☹	☹☹☹	
	Time to update if geometry/size changes	☹	☹☹	☹☹☹	☺☺☺	☺☺☺	☺☺☺	
	Connection on curved members	☺☺☺	☹☹☹	☹☹☹	☺☺☺	☺☺☺	☺☺☺	
	Link to existing workflow	☺☺	☹☹	☹☹☹	☺☺	☺☺☺	☺☺☺	
	Connection be Schedulable and Linked to Excel/Dynamo	☺☺ ⌖	☺ ⌖	☹☹☹	☺☺	😐 ✡	☺☺☺	
	Resources/Training of Team	☺	☺☺	☺☺☺	☹☹☹	☹☹☹	☹☹☹	☹☹☹
	Interactive / Exploded Views	☺	☺☺	☺☺☺	☹☹	☺☺☺	☺☺☺	
	2D drawing requirement	☺	☺☺	☺☺☺	☹☹	☺☺☺	☺☺☺	
	Optimising plate size				☺☺☺			☺☺☺ ✞
	Can be used downstream for shop detailer	☹	☹☹	☹☹☹	☺☺☺	☹☹☹	☺☺☺ ☼	☺☺☺
	Checking of shop model/drawings	☹	☹☹	☹☹☹	☺☺☺	😐	☺☺☺ ☼	☺☺☺

✡	Grasshopper scripted components have limited flexibility when brought into Revit - May not be able to schedule connection parameters
⌖	Additional time required to consider how to schedule within Revit required
☼	Collaboration/information exchange with shop detailer to be agreed
✞	Opportunity to optimise connection through statica/advance steel and possible benefits downstream for shop model/drawing checks

Recommendations

- One size does not fit all, assess each job on a case by case basis against what is important from the judging criteria

- If there is ***sufficient time & resource Dynamo / Revit*** would give the most automated / flexible workflow to accommodate possible architectural changes, builder preferences, and cost implications

- For ***downstream checking*** of the shop detailers model, ***Advance Steel*** or ***Tekla*** would be the preferred deliverable

- For ***one off bespoke connection*** details where the geometry is not likely to affect the connection design, ***3 No. options*** are available ***within Revit*** with varying degrees of upfront effort required

Further Research

- FEA analysis of connection in ***Statica*** linked to Revit/Advanced steel to ***optimize plate thickness***

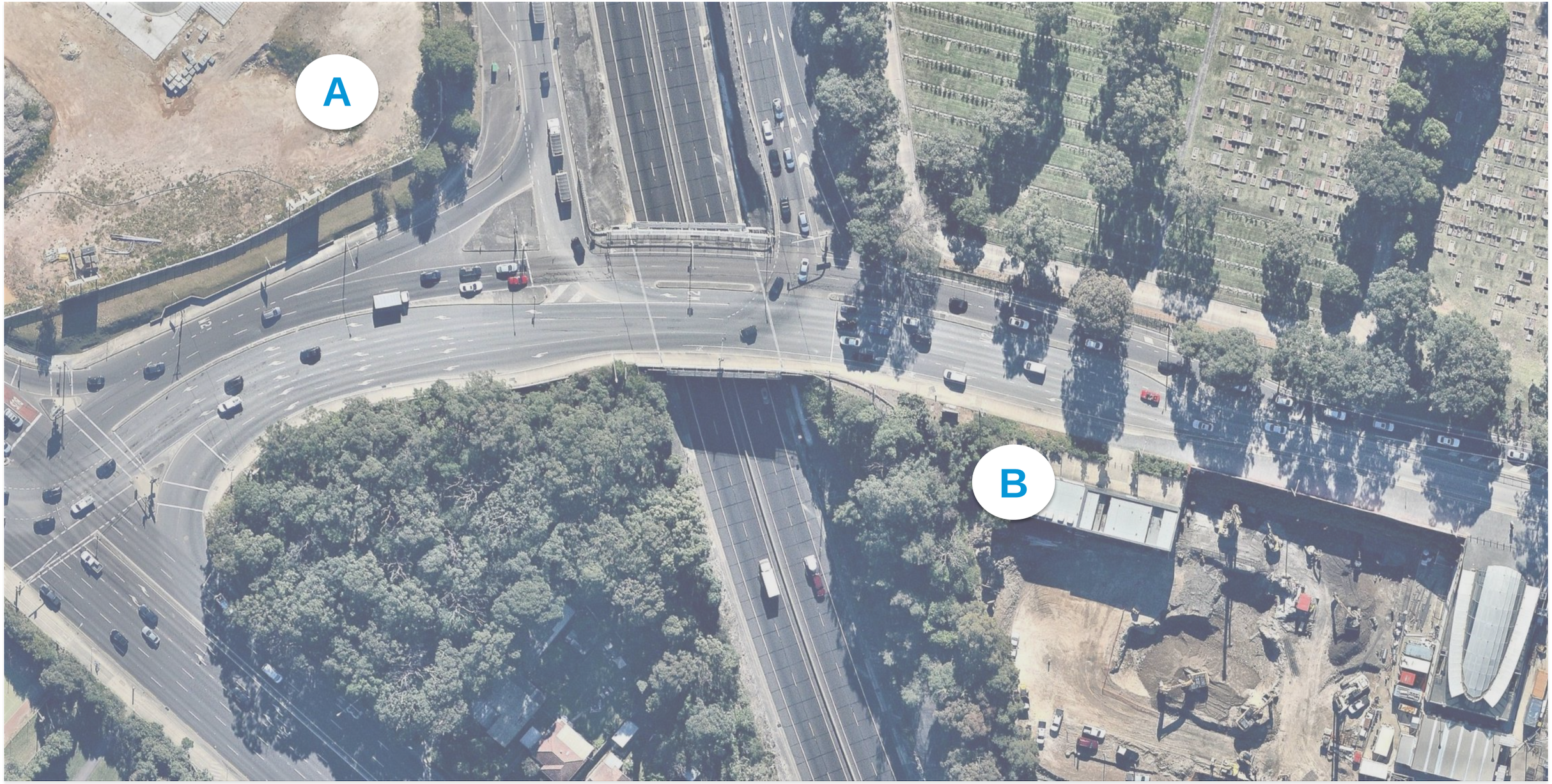
- Look at workflow beyond ***typical scope*** – How can we exchange information to and from the ***Shop Detailer / Fabricator*** to ***minimize time*** in the checking process (Geometry Gym could help bridge the gap)

- ***Quantity Surveyor*** – Use model to price connection options for entire job using ***Material Take-Off*** within ***Revit***

Innovation ‘v’ Effort

- We are ***pushing the boundaries*** of the software and workflows. The findings of the previous workflows have been through a number of trial/error tests.

- Leadership need to be aware that ***innovation doesn't just happen*** and there will be an ***upfront cost***


A
B


A
B

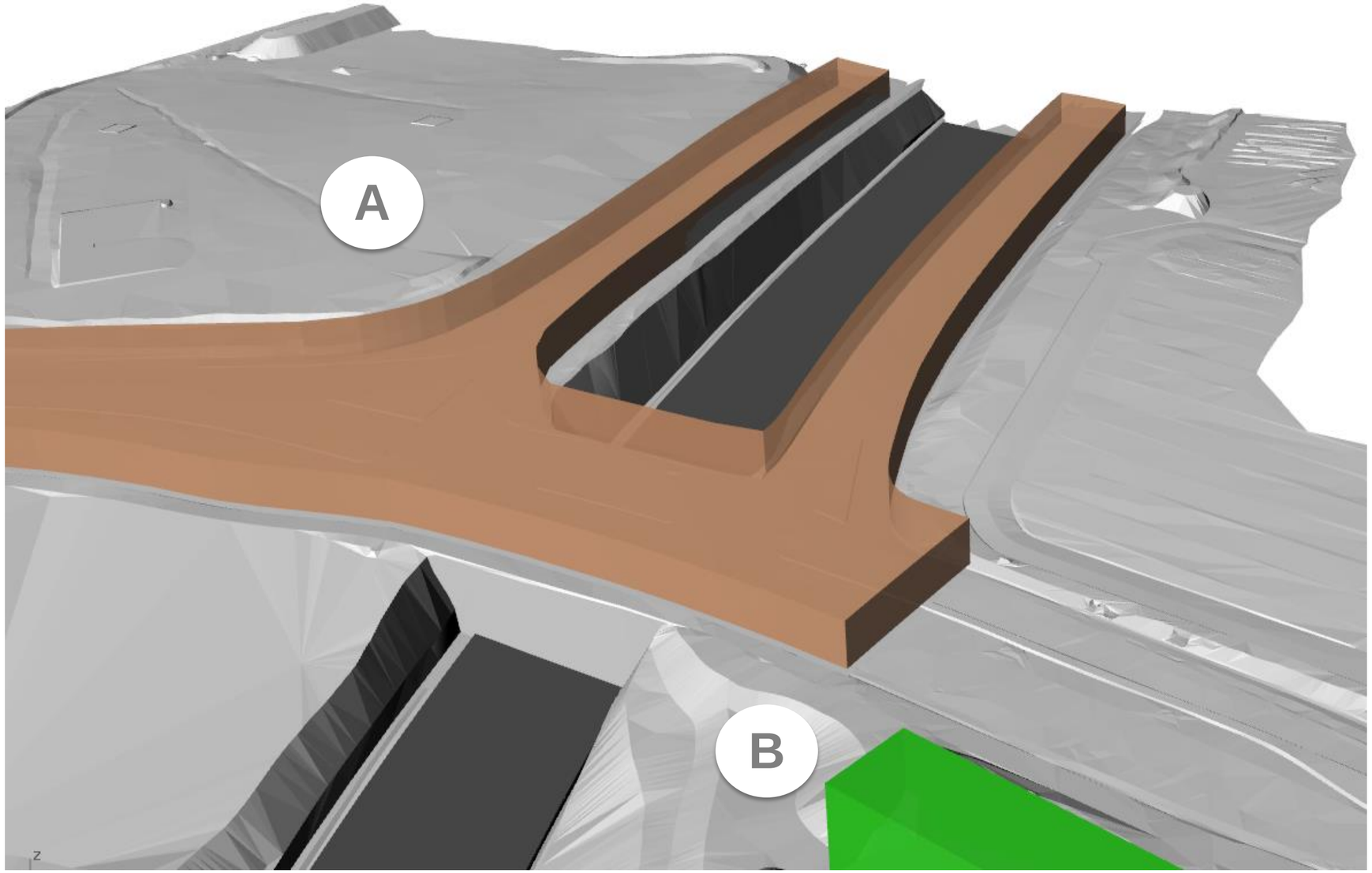
what if...

*we could find the best **alignment**?*

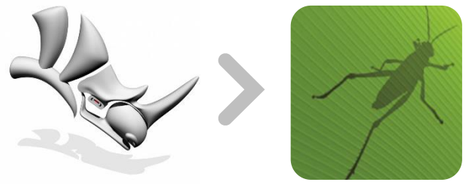
Q1.

Key Constraints

- 5.5m ***vertical clearance***
- ***Code compliant*** ramps and landings
- Deck levels set accounting for structural ***depth and deflections***

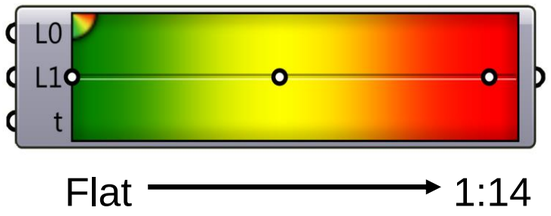


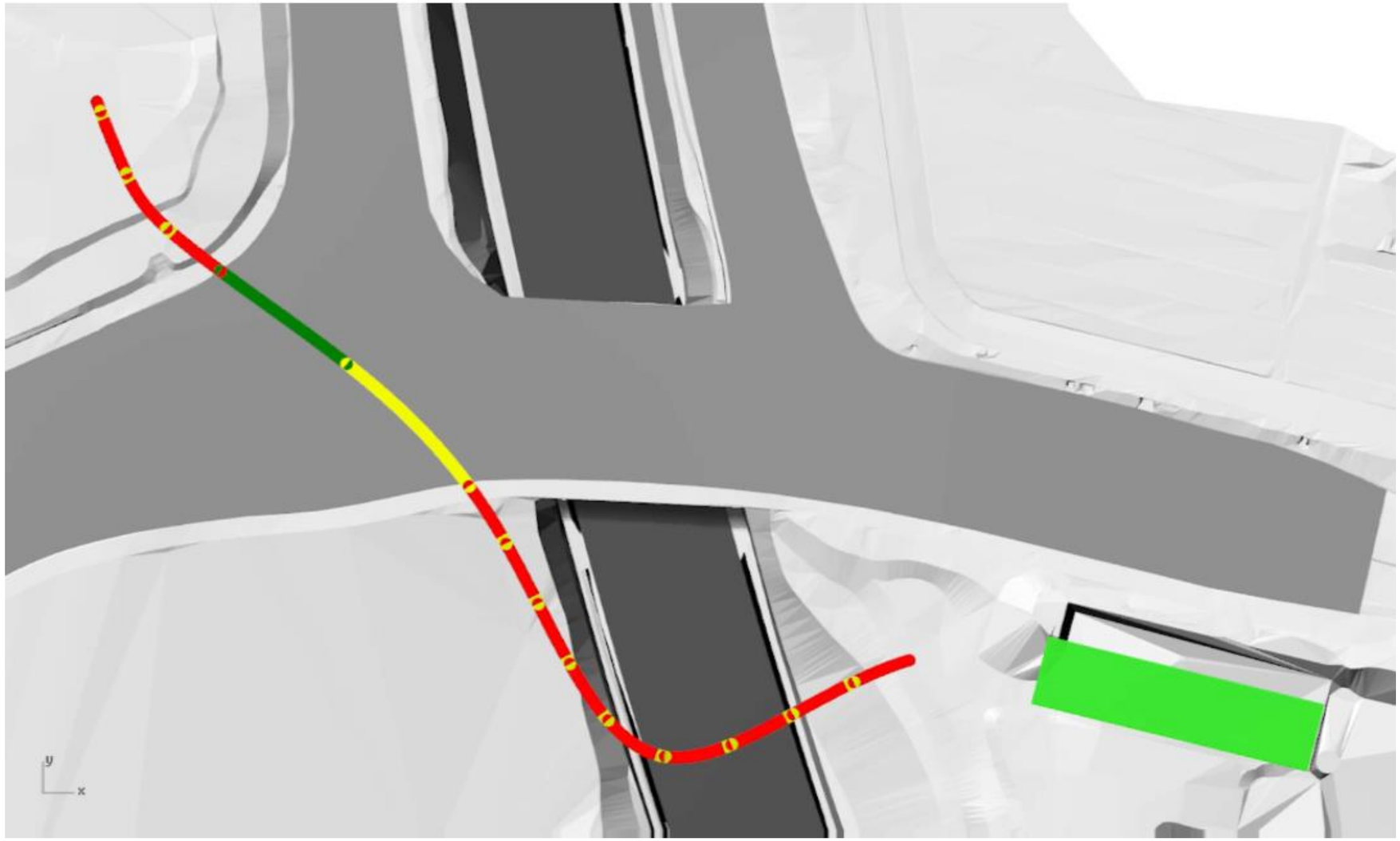
Workflow



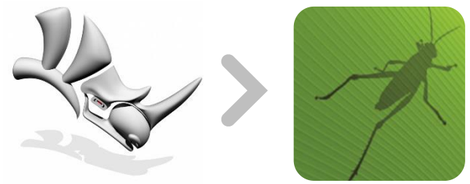
Key Constraints

Alignment generated parametrically



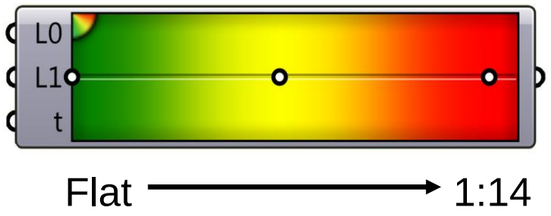


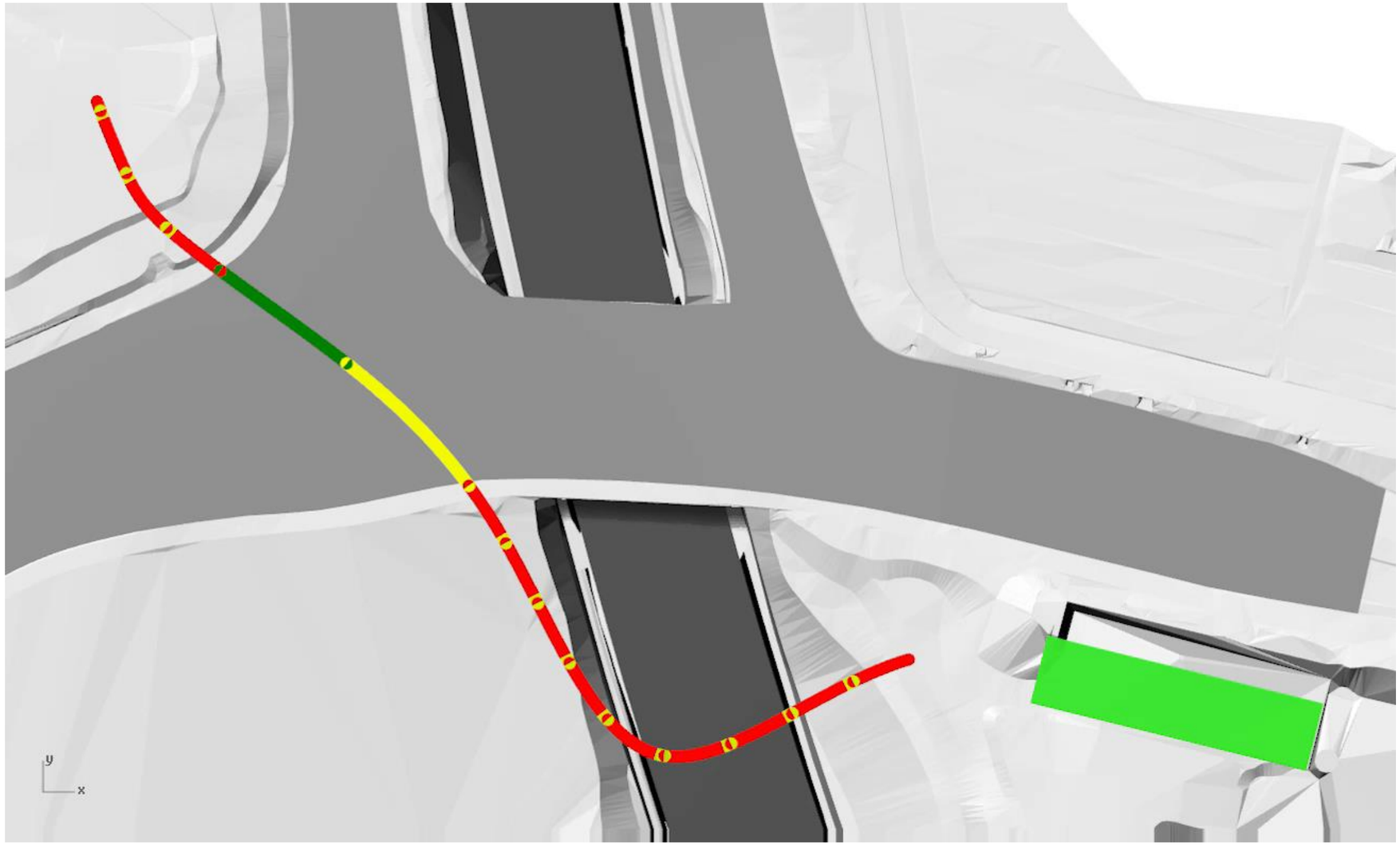
Workflow



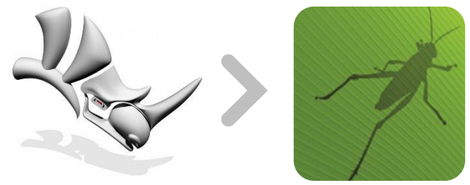
Key Constraints

Alignment generated parametrically





Workflow



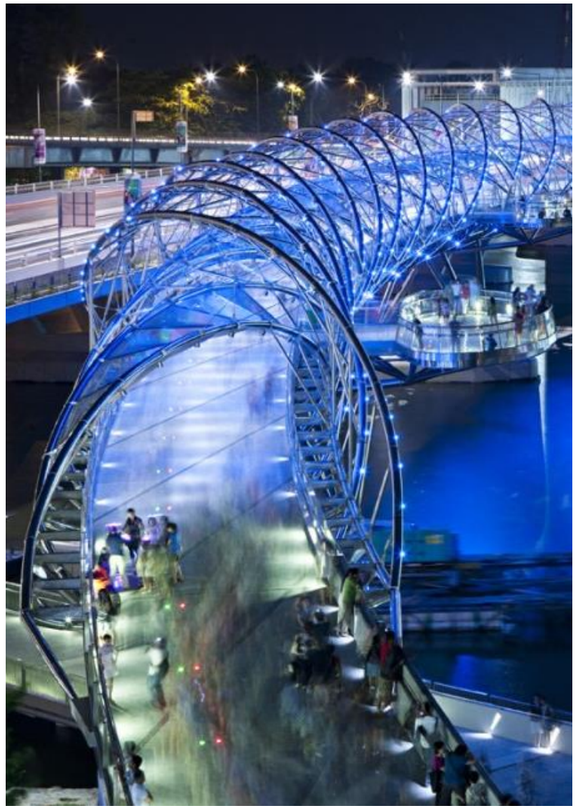
how could...

*we find the best **structural form**?*

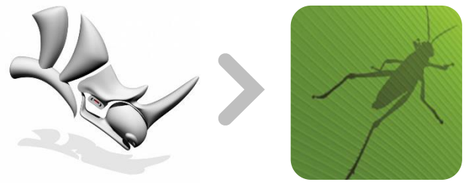
Q2.

Structural Concept

- Client was keen on a ***tubular structure***



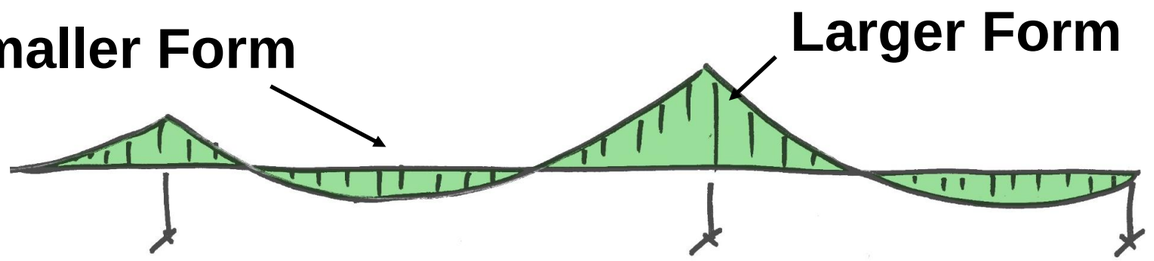
Workflow



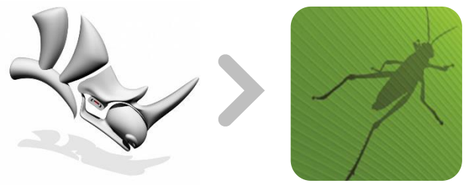
Structural Concept

- ***Scale*** and ***form*** derived from structural principles

- Support points located to ***minimise span lengths***

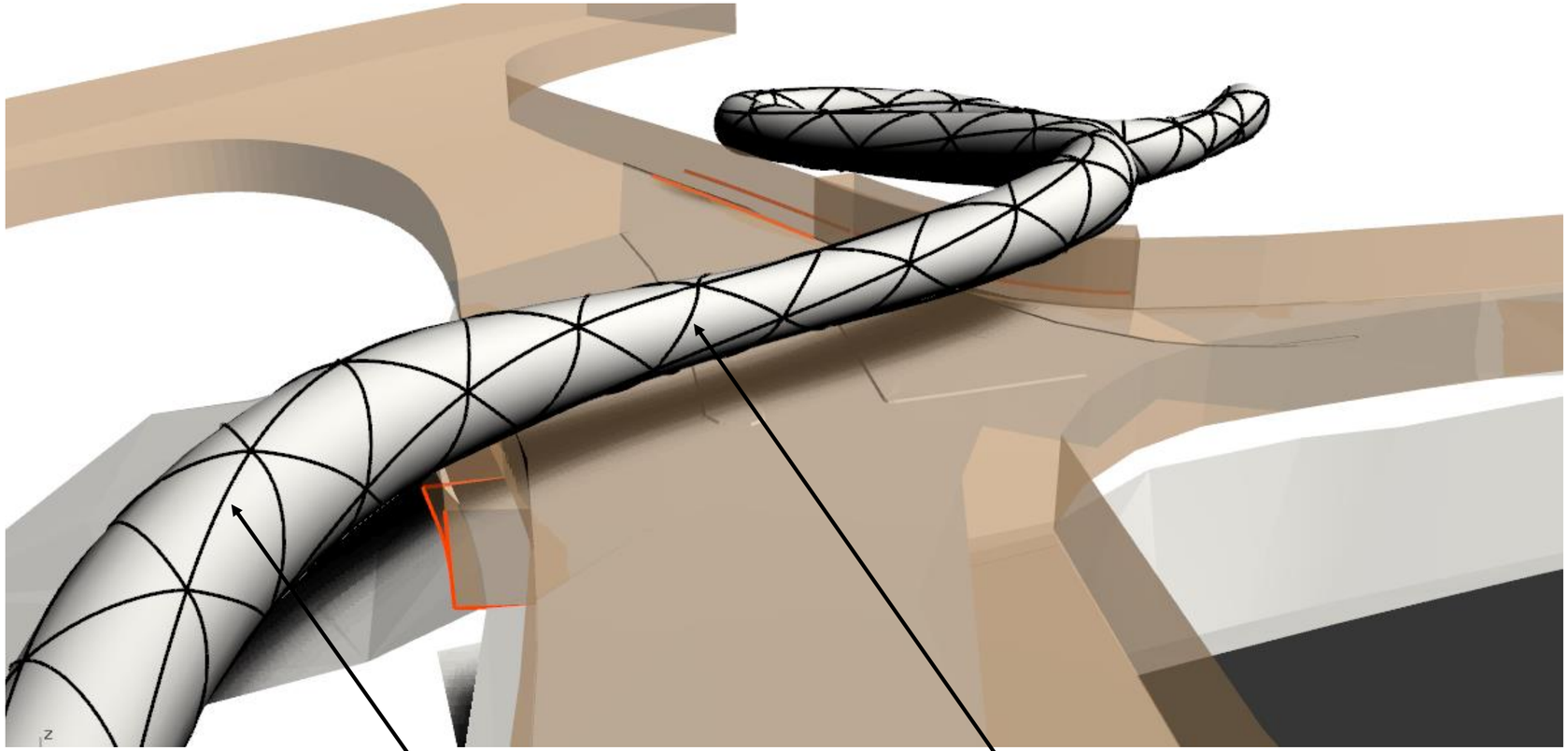


Workflow



Structural Concept

- ***3D*** truss frame
- Spiralling ***helical*** geometry
- Chord members located for ***optimum structural efficiency***



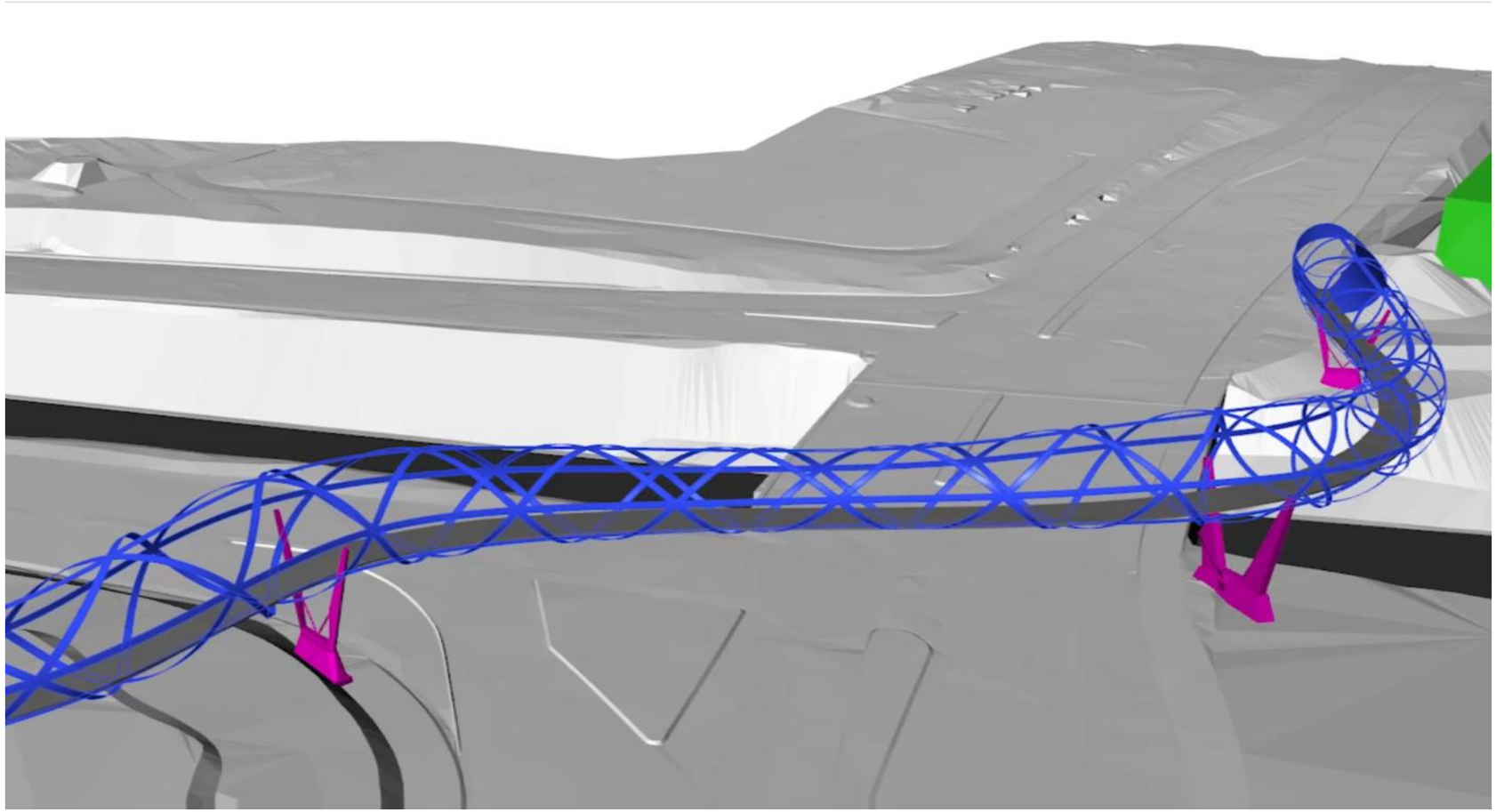
Chord members have a gradual rotation

Diagonal members corkscrew significantly quicker

Workflow

Structural Concept

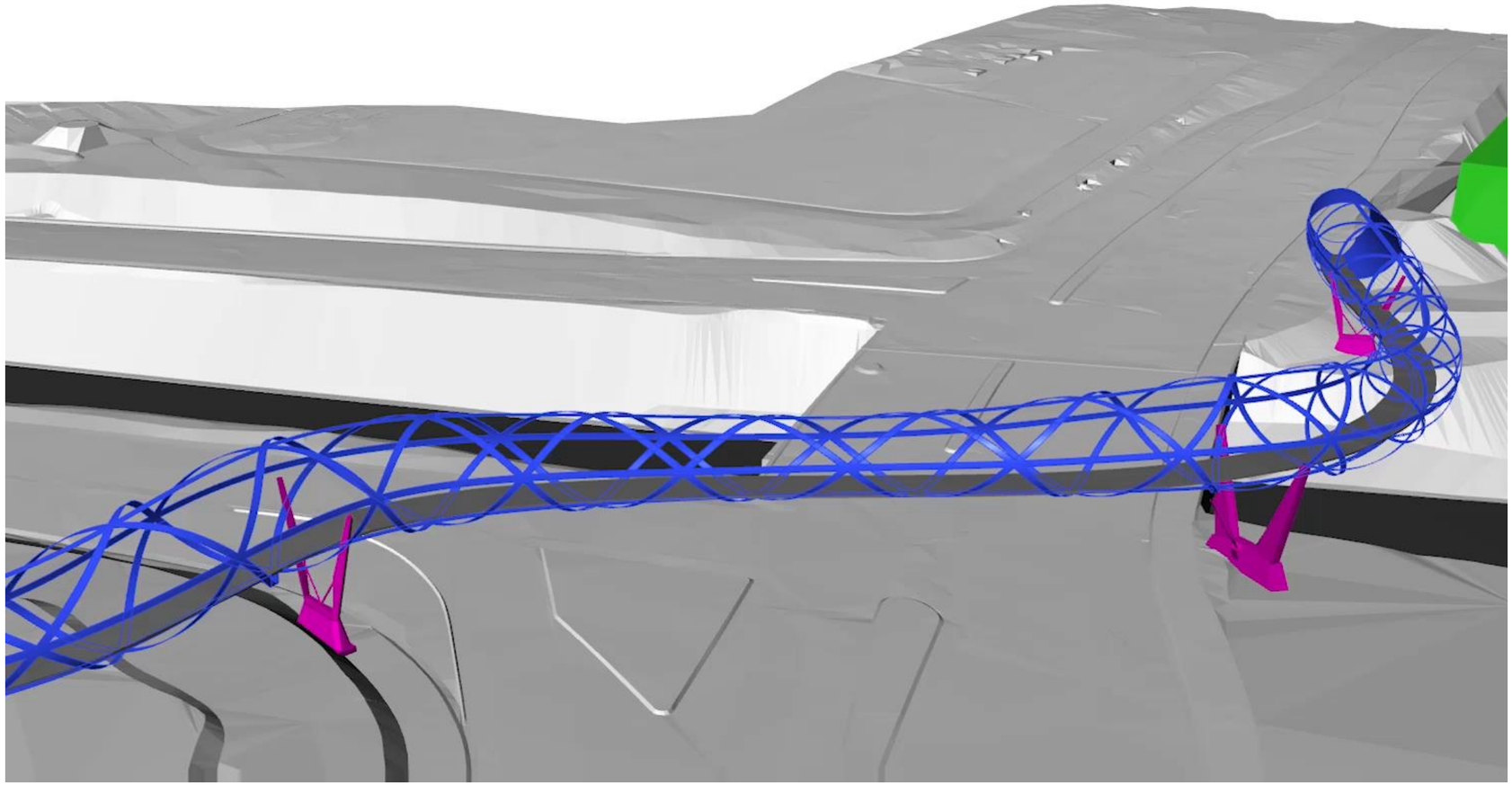
- ***3D*** truss frame
- Spiralling ***helical*** geometry
- Chord members located for ***optimum structural efficiency***



Workflow

Structural Concept

- ***3D*** truss frame
- Spiralling ***helical*** geometry
- Chord members located for ***optimum structural efficiency***



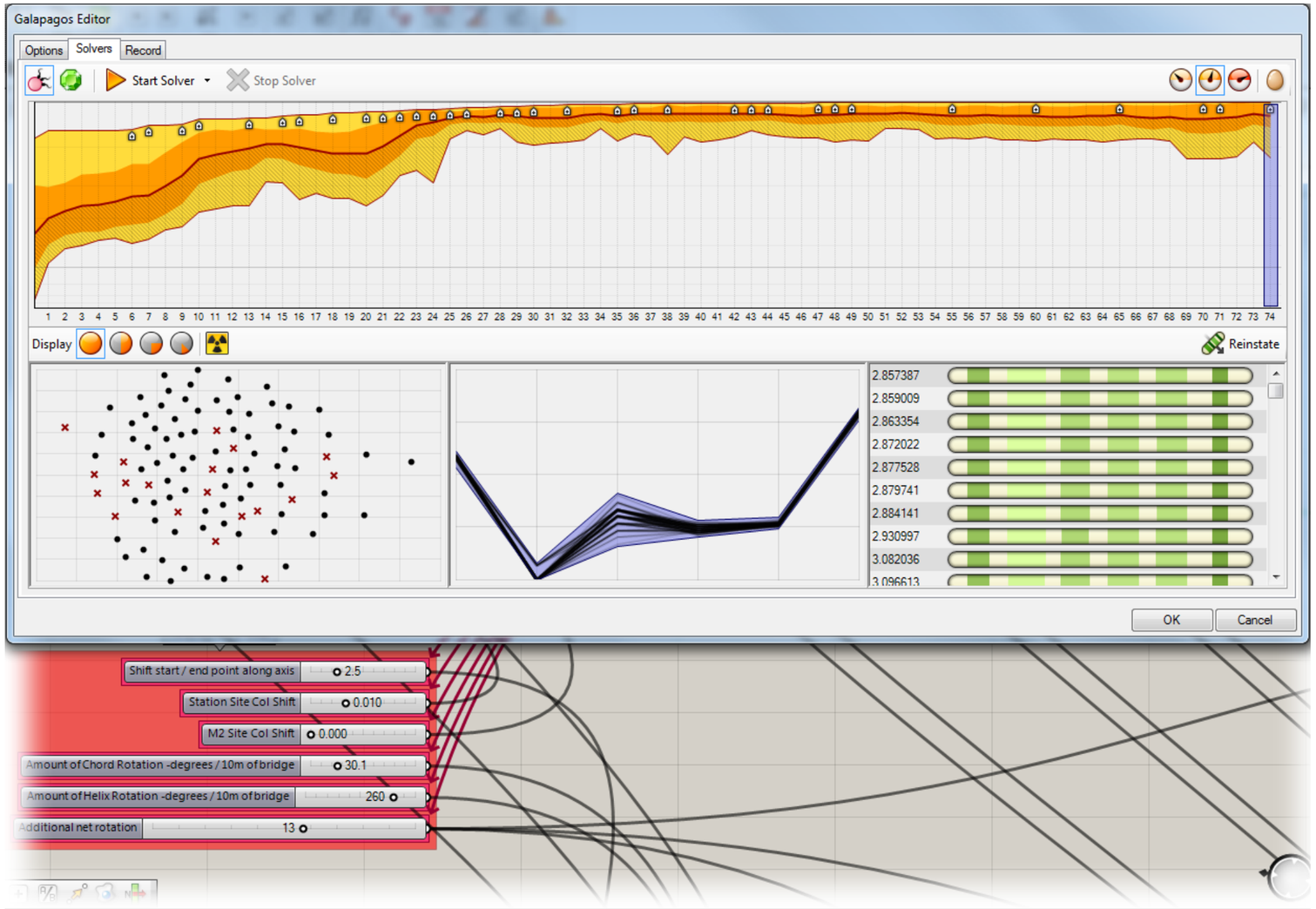
Workflow

Structural Concept

- **Geometry iteratively optimised** using an evolutionary solver

Variables

- Corkscrew starting position
- Diagonal Rotation Speed
- Chord Rotation Speed
- Column Locations



Workflow

how can...

***structurally analyse** the geometry?*

Q3.

Geometry to Analysis

Helix centre line geometry split into ***300mm straight segments***

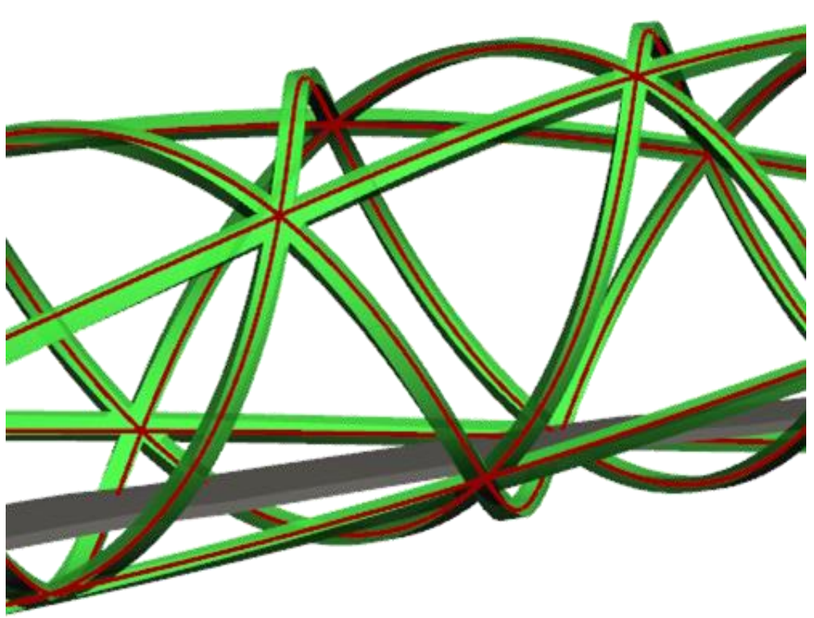
Geometry Gym:

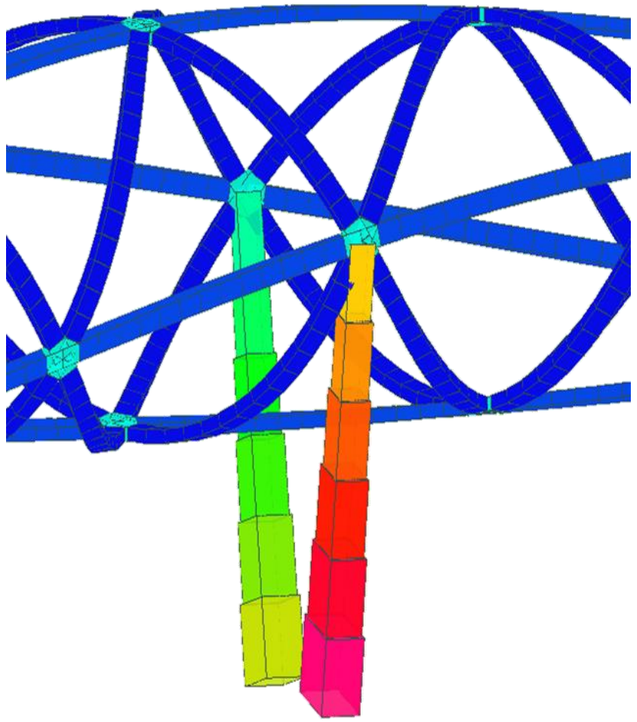
- Assigns member ***properties***
- Applies ***restraints***
- Creates ***load patterns***
- Creates ***load cases***
- Creates ***analysis*** tasks

Geometry Gym

← Rhino centre line model

Analysis Stick Model →

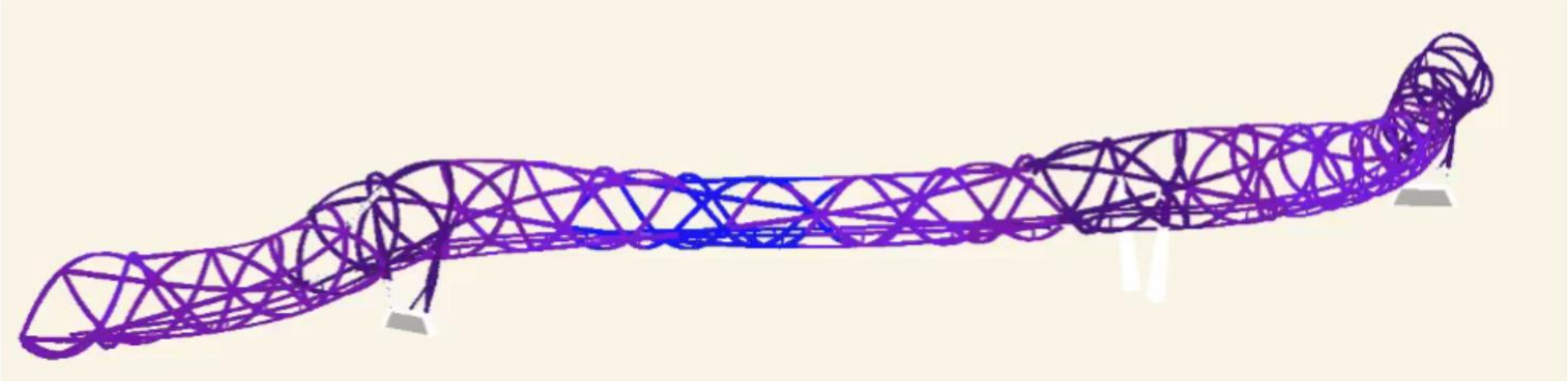




Workflow

Geometry to Analysis

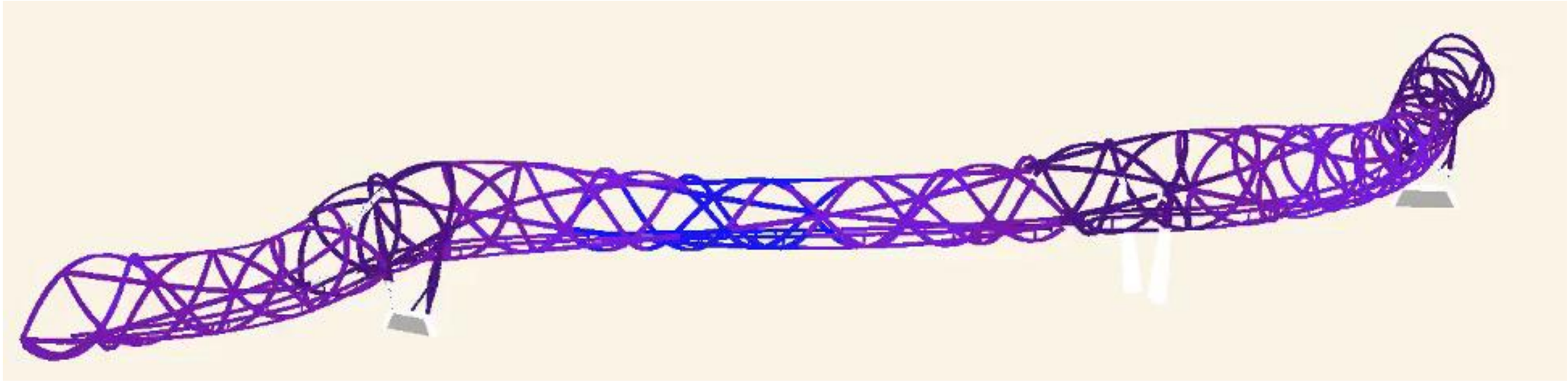
- Rapidly ***experiment with***, and ***quantify***, change



Workflow

Geometry to Analysis

- Rapidly ***experiment with***, and ***quantify***, change



Workflow

could we...

*optimise **each individual** member?*

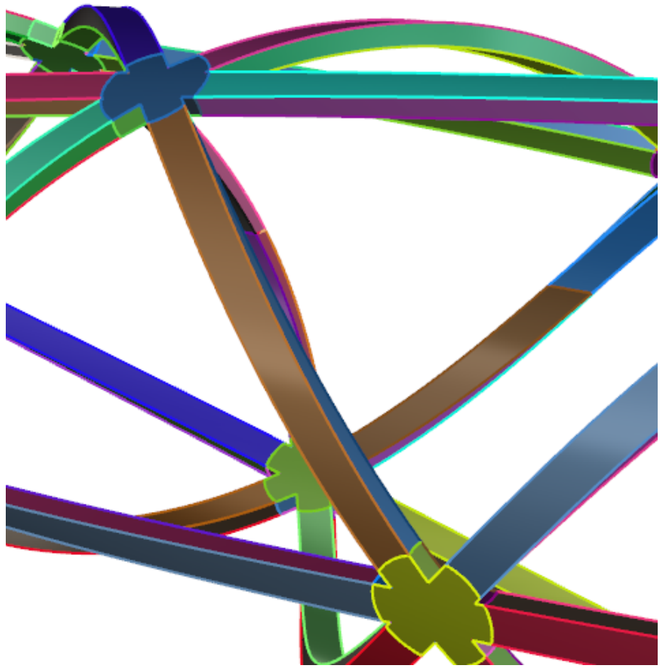
Q4.

Structural Optimisation

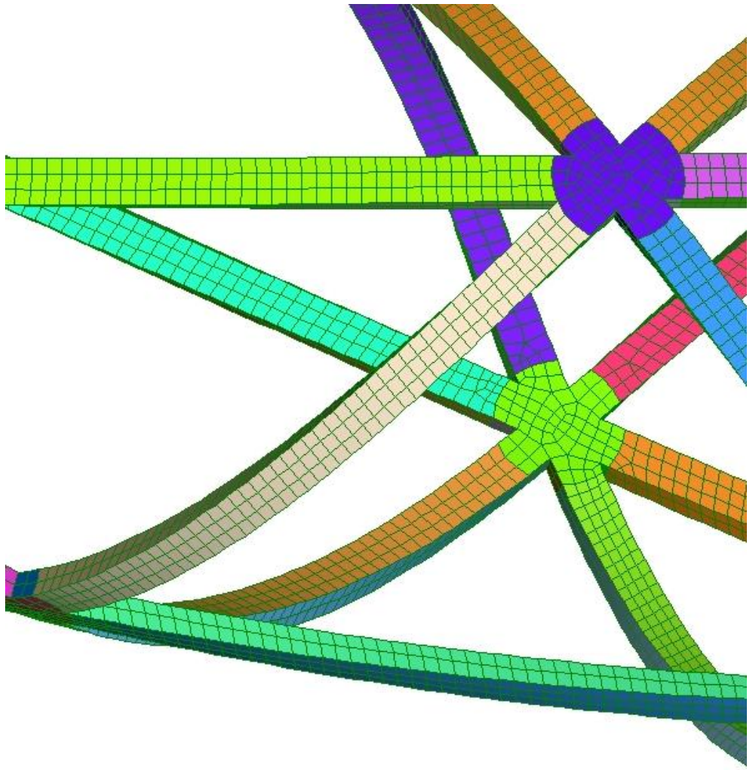
- Grasshopper bakes ***each face*** of the helix onto a different Rhino layer

- Auto-meshed with Strand 7

Rhino Model



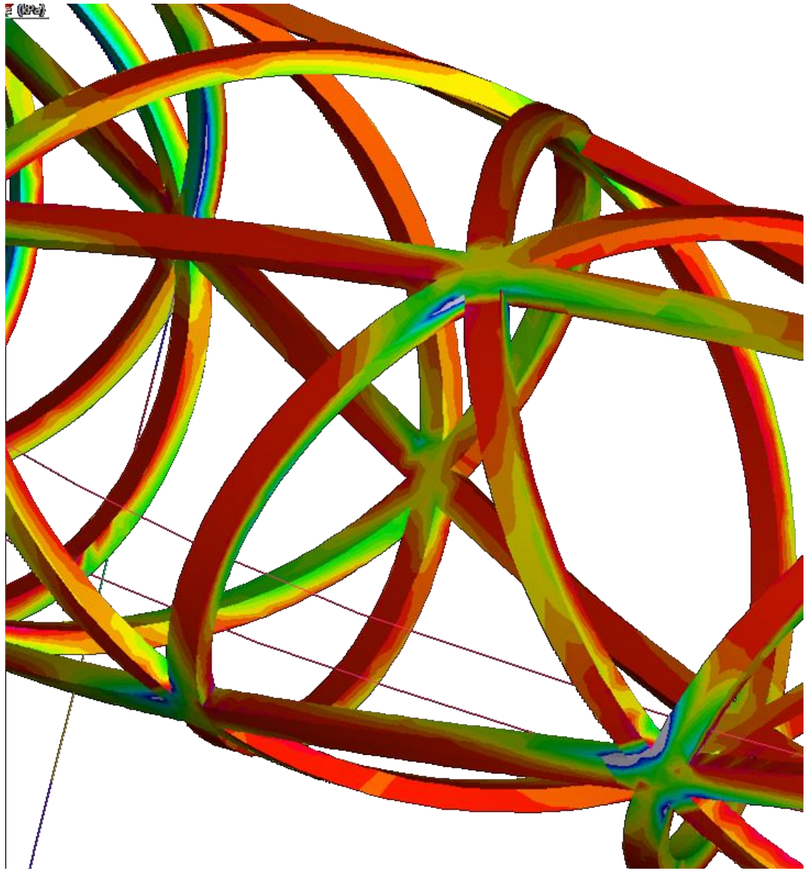
Strand7 Plate Model



Workflow

Structural Optimisation

- Each plate automeshed and assigned a ***different structural property***
- Excel loops through and optimise ***each structural property*** based on ULS stress
- User ***reviews and simplifies***



what if...

*we could **link** analysis model to documentation model?*

Q5.

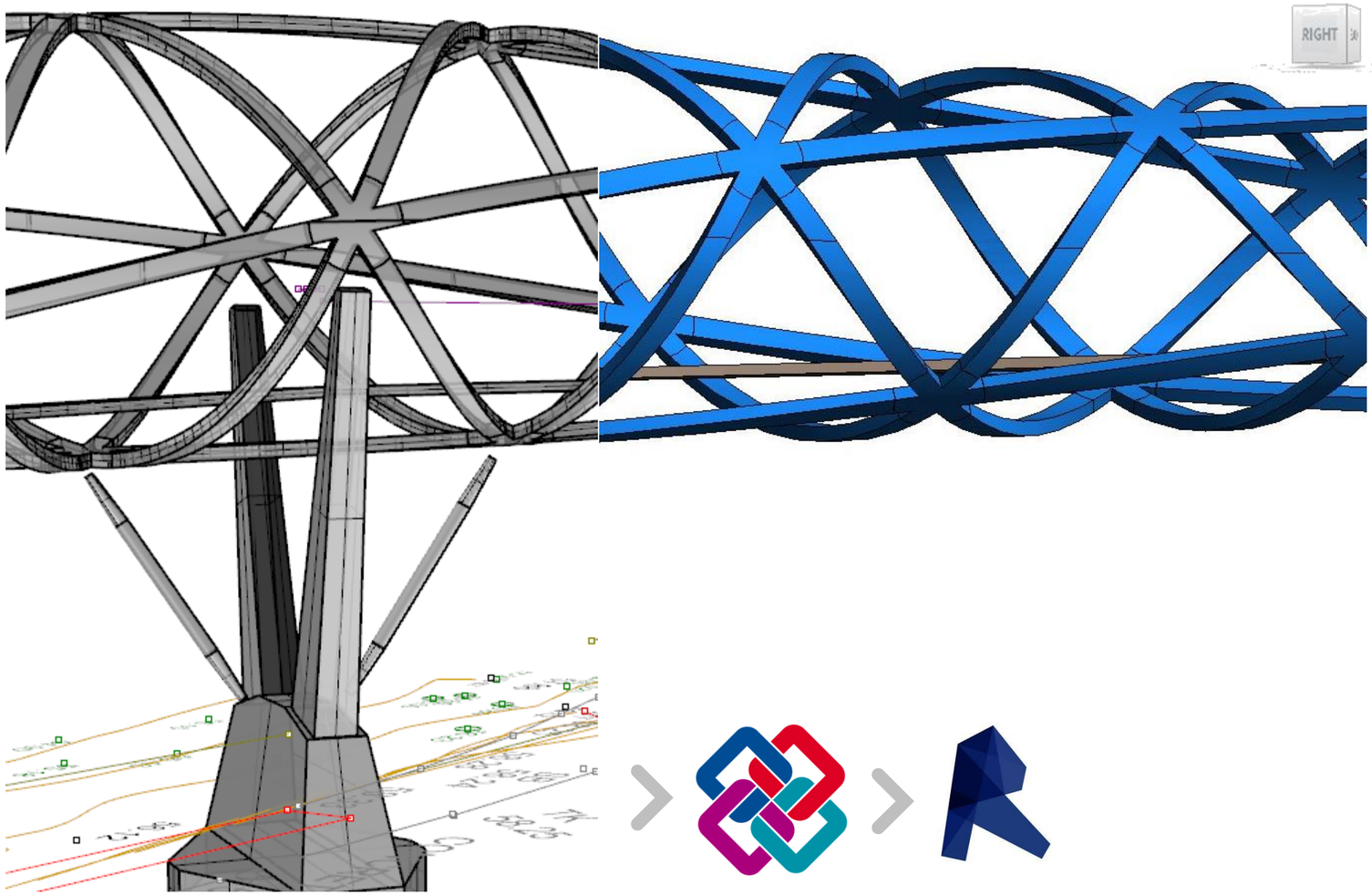
Geometry to Revit

- Generates ***IFC files*** for each Helix Component
- Imports each ***individual file into Revit***

Geometry Gym

Rhino Model

Revit Model



Workflow

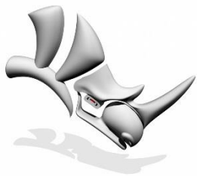
so where has this journey taken us?

Workflows

GEOMETRY HUB

Geometry Gym

Geometry Gym



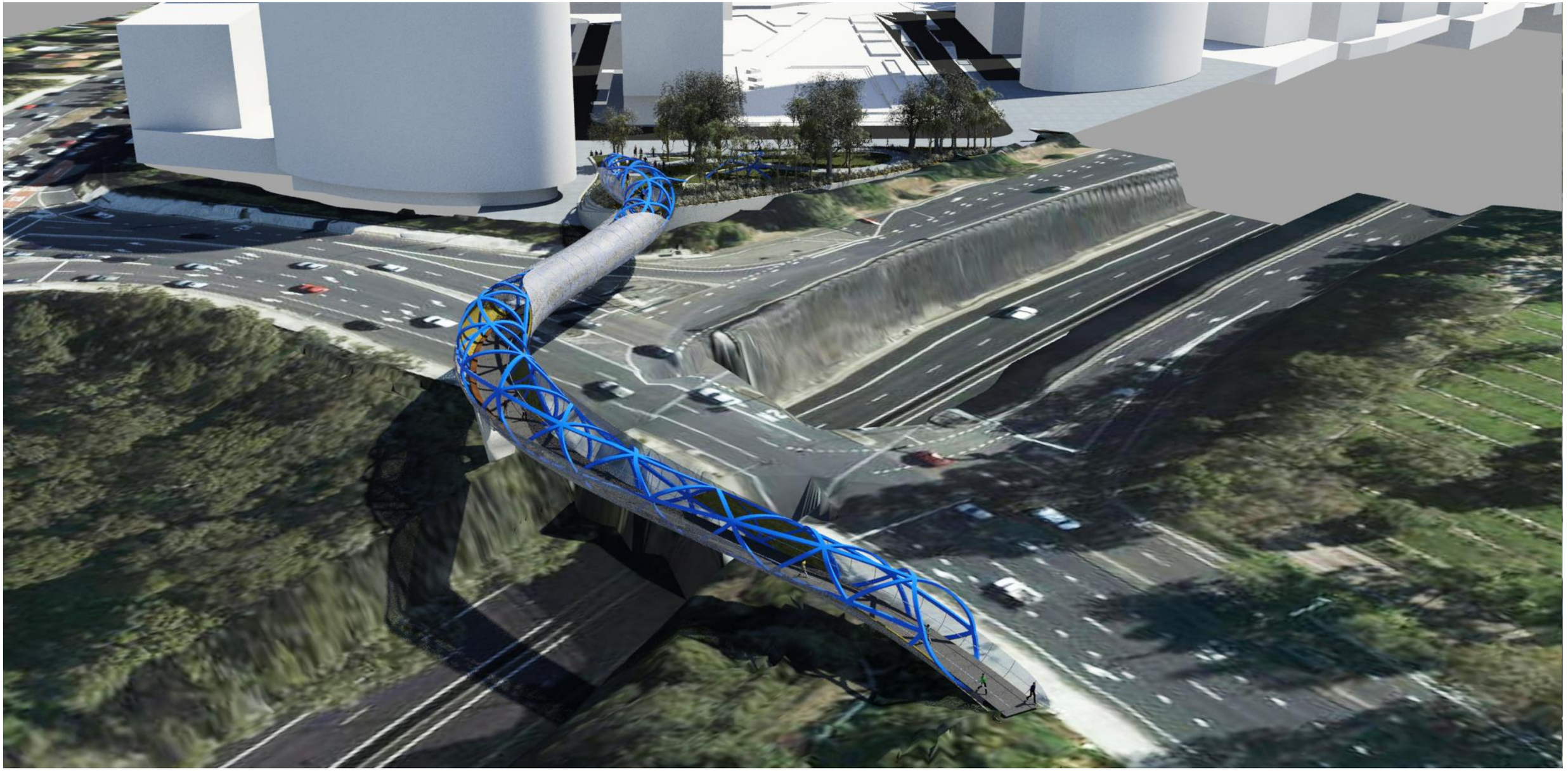
AUTOMATED

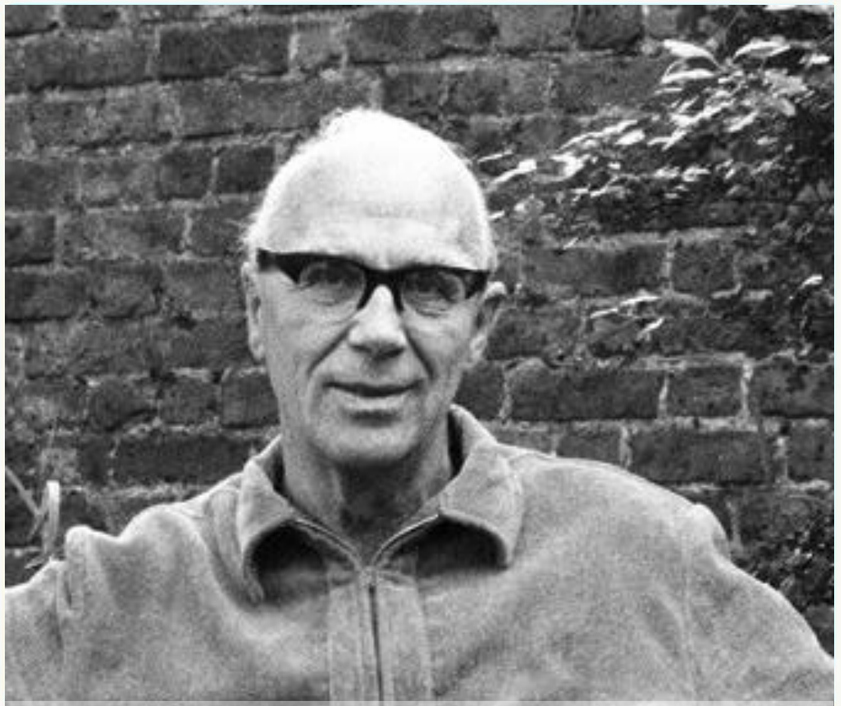
- Architectural Model
- GSA Concept Analysis
- Strand 7 FE Analysis
- Structural Documentation

you can't connect the dots looking forward;

you can't connect the dots looking forward;
you can only connect them looking backwards.

Steve Jobs



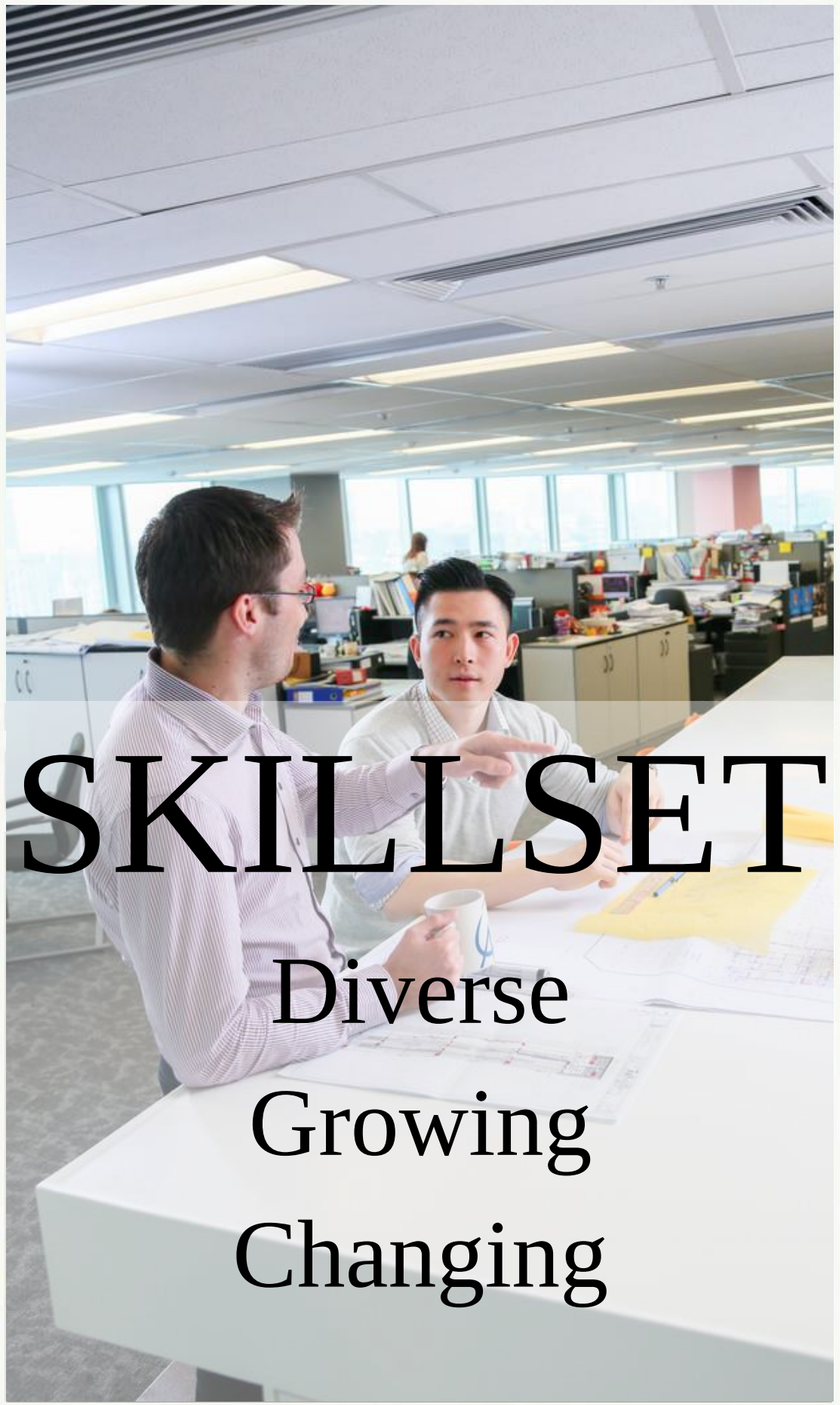


MINDSET

Inspire

Make a Difference

Best in Class

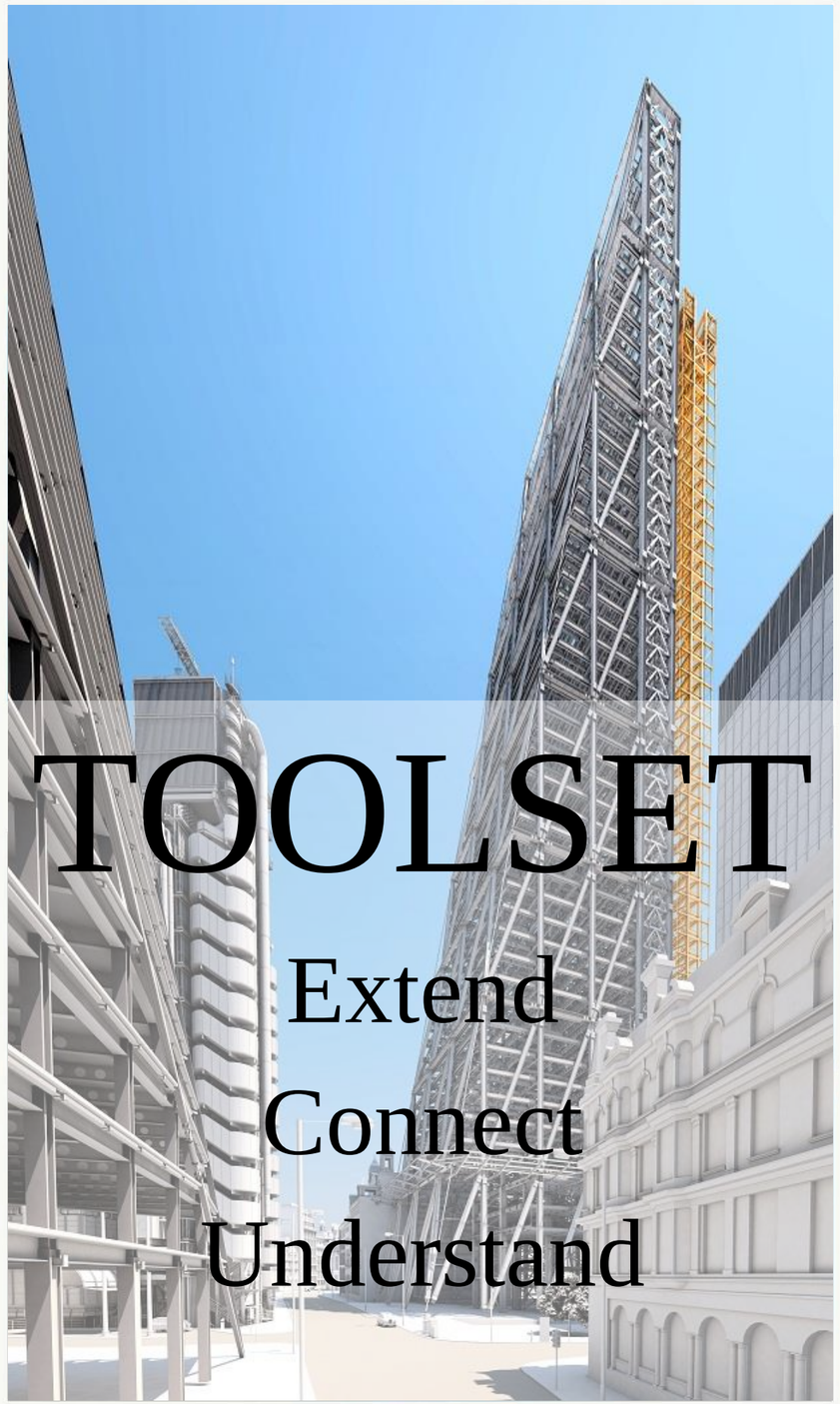


SKILLSET

Diverse

Growing

Changing

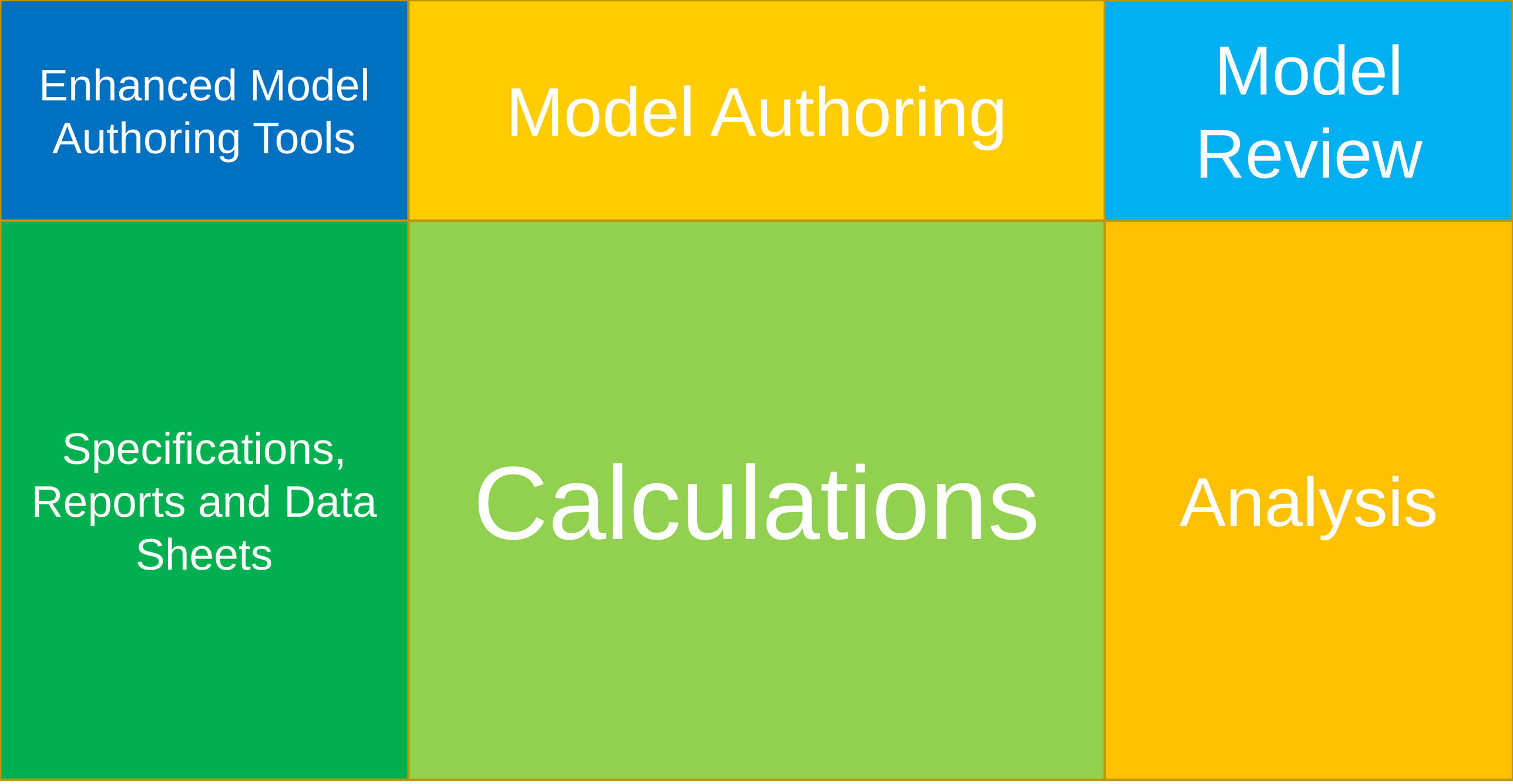


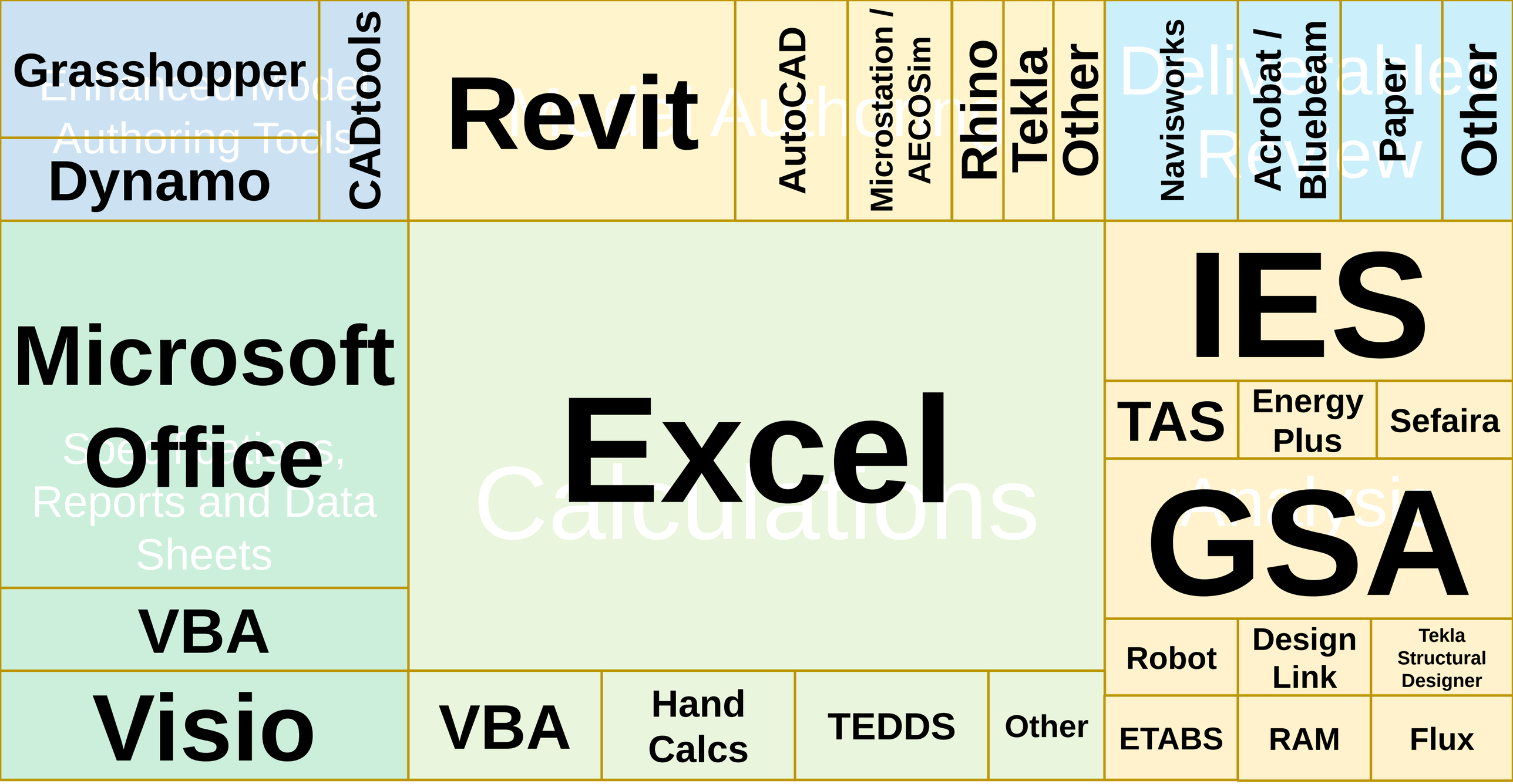
TOOLSET

Extend

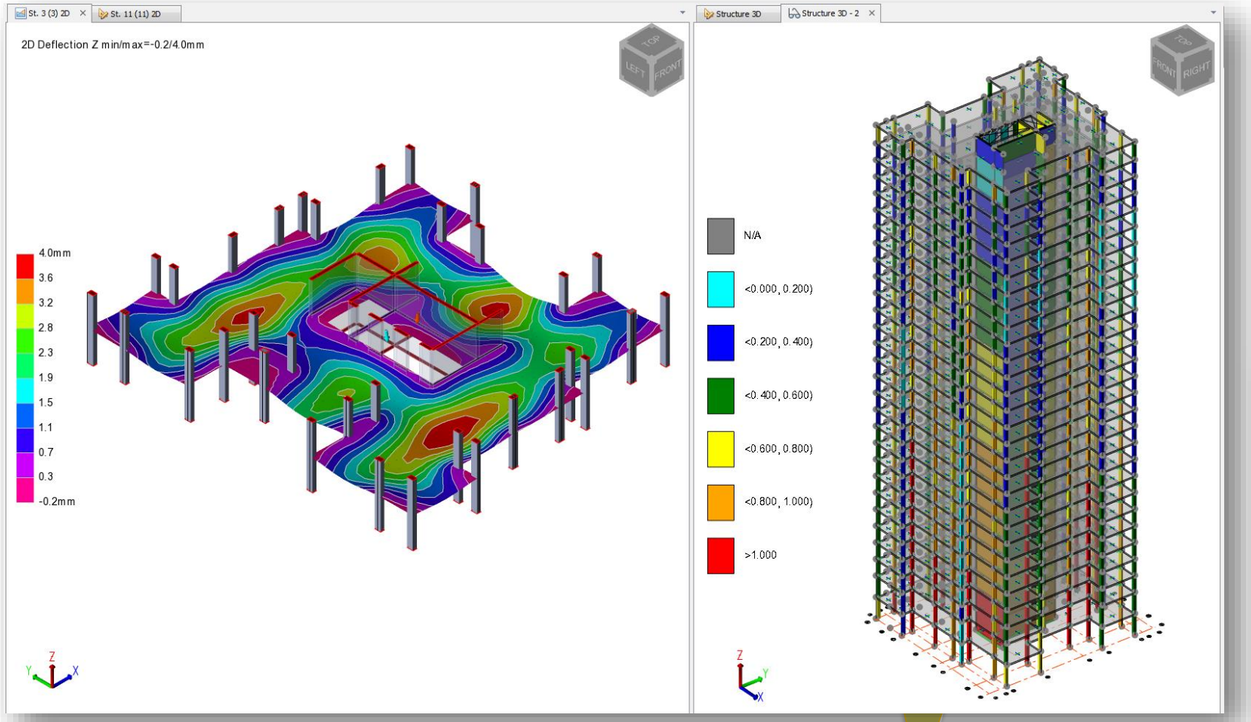
Connect

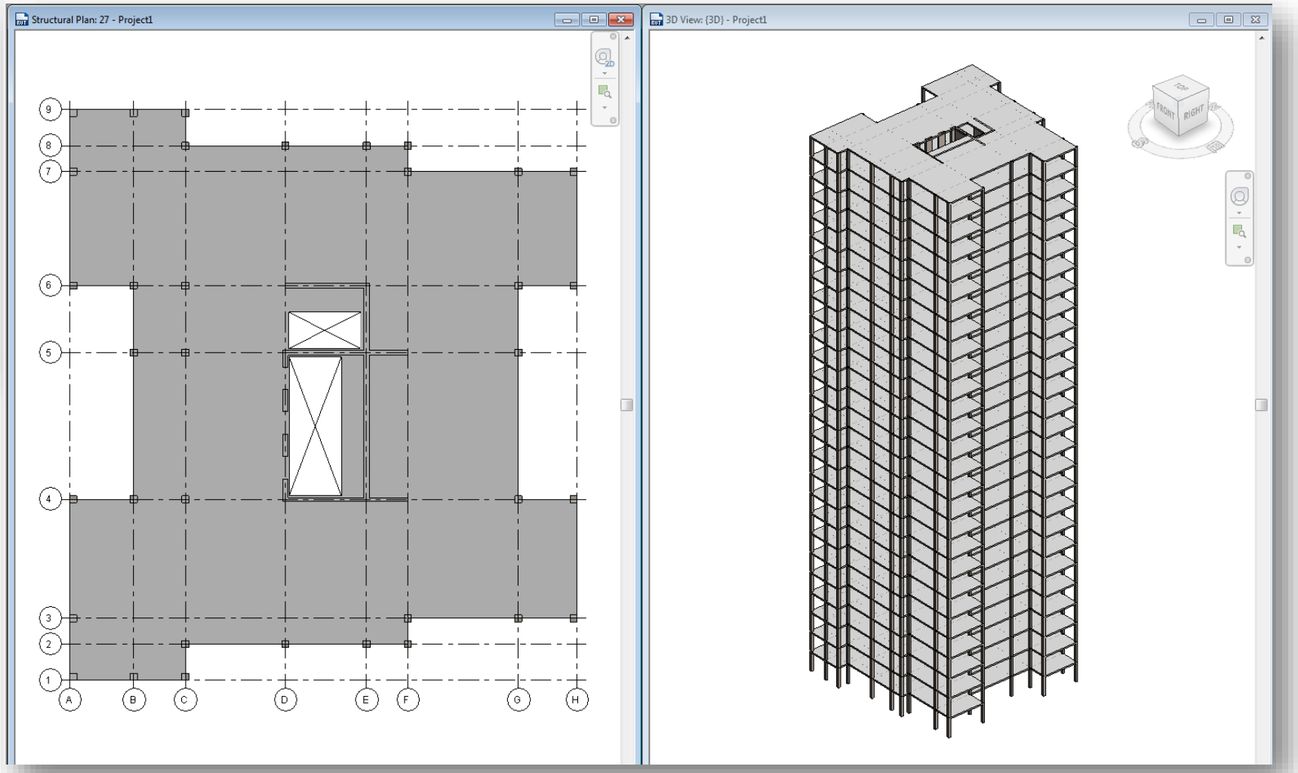
Understand


Enhanced Model Authoring Tools
Model Authoring
Model Review
Specifications, Reports and Data Sheets
Calculations
Analysis


Grasshopper
Dynamo
CADtools
Revit
AutoCAD
Microstation / AECOSim
Rhino
Tekla
Other
Navisworks
Acrobat / Bluebeam
Paper
Other
Microsoft Office
VBA
Visio
Excel
VBA
Hand Calcs
TEDDS
Other
IES
TAS
Energy Plus
Sefaira
GSA
Robot
Design Link
Tekla Structural Designer
ETABS
RAM
Flux

Workflow Interoperability is Key…

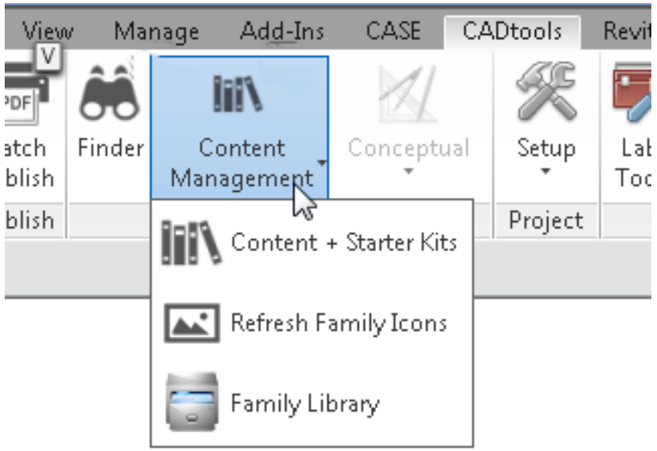


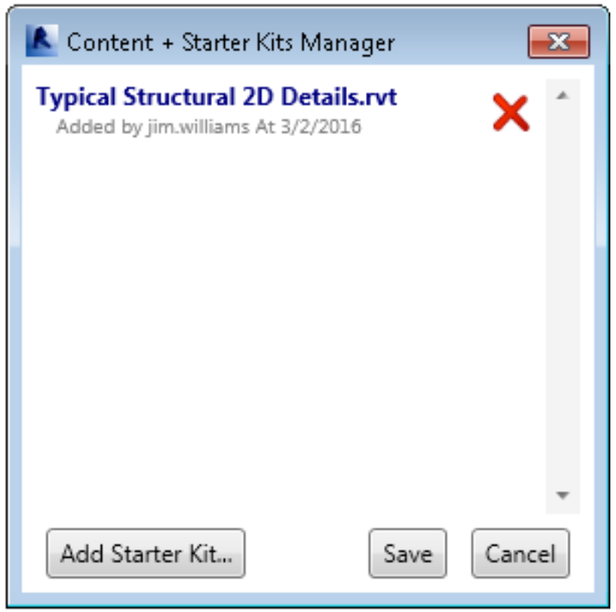


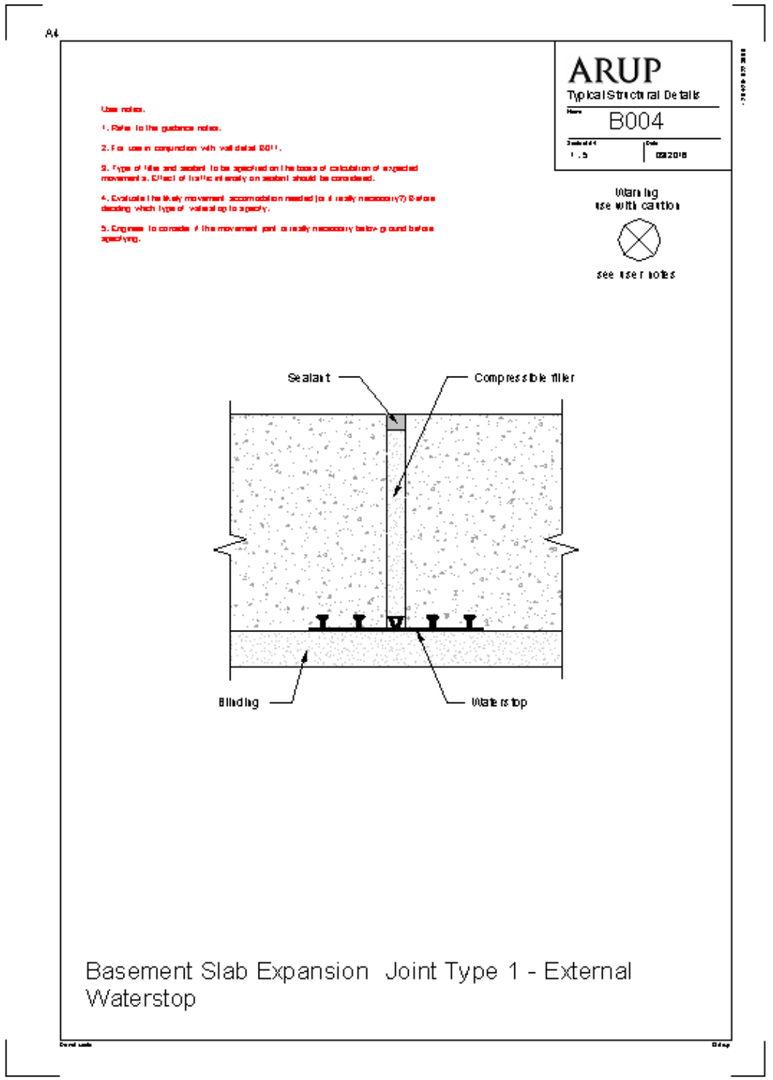
…but Content is King…

- Typical Content – some examples
  - 2D Details
  - General Notes
  - Rebar Content

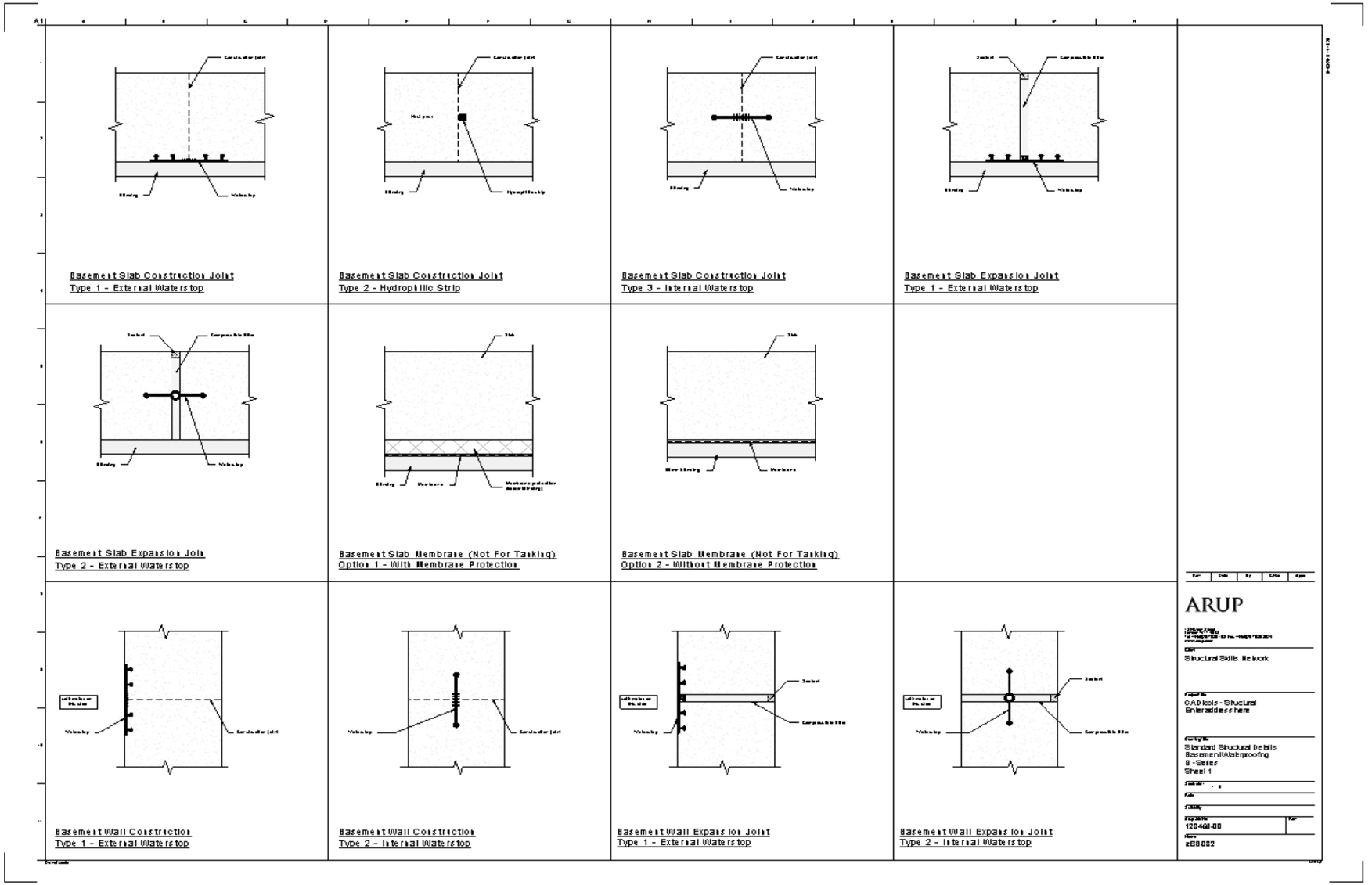
Typical 2D Structural Details



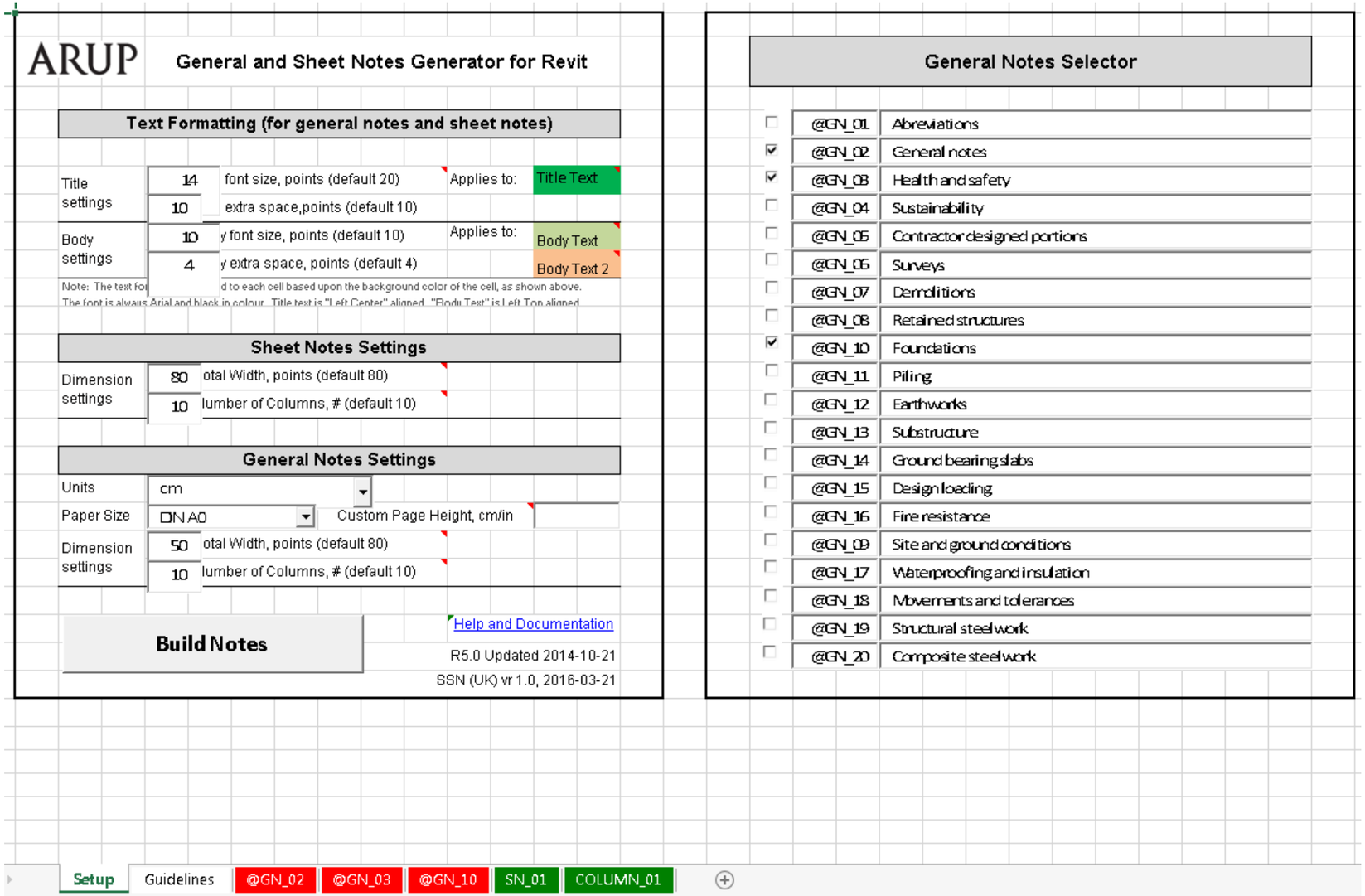




Typical 2D Structural Details



Text Generator – Typical Notes



Text Generator – Typical Notes

		Foundations
	1	All foundations and concrete surrounding steelwork below the ground floor slab shall be grade [tbc] unless noted otherwise
	2	The foundations have been designed on a permissible bearing pressure of [...] kN/m². This is based on formation level being a minimum of 200mm into the [....insert appropriate strata....]
Exclude	2	The foundations have been designed in accordance with the requirements of Eurocode 7 based on founding within the [...insert appropriate strata...] which is to be confirmed by inspection on site. The SLS bearing pressure is [...] kN/m²
	3	A competent engineer is to be employed by the Contractor to inspect the formation of every foundation immediately prior to concreting.
	4	Insitu hand vane testing is to be carried out at all pad locations to confirm the required bearing capacity at foundation level.
Exclude	5	The engineer must be notified immediately if any bad ground is met at the formation level. If then instructed to do so, the Contractor will lower the formation level and fill the excess excavation with Grade [???] mass concrete.
	6	All exposed formations shall be kept dry and shall be immediately protected from softening by blinding the surface with 50mm of blinding concrete.
	7	Under no circumstances may a completed excavation for a foundation or retaining wall base remain exposed overnight. The formation must be blinded as note [4] or the final 200mm of excavation be completed on the day the concrete is poured.
	8	Backfill to excavations to be approved selected backfill compacted in accordance with the [Earthworks Specification]
	9	Refer to the Architect's drawings for waterproofing details and cast-in fixxings and fittings.
Exclude	10	The Engineer must be given 48 hours notice of the excavation of the foundations so that he may have the opportunity inspect the formation level.
Exclude	11	The design chemical class for foundations is [....].

Text Generator – Typical Notes

Foundations

1 All foundations and concrete surrounding steelwork below the ground floor slab shall be grade [tbc] unless noted otherwise

2 The foundations have been designed on a permissible bearing pressure of [...] kN/m². This is based on formation level being a minimum of 200mm into the [....insert appropriate strata....]

3 A competent engineer is to be employed by the Contractor to inspect the formation of every foundation immediately prior to concreting.

4 Insitu hand vane testing is to be carried out at all pad locations to confirm the required bearing capacity at foundation level.

6 All exposed formations shall be kept dry and shall be immediately protected from softening by blinding the surface with 50mm of blinding concrete.

7 Under no circumstances may a completed excavation for a foundation or retaining wall base remain exposed overnight. The formation must be blinded as note [4] or the final 200mm of excavation be completed on the day the concrete is poured.

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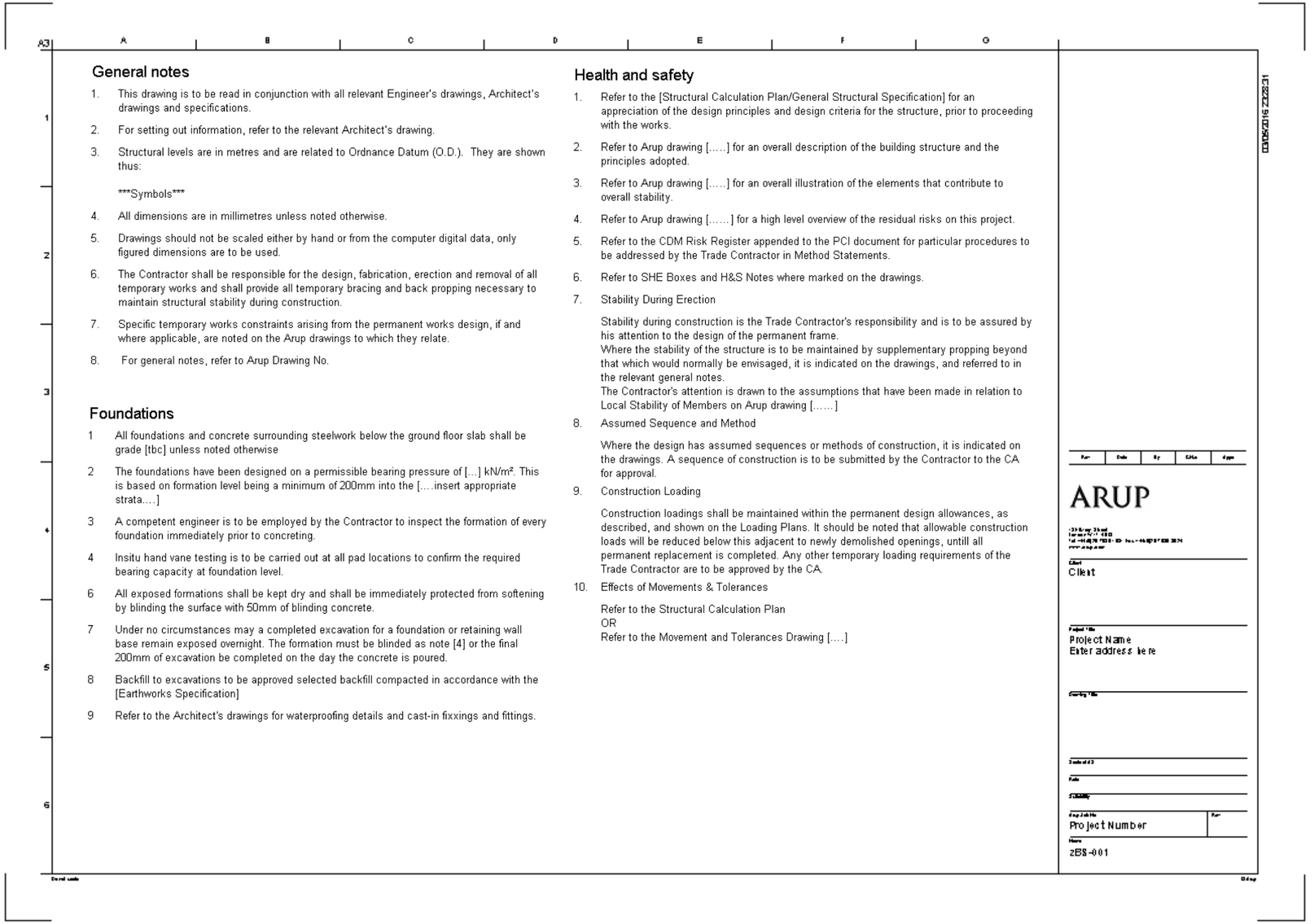
9 Refer to the Architect's drawings for waterproofing details and cast-in fixxings and fittings.

Text Generator – Typical Notes



General notes

1. This drawing is to be read in conjunction with all relevant Engineer's drawings, Architect's drawings and specifications.
2. For setting out information, refer to the relevant Architect's drawing.
3. Structural levels are in metres and are related to Ordnance Datum (O.D.). They are shown thus:

   Symbols
4. All dimensions are in millimetres unless noted otherwise.
5. Drawings should not be scaled either by hand or from the computer digital data, only figured dimensions are to be used.
6. The Contractor shall be responsible for the design, fabrication, erection and removal of all temporary works and shall provide all temporary bracing and back propping necessary to maintain structural stability during construction.
7. Specific temporary works constraints arising from the permanent works design, if and where applicable, are noted on the Arup drawings to which they relate.
8. For general notes, refer to Arup Drawing No.

Foundations

1 All foundations and concrete surrounding steelwork below the ground floor slab shall be grade [tbc] unless noted otherwise

2 The foundations have been designed on a permissible bearing pressure of [...] kN/m². This is based on formation level being a minimum of 200mm into the [....insert appropriate strata....]

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8 Backfill to excavations to be approved selected backfill compacted in accordance with the [Earthworks Specification]

9 Refer to the Architect's drawings for waterproofing details and cast-in fixxings and fittings.

Health and safety

1. Refer to the [Structural Calculation Plan/General Structural Specification] for an appreciation of the design principles and design criteria for the structure, prior to proceeding with the works.
2. Refer to Arup drawing [.....] for an overall description of the building structure and the principles adopted.
3. Refer to Arup drawing [.....] for an overall illustration of the elements that contribute to overall stability.
4. Refer to Arup drawing [.....] for a high level overview of the residual risks on this project.
5. Refer to the CDM Risk Register appended to the PCI document for particular procedures to be addressed by the Trade Contractor in Method Statements.
6. Refer to SHE Boxes and H&S Notes where marked on the drawings.
7. Stability During Erection

   Stability during construction is the Trade Contractor's responsibility and is to be assured by his attention to the design of the permanent frame.
   Where the stability of the structure is to be maintained by supplementary propping beyond that which would normally be envisaged, it is indicated on the drawings, and referred to in the relevant general notes.
   The Contractor's attention is drawn to the assumptions that have been made in relation to Local Stability of Members on Arup drawing [.....]
8. Assumed Sequence and Method

   Where the design has assumed sequences or methods of construction, it is indicated on the drawings. A sequence of construction is to be submitted by the Contractor to the CA for approval.
9. Construction Loading

   Construction loadings shall be maintained within the permanent design allowances, as described, and shown on the Loading Plans. It should be noted that allowable construction loads will be reduced below this adjacent to newly demolished openings, untill all permanent replacement is completed. Any other temporary loading requirements of the Trade Contractor are to be approved by the CA.
10. Effects of Movements & Tolerances

    Refer to the Structural Calculation Plan
    OR
    Refer to the Movement and Tolerances Drawing [....]

ARUP

Client

Project Name
Enter address here

Project Number

2BS-001

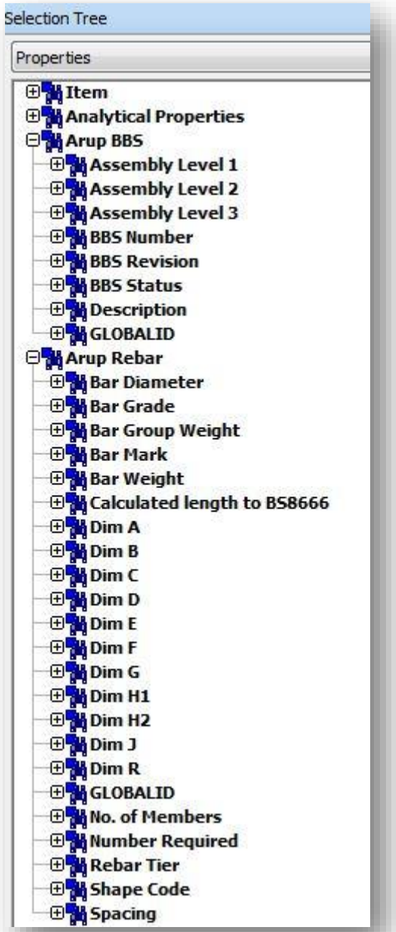
Template Design and Checking Views

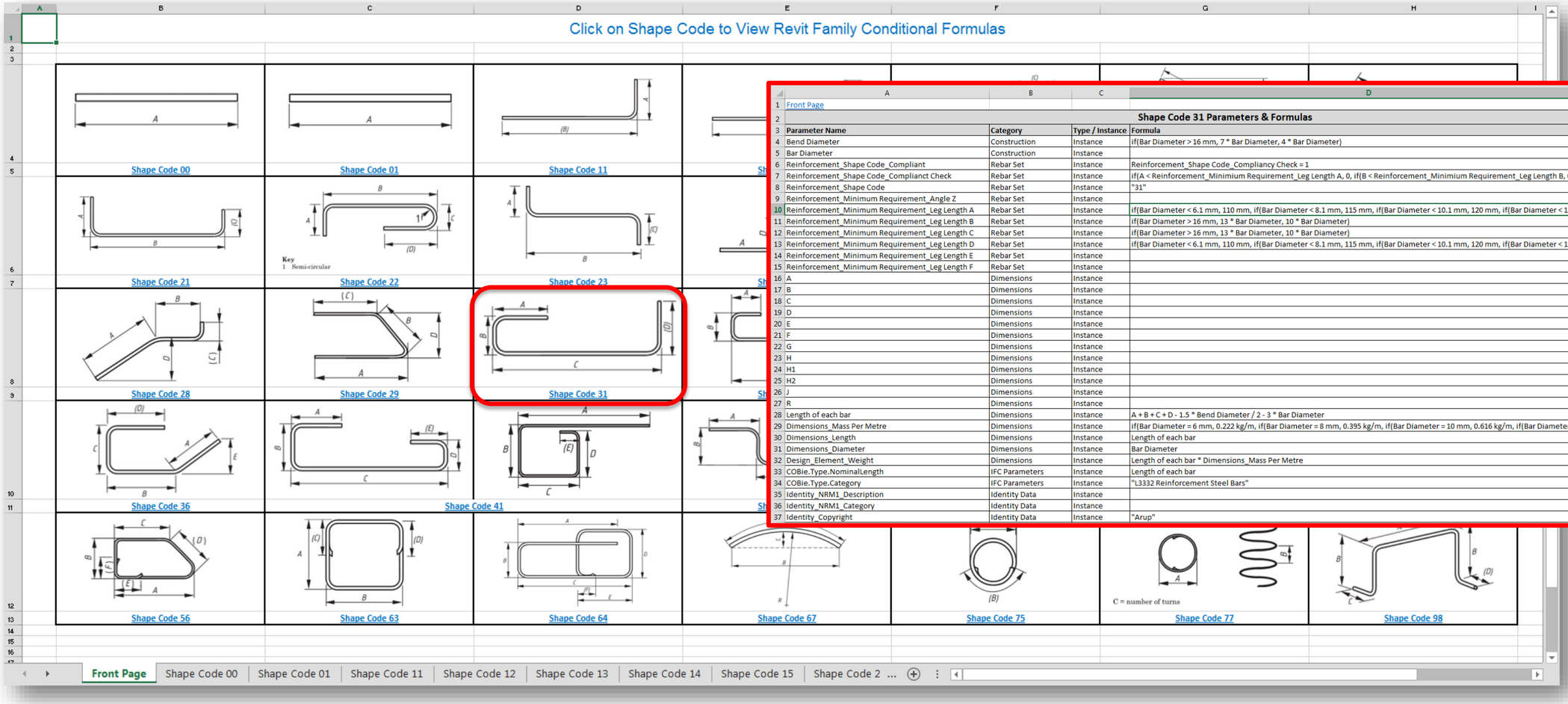
- 20 - Design Views
  - De -3D Building (Analytical)
    - 3D View: De - 3D Building (Analytical)
    - 3D View: De - 3D Building (Analytical) Node Connectivity

- 30 - Checking Views
  - Ch - 3D Building
    - 3D View: Ch - 3D Building (Bearing Pad Utilisation)
    - 3D View: Ch - 3D Building (Bearing Pressure Allowable)
    - 3D View: Ch - 3D Building (Design Element Weight)
    - 3D View: Ch - 3D Building (Fire Period Minutes)
    - 3D View: Ch - 3D Building (Is Steel Readily Available)
    - 3D View: Ch - 3D Building (Key Structural Element)
    - 3D View: Ch - 3D Building (Level of Development)
    - 3D View: Ch - 3D Building (Lightning Path)
    - 3D View: Ch - 3D Building (Primary Structure)
    - 3D View: Ch - 3D Building (Span Depth Ratio)
    - 3D View: Ch - 3D Building (Stability System)
    - 3D View: Ch - 3D Building (Strength Grade - Concrete)
    - 3D View: Ch - 3D Building (Strength Grade - Steel)
    - 3D View: Ch - 3D Building (Sub Grade - Steel)
    - 3D View: Ch - 3D Building (Suitability Code)

- Ch - 3D RC Building
  - 3D View: Ch - 3D RC Building (Colour by Bar Grade)
  - 3D View: Ch - 3D RC Building (Colour by Bar Size)
  - 3D View: Ch - 3D RC Building (Colour by Reinforcement Bar Length)
  - 3D View: Ch - 3D RC Building (Colour by Reinforcement Design Element Weight)
  - 3D View: Ch - 3D RC Building (Colour by Reinforcement End Prepared Bar Type)
  - 3D View: Ch - 3D RC Building (Colour by Shape Code Compliancy Check)

Content: Rebar Family Conditional Formulae



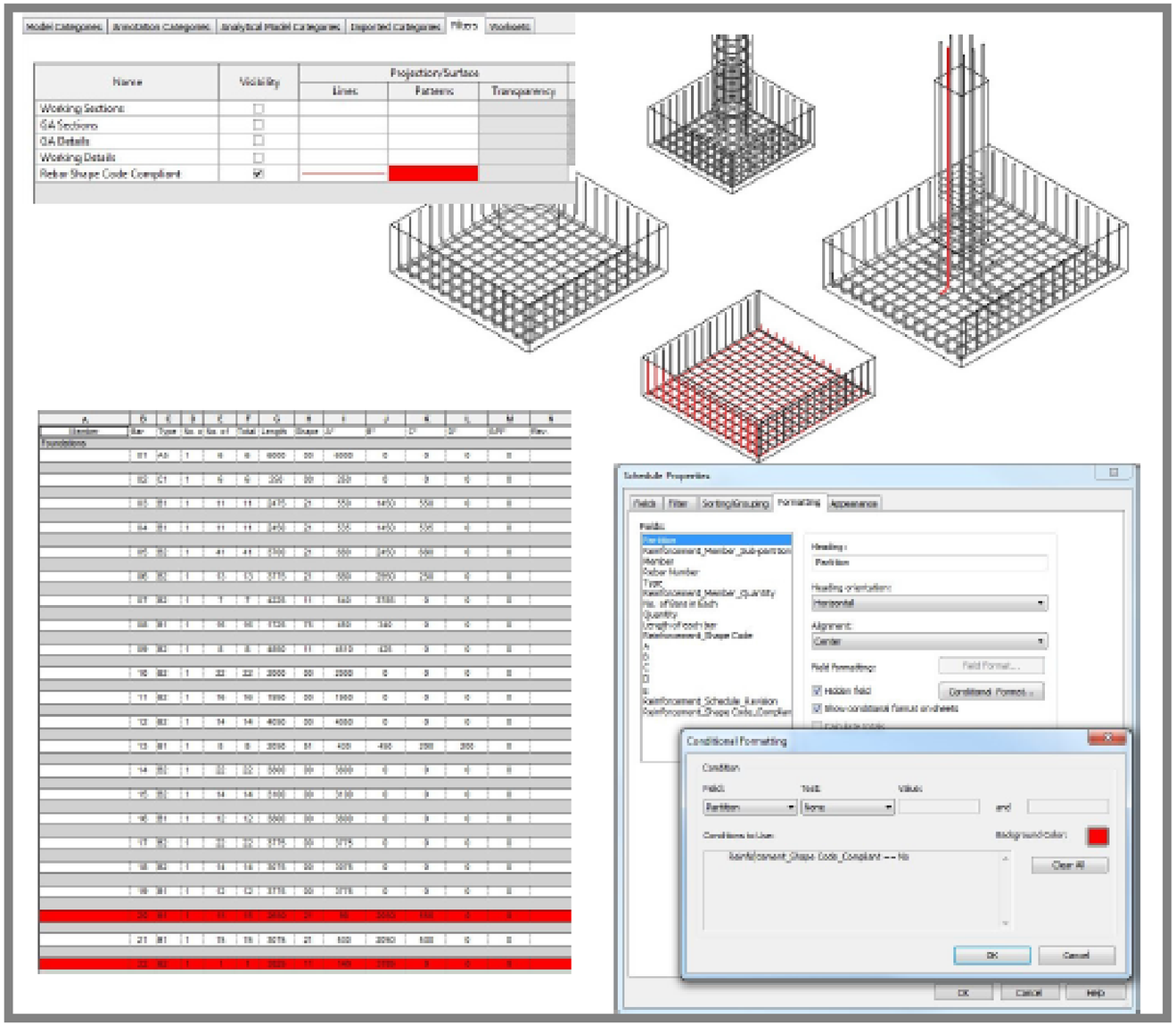


Front Page

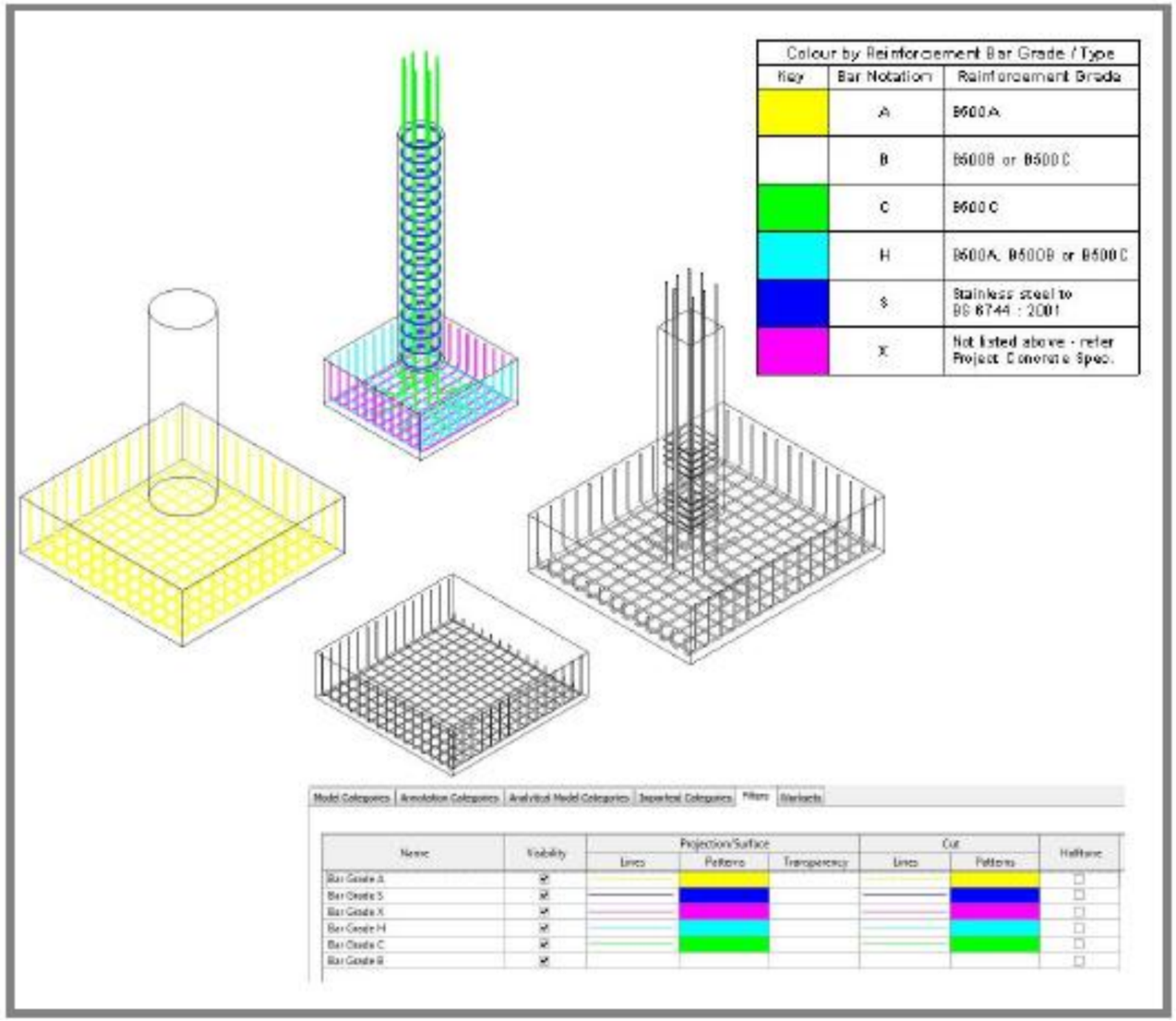
Shape Code 31 Parameters & Formulas

Parameter Name	Category	Type / Instance	Formula
Bend Diameter	Construction	Instance	if(Bar Diameter > 16 mm, 7 * Bar Diameter, 4 * Bar Diameter)
Bar Diameter	Construction	Instance	
Reinforcement_Shape Code_Compliant	Rebar Set	Instance	Reinforcement_Shape Code_Compliancy Check = 1
Reinforcement_Shape Code_Compliant Check	Rebar Set	Instance	if(A < Reinforcement_Minimum Requirement_Leg Length A, 0, if(B < Reinforcement_Minimum Requirement_Leg Length B, 0, if(C
Reinforcement_Shape Code	Rebar Set	Instance	"31"
Reinforcement_Minimum Requirement_Angle Z	Rebar Set	Instance	
Reinforcement_Minimum Requirement_Leg Length A	Rebar Set	Instance	if(Bar Diameter < 6.1 mm, 110 mm, if(Bar Diameter < 8.1 mm, 115 mm, if(Bar Diameter < 10.1 mm, 120 mm, if(Bar Diameter < 12.1 mm
Reinforcement_Minimum Requirement_Leg Length B	Rebar Set	Instance	if(Bar Diameter > 16 mm, 13 * Bar Diameter, 10 * Bar Diameter)
Reinforcement_Minimum Requirement_Leg Length C	Rebar Set	Instance	if(Bar Diameter > 16 mm, 13 * Bar Diameter, 10 * Bar Diameter)
Reinforcement_Minimum Requirement_Leg Length D	Rebar Set	Instance	if(Bar Diameter < 6.1 mm, 110 mm, if(Bar Diameter < 8.1 mm, 115 mm, if(Bar Diameter < 10.1 mm, 120 mm, if(Bar Diameter < 12.1 mm
Reinforcement_Minimum Requirement_Leg Length E	Rebar Set	Instance	
Reinforcement_Minimum Requirement_Leg Length F	Rebar Set	Instance	
A	Dimensions	Instance	
B	Dimensions	Instance	
C	Dimensions	Instance	
D	Dimensions	Instance	
E	Dimensions	Instance	
F	Dimensions	Instance	
G	Dimensions	Instance	
H	Dimensions	Instance	
H1	Dimensions	Instance	
H2	Dimensions	Instance	
J	Dimensions	Instance	
R	Dimensions	Instance	
Length of each bar	Dimensions	Instance	A + B + C + D - 1.5 * Bend Diameter / 2 - 3 * Bar Diameter
Dimensions_Mass Per Metre	Dimensions	Instance	if(Bar Diameter = 6 mm, 0.222 kg/m, if(Bar Diameter = 8 mm, 0.395 kg/m, if(Bar Diameter = 10 mm, 0.616 kg/m, if(Bar Diameter = 12
Dimensions_Length	Dimensions	Instance	Length of each bar
Dimensions_Diameter	Dimensions	Instance	Bar Diameter
Design_Element_Weight	Dimensions	Instance	Length of each bar * Dimensions_Mass Per Metre
COBie.Type.NominalLength	IFC Parameters	Instance	Length of each bar
COBie.Type.Category	IFC Parameters	Instance	"L3332 Reinforcement Steel Bars"
Identity_NRM1_Description	Identity Data	Instance	
Identity_NRM1_Category	Identity Data	Instance	
Identity_Copyright	Identity Data	Instance	"Arup"

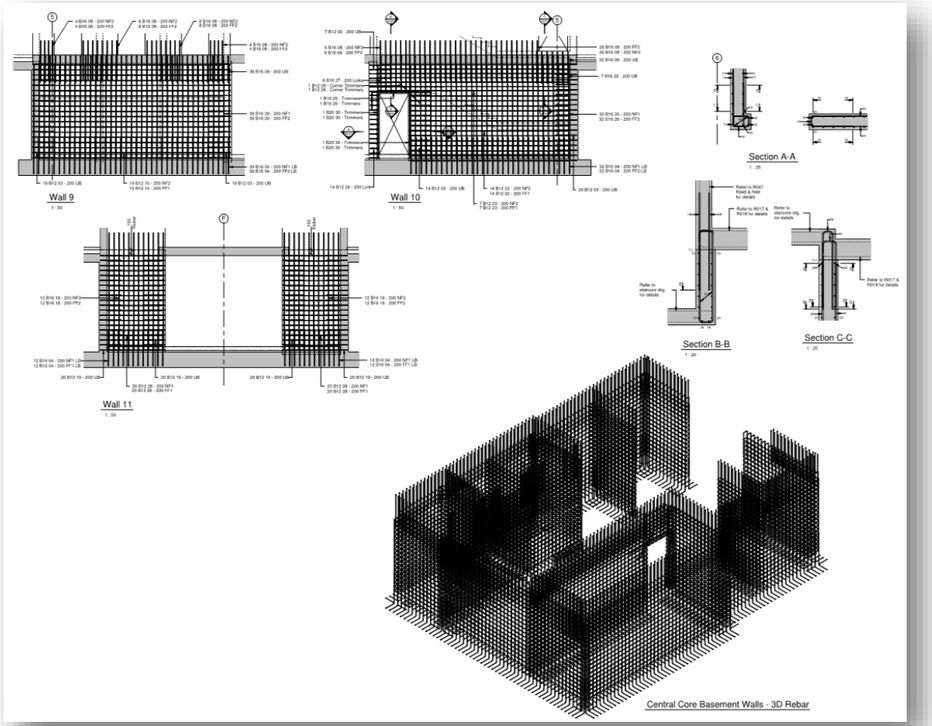
Rebar Content – Compliance Views

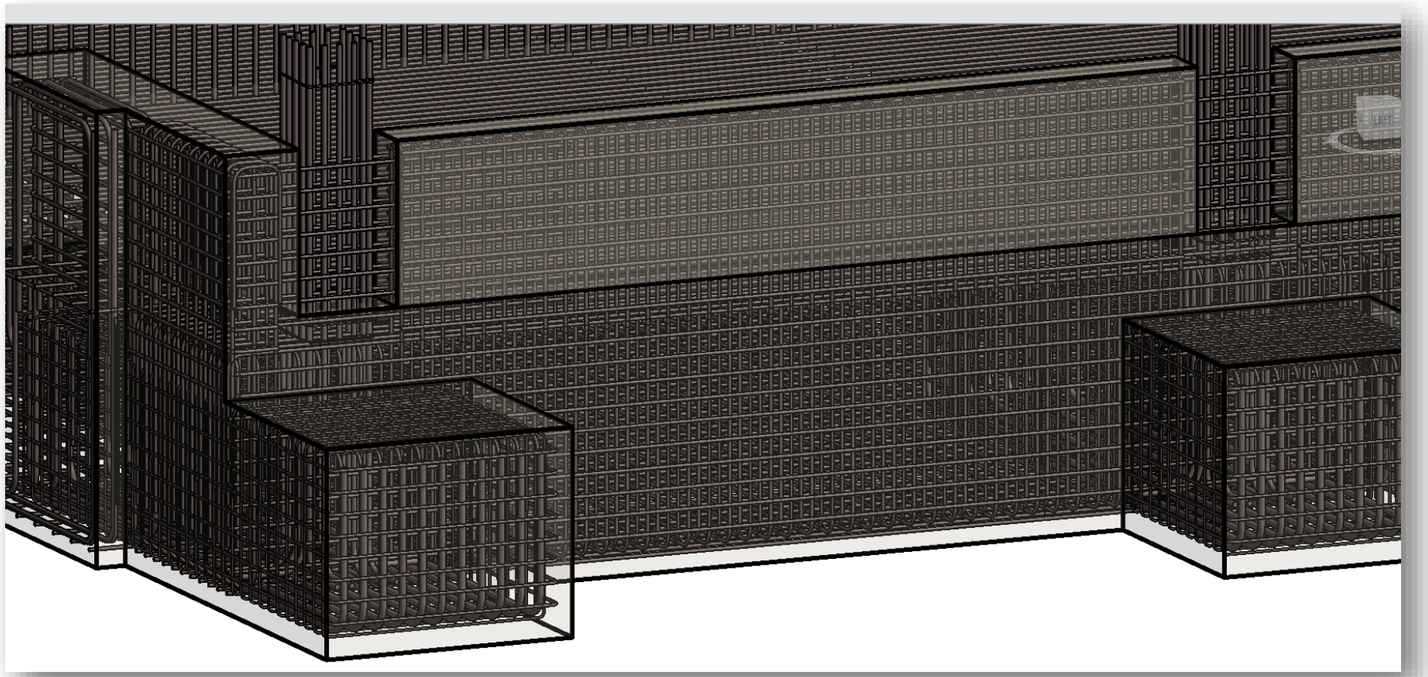


Rebar Content – Bar Grades

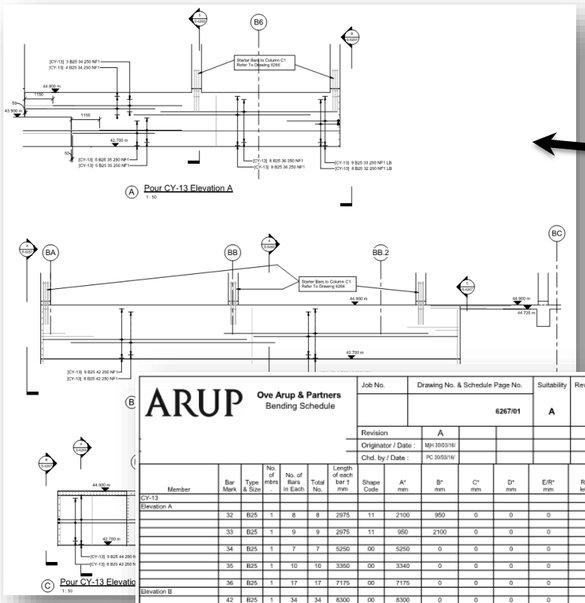


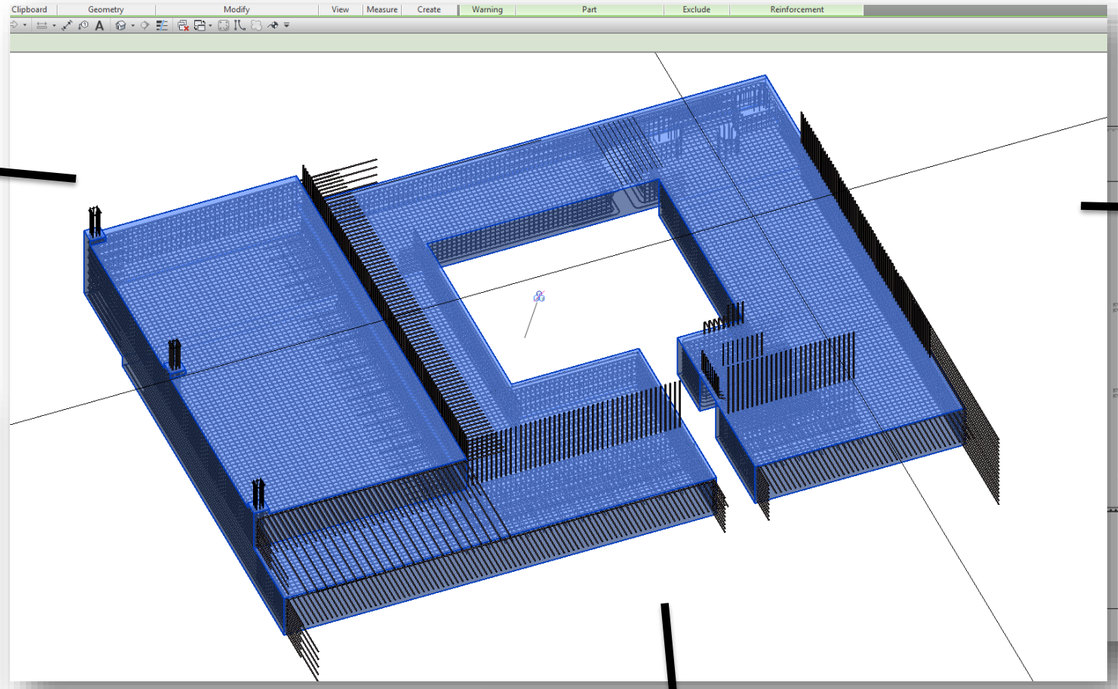
Concrete Reinforcement

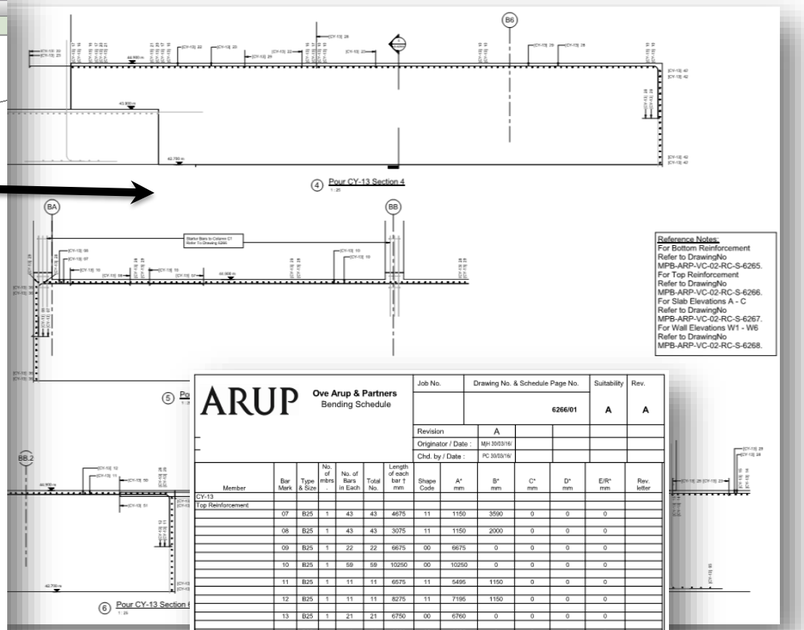




Concrete Reinforcement







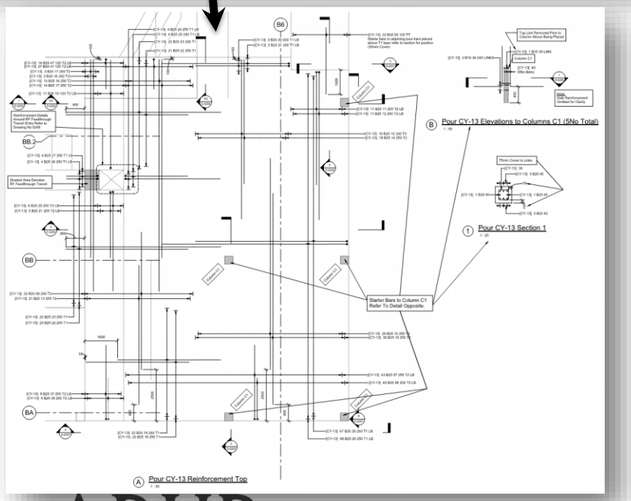
ARUP **Ove Arup & Partners**
Bending Schedule

Job No.	Drawing No. & Schedule Page No.	Suitability	Rev.
	6267/01	A	A

Revision	A
Originator / Date :	MH 30/03/16
Chd. by / Date :	PC 30/03/16

Member	Bar Mark	Type & Size	No. of mbrs	No. of Bars in Each	Total No.	Length of each bar † mm	Shape Code	A* mm	B* mm	C* mm	D* mm	E/R* mm	Rev. letter
CY-13													
Elevation A													
	32	B25	1	8	8	2975	11	2100	950	0	0	0	
	33	B25	1	9	9	2975	11	950	2100	0	0	0	
	34	B25	1	7	7	5250	00	5250	0	0	0	0	
	35	B25	1	10	10	3350	00	3340	0	0	0	0	
	36	B25	1	17	17	7175	00	7175	0	0	0	0	
Elevation B													
	42	B25	1	34	34	8300	00	8300	0	0	0	0	
Elevation C													
	43	B25	1	8	8	4375	11	950	3500	0	0	0	
	44	B25	1	9	9	5525	11	2100	3500	0	0	0	

This Schedule conforms to BS 8666:2005
* Specified in multiples of 5 mm + Specified in multiples of 25 mm



ARUP **Ove Arup & Partners**
Bending Schedule

Job No.	Drawing No. & Schedule Page No.	Suitability	Rev.
	6266/01	A	A

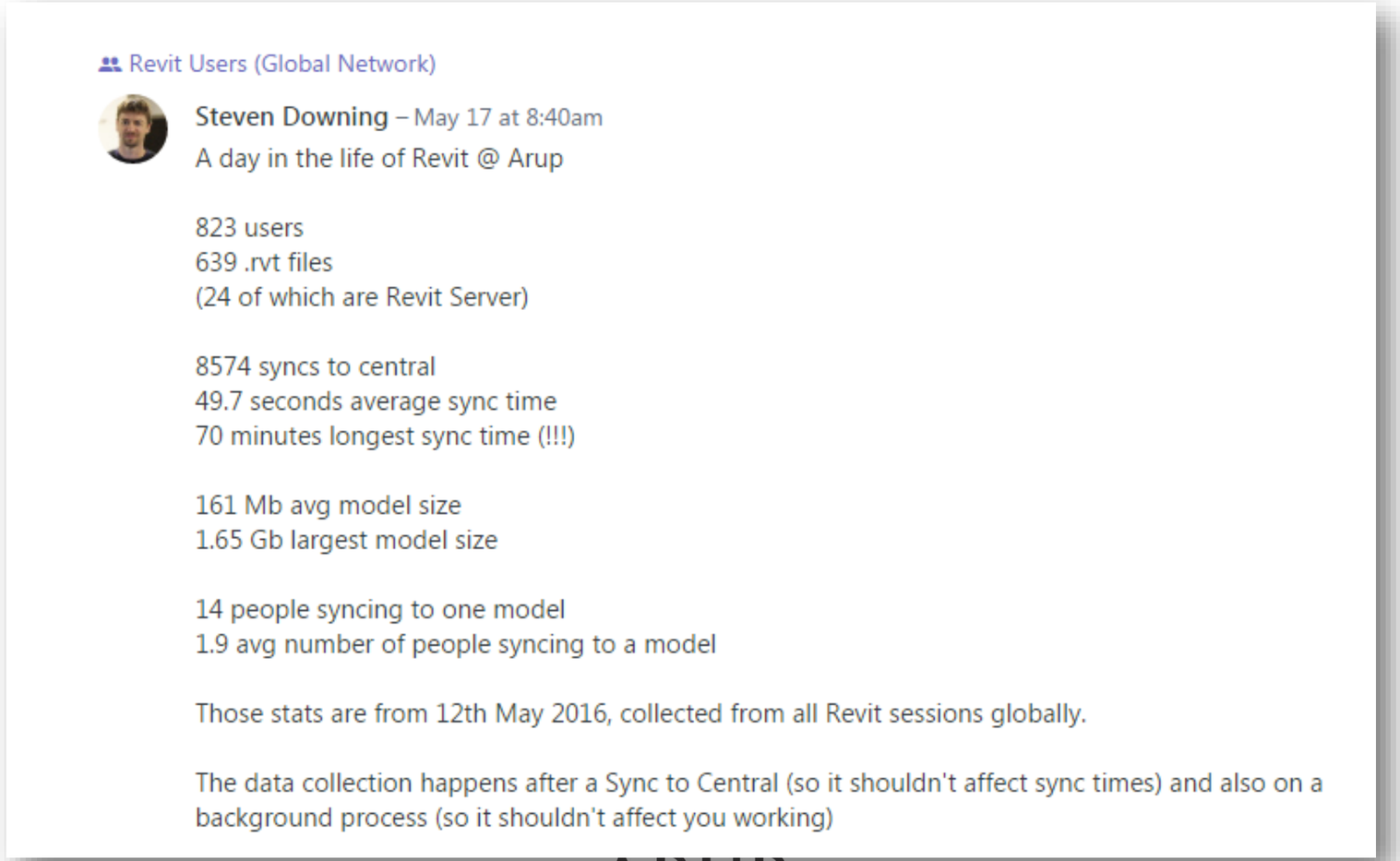
Revision	A
Originator / Date :	MH 30/03/16
Chd. by / Date :	PC 30/03/16

Member	Bar Mark	Type & Size	No. of mbrs	No. of Bars in Each	Total No.	Length of each bar † mm	Shape Code	A* mm	B* mm	C* mm	D* mm	E/R* mm	Rev. letter
CY-13													
Top Reinforcement													
	07	B25	1	43	43	4675	11	1150	3590	0	0	0	
	08	B25	1	43	43	3075	11	1150	2000	0	0	0	
	09	B25	1	22	22	6675	00	6675	0	0	0	0	
	10	B25	1	59	59	10250	00	10250	0	0	0	0	
	11	B25	1	11	11	6575	11	5495	1150	0	0	0	
	12	B25	1	11	11	8275	11	7195	1150	0	0	0	
	13	B25	1	21	21	6750	00	6760	0	0	0	0	
	14	B25	1	18	18	6050	00	6055	0	0	0	0	
	15	B25	1	19	19	7750	00	7755	0	0	0	0	
	16	B25	1	15	15	11250	00	11240	0	0	0	0	
	17	B25	1	17	17	9625	00	9630	0	0	0	0	
	18	B25	1	44	44	5000	00	5000	0	0	0	0	
	19	B25	1	11	11	6050	11	875	5250	0	0	0	
	20	B25	1	6	6	5600	11	875	4805	0	0	0	
	21	B25	1	5	5	4000	11	875	3205	0	0	0	
	22	B25	1	44	44	5900	00	5910	0	0	0	0	
	23	B25	1	44	44	7500	00	7510	0	0	0	0	
	24	B25	1	4	4	5425	11	875	4610	0	0	0	
	25	B25	1	4	4	3825	11	870	3020	0	0	0	
	26	B25	1	4	4	2300	11	875	1500	0	0	0	
	27	B25	1	4	4	2300	11	870	1500	0	0	0	
	28	B25	1	67	67	8450	11	1150	7375	0	0	0	
	29	B25	1	68	68	10050	11	1150	8970	0	0	0	
	30	B25	1	3	3	6575	11	2075	4560	0	0	0	
	31	B25	1	3	3	8175	11	2075	6170	0	0	0	
	37	B25	1	8	8	4400	11	875	3590	0	0	0	
	38	B25	1	8	8	2800	11	875	2000	0	0	0	
	41	B25	1	27	27	2525	11	1150	1450	0	0	0	
	47	B25	1	16	16	2250	11	875	1450	0	0	0	
	50	B20	1	22	22	3250	00	3250	0	0	0	0	

This Schedule conforms to BS 8666:2005
* Specified in multiples of 5 mm + Specified in multiples of 25 mm

Data Harvesting

- Revit – a “day in the life”



Revit Users (Global Network)

Steven Downing – May 17 at 8:40am

A day in the life of Revit @ Arup

823 users
639 .rvt files
(24 of which are Revit Server)

8574 syncs to central
49.7 seconds average sync time
70 minutes longest sync time (!!!)

161 Mb avg model size
1.65 Gb largest model size

14 people syncing to one model
1.9 avg number of people syncing to a model

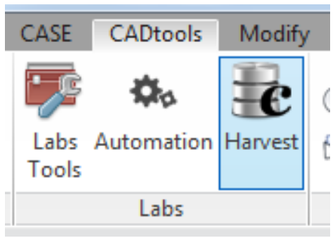
Those stats are from 12th May 2016, collected from all Revit sessions globally.

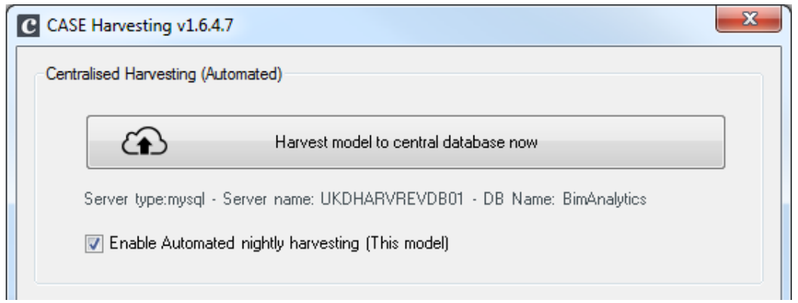
The data collection happens after a Sync to Central (so it shouldn't affect sync times) and also on a background process (so it shouldn't affect you working)

Data Harvesting

Automated Publishing of:
NWC / DWF / IFC / PDF

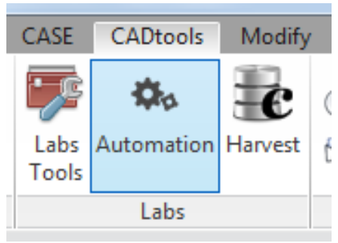
Manual – Run once

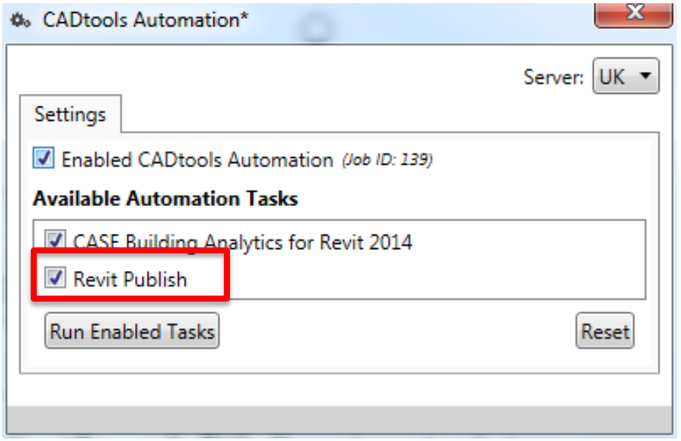




If the ‘Harvest model to central database’ button is enabled, data will be harvested to the database. Can be run ‘on-demand’.

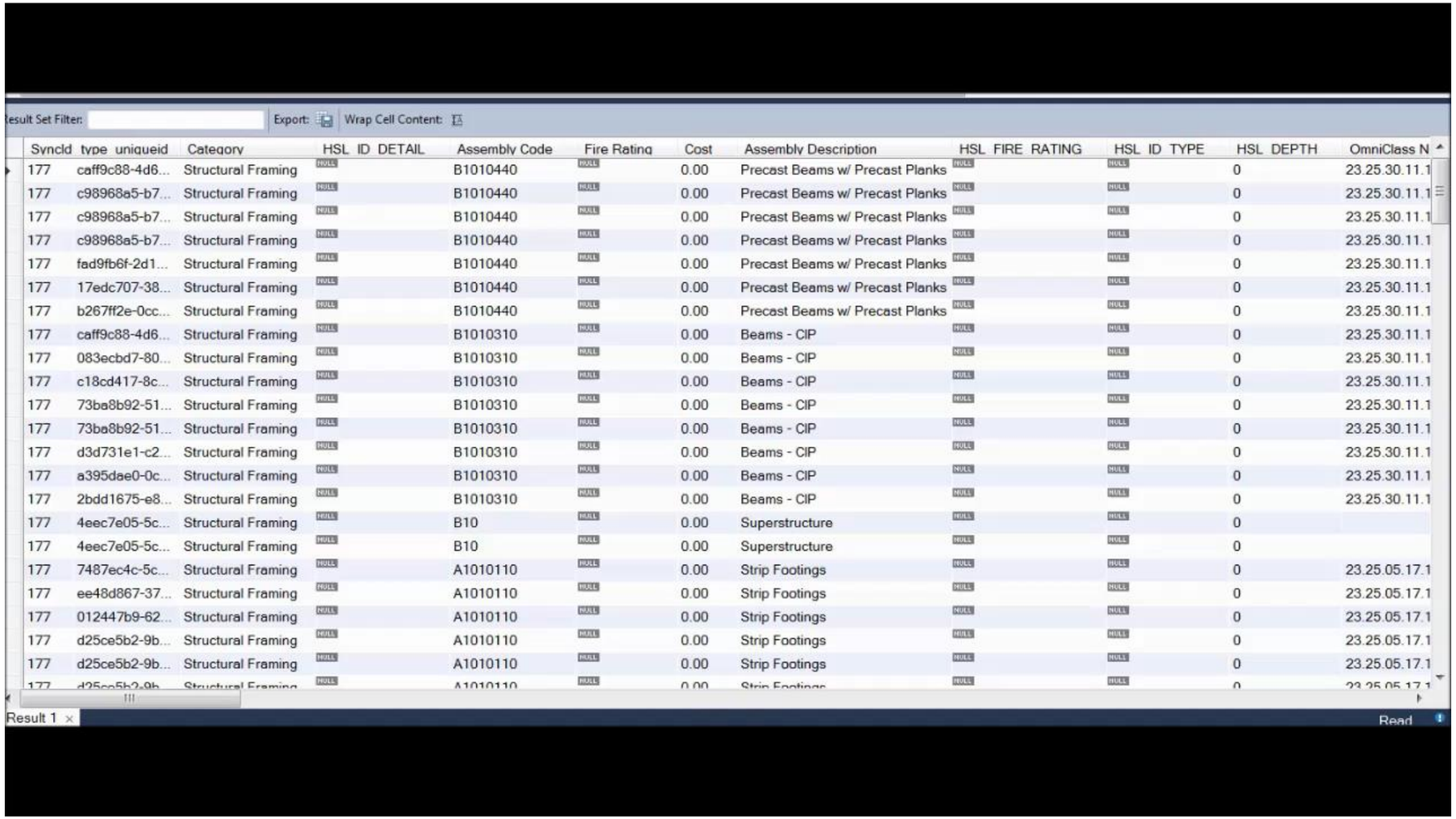
Automatic – Run nightly





‘Enable CADtools Automation’ and then tick ‘CASE Building Analytics for Revit’. A snapshot will be taken each day when a ‘Sync to Central’ occurs.

Using the Data harvester



Result Set Filter: Export: Wrap Cell Content:

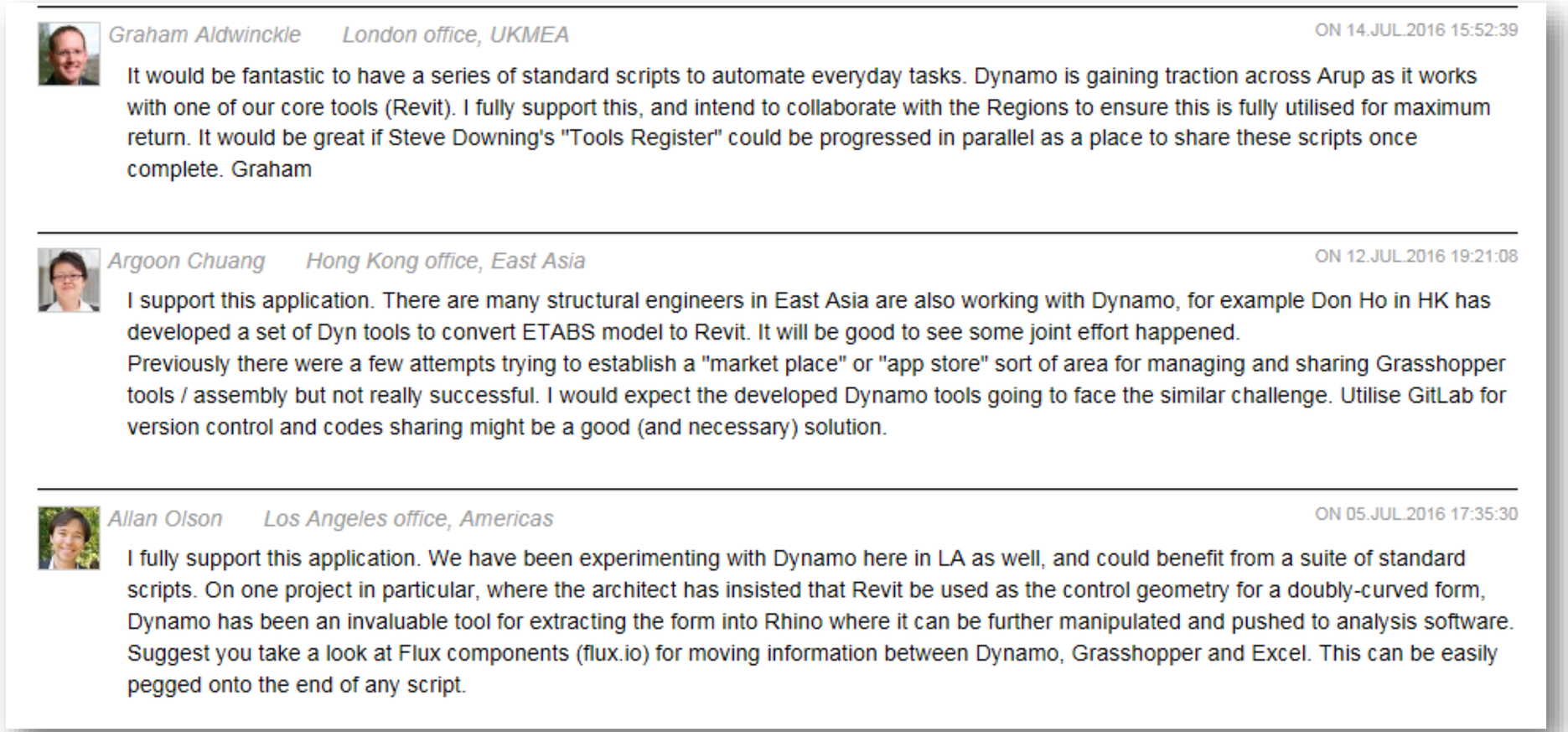
SyncId	type_uniqueid	Category	HSL_ID_DETAIL	Assembly Code	Fire Rating	Cost	Assembly Description	HSL_FIRE_RATING	HSL_ID_TYPE	HSL_DEPTH	OmniClass N
177	caff9c88-4d6...	Structural Framing	NULL	B1010440	NULL	0.00	Precast Beams w/ Precast Planks	NULL	NULL	0	23.25.30.11.1
177	c98968a5-b7...	Structural Framing	NULL	B1010440	NULL	0.00	Precast Beams w/ Precast Planks	NULL	NULL	0	23.25.30.11.1
177	c98968a5-b7...	Structural Framing	NULL	B1010440	NULL	0.00	Precast Beams w/ Precast Planks	NULL	NULL	0	23.25.30.11.1
177	c98968a5-b7...	Structural Framing	NULL	B1010440	NULL	0.00	Precast Beams w/ Precast Planks	NULL	NULL	0	23.25.30.11.1
177	fad9fb6f-2d1...	Structural Framing	NULL	B1010440	NULL	0.00	Precast Beams w/ Precast Planks	NULL	NULL	0	23.25.30.11.1
177	17edc707-38...	Structural Framing	NULL	B1010440	NULL	0.00	Precast Beams w/ Precast Planks	NULL	NULL	0	23.25.30.11.1
177	b267ff2e-0cc...	Structural Framing	NULL	B1010440	NULL	0.00	Precast Beams w/ Precast Planks	NULL	NULL	0	23.25.30.11.1
177	caff9c88-4d6...	Structural Framing	NULL	B1010310	NULL	0.00	Beams - CIP	NULL	NULL	0	23.25.30.11.1
177	083ecbd7-80...	Structural Framing	NULL	B1010310	NULL	0.00	Beams - CIP	NULL	NULL	0	23.25.30.11.1
177	c18cd417-8c...	Structural Framing	NULL	B1010310	NULL	0.00	Beams - CIP	NULL	NULL	0	23.25.30.11.1
177	73ba8b92-51...	Structural Framing	NULL	B1010310	NULL	0.00	Beams - CIP	NULL	NULL	0	23.25.30.11.1
177	73ba8b92-51...	Structural Framing	NULL	B1010310	NULL	0.00	Beams - CIP	NULL	NULL	0	23.25.30.11.1
177	d3d731e1-c2...	Structural Framing	NULL	B1010310	NULL	0.00	Beams - CIP	NULL	NULL	0	23.25.30.11.1
177	a395dae0-0c...	Structural Framing	NULL	B1010310	NULL	0.00	Beams - CIP	NULL	NULL	0	23.25.30.11.1
177	2bdd1675-e8...	Structural Framing	NULL	B1010310	NULL	0.00	Beams - CIP	NULL	NULL	0	23.25.30.11.1
177	4eec7e05-5c...	Structural Framing	NULL	B10	NULL	0.00	Superstructure	NULL	NULL	0	
177	4eec7e05-5c...	Structural Framing	NULL	B10	NULL	0.00	Superstructure	NULL	NULL	0	
177	7487ec4c-5c...	Structural Framing	NULL	A1010110	NULL	0.00	Strip Footings	NULL	NULL	0	23.25.05.17.1
177	ee48d867-37...	Structural Framing	NULL	A1010110	NULL	0.00	Strip Footings	NULL	NULL	0	23.25.05.17.1
177	012447b9-62...	Structural Framing	NULL	A1010110	NULL	0.00	Strip Footings	NULL	NULL	0	23.25.05.17.1
177	d25ce5b2-9b...	Structural Framing	NULL	A1010110	NULL	0.00	Strip Footings	NULL	NULL	0	23.25.05.17.1
177	d25ce5b2-9b...	Structural Framing	NULL	A1010110	NULL	0.00	Strip Footings	NULL	NULL	0	23.25.05.17.1

Result 1 Read

- "*Our engineer on a 60metre (200ft), 2 span, internal abutment, reinforced concrete, highway bridge will know throughout their design effort what the Arup norm is for the % of reinforcing steel in the deck*“

Parametric Modelling for Everyday Structures using Dynamo for Revit – Innovation Investment

- Global Sharing of Knowledge and Skills



Graham Aldwinckle *London office, UKMEA* ON 14.JUL.2016 15:52:39

It would be fantastic to have a series of standard scripts to automate everyday tasks. Dynamo is gaining traction across Arup as it works with one of our core tools (Revit). I fully support this, and intend to collaborate with the Regions to ensure this is fully utilised for maximum return. It would be great if Steve Downing's "Tools Register" could be progressed in parallel as a place to share these scripts once complete. Graham

Argoon Chuang *Hong Kong office, East Asia* ON 12.JUL.2016 19:21:08

I support this application. There are many structural engineers in East Asia are also working with Dynamo, for example Don Ho in HK has developed a set of Dyn tools to convert ETABS model to Revit. It will be good to see some joint effort happened.
Previously there were a few attempts trying to establish a "market place" or "app store" sort of area for managing and sharing Grasshopper tools / assembly but not really successful. I would expect the developed Dynamo tools going to face the similar challenge. Utilise GitLab for version control and codes sharing might be a good (and necessary) solution.

Allan Olson *Los Angeles office, Americas* ON 05.JUL.2016 17:35:30

I fully support this application. We have been experimenting with Dynamo here in LA as well, and could benefit from a suite of standard scripts. On one project in particular, where the architect has insisted that Revit be used as the control geometry for a doubly-curved form, Dynamo has been an invaluable tool for extracting the form into Rhino where it can be further manipulated and pushed to analysis software. Suggest you take a look at Flux components (flux.io) for moving information between Dynamo, Grasshopper and Excel. This can be easily pegged onto the end of any script.

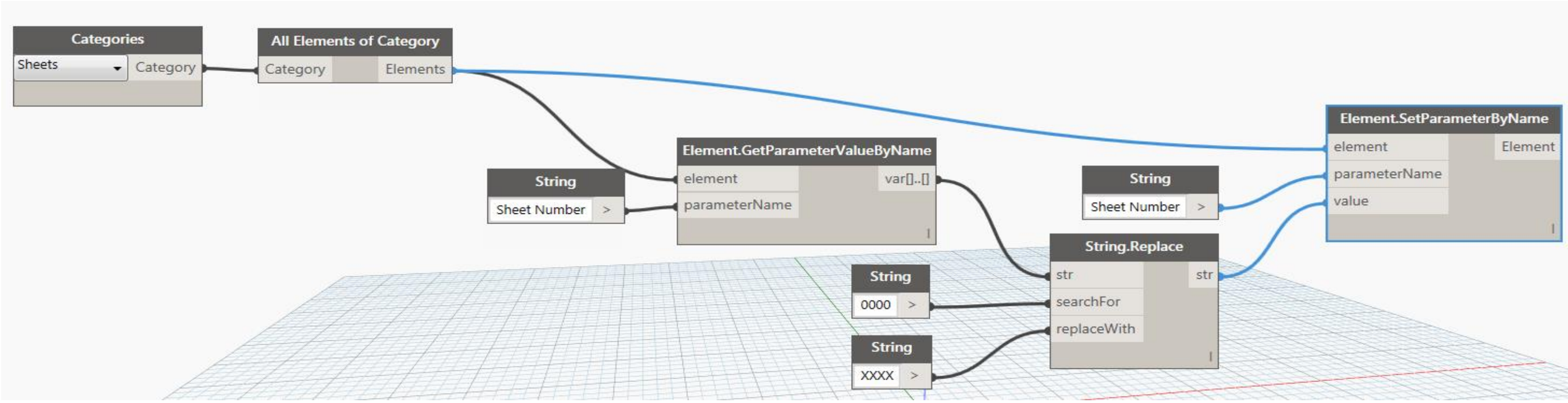
Parametric Modelling for Everyday Structures using Dynamo for Revit – Sample of Scripts

- Use Architectural Model to set up levels, grids, views etc. at start of project
- Automate generation of sections on grid, beam elevations, wall elevations
- Compare Revit geometry with analysis geometry
- Create openings in structure for MEP requirements
- Using Excel as a database for engineering excel calcs to update Revit and eliminate mark ups
- Limcon connection design, export to excel, map parameters to detail components
- Secant pile automation based on boundary line
- Pile length calculator based on rock strata from topography
- Model Steel beams flat and then align structural members to a surface to avoid use of reference planes
- Align similar views on sheets
- Sheet Number Editor Script

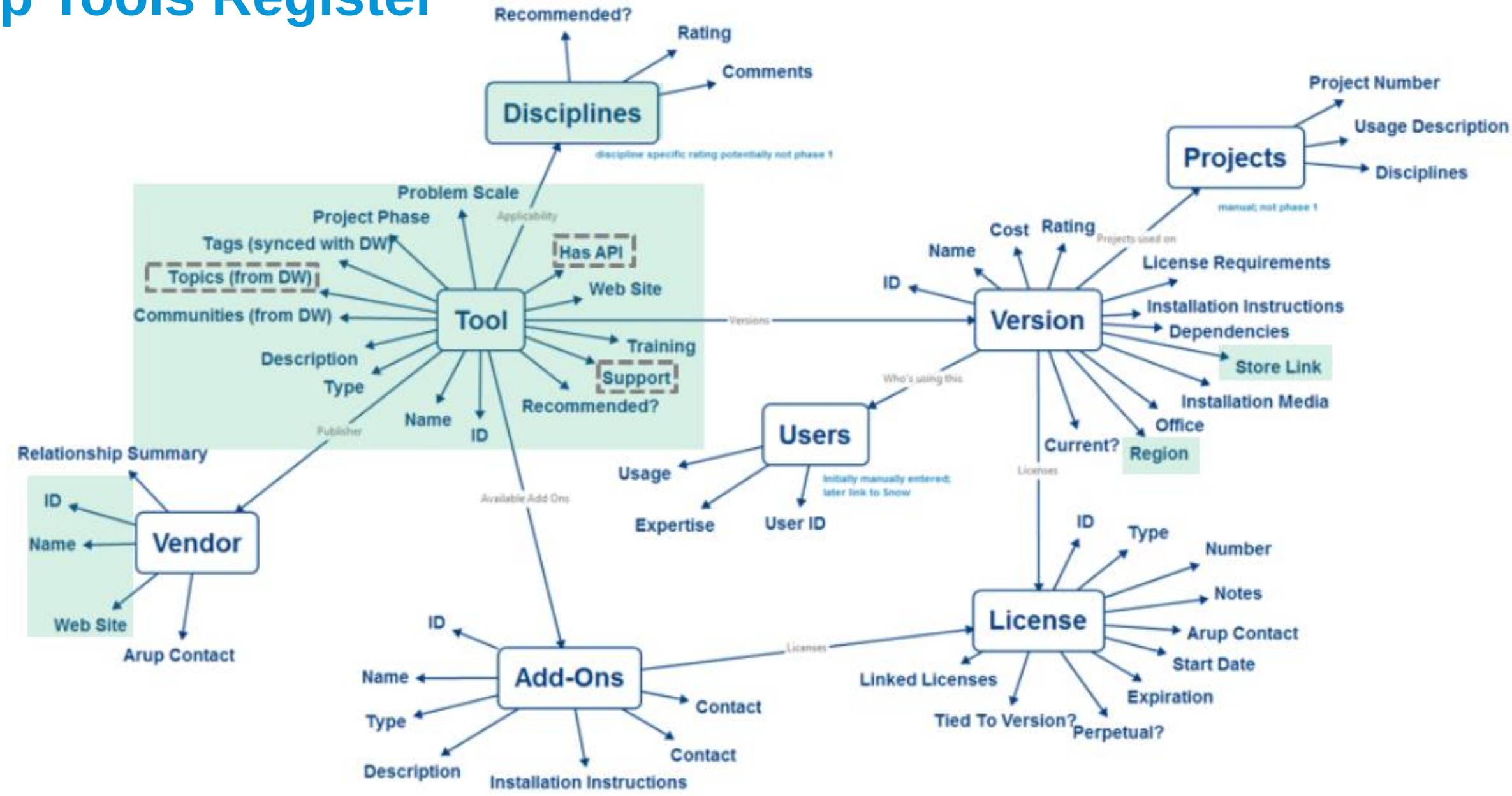
Sheet Number Editor Script

Find and replace all drawing numbers containing ‘0000’ with ‘XXXX’

Collect Revit Drawing numbers → Interrogates the drawing list (to find all 0000 drawings) → Replaces all ‘0000’ with ‘XXXX’ within Revit drawing numbers



Arup Tools Register



Sharing Knowledge

Welcome to the Arup Dynamo Library

Here you can find links to Dynamo scripts which people have shared by uploading to \\cadtools\cadtools\Miscellaneous\Dynamo\Scripts

You can quickly search the index using the search box below, and then open the folder containing the .DYN files, plus any documentation

Instructions on adding scripts to the library

Search: Giovanni

Name	Author	Works with	Requires	Date	Purpose
Secant Piles Creator (file://cadtools/cadtools/Miscellaneous/Dynamo/Scripts/Sandbox/GBrogiolo/Secant%20Piles%20Creator)	Giovanni Brogiolo	Dynamo 0.8.2 or Dynamo 1.2.0	Standard Dynamo Built-in Packages	2016-09-21	Places secant p families at spec distance along line.
Dimension Gridlines (file://cadtools/cadtools/Miscellaneous/Dynamo/Scripts/Sandbox/GBrogiolo/Dimension%20Gridlines)	Giovanni Brogiolo	Dynamo 0.8.2	Standard Dynamo Built-in Packages	2016-08-18	Place dimensio between gridlin (similar to T4R
Grid Bubble End (file://cadtools/cadtools/Miscellaneous/Dynamo/Scripts/Sandbox/GBrogiolo/Grid%20Bubble%20End)	Giovanni Brogiolo	Dynamo 1.2.0 and Revit 2015 or newer	Standard Dynamo Built-in Packages	2016-08-22	Swap the Grid End side of sel gridlines

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