AUTODESK UNIVERSITY

ES20821

Digital Craftsmanship of a Half-Size Eiffel Tower Replica

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Learning Objectives

- Appreciate the power of Revit
- Learn how we pushed Revit to its limits
- Discover the process from model to site
- Discover lessons learned on the project

Description

The completion of the world's first true Eiffel Tower replica in Macau was a culmination of inventive digital craftsmanship by Aurecon's modelers and engineers in Thailand and Hong Kong, supported by modern technology. No intricate detail was left unturned right from the start, making the work of others down the construction chain much easier, and exceeding expectations at all levels. This design intent model was truly a triumph to all involved.

The tower was topped out in late 2015, and the half-size replica of the Eiffel Tower is now a notable inclusion of the Macau skyline.

Your AU Expert

A Building Information Modeling (BIM) manager with over 30 years' experience on civil and structural projects, Marty Collins has been based in Asia for over 20 years working on many major projects.

With the introduction of BIM (Revit software), Marty has been at the forefront of its development throughout Aurecon, and he's been involved with the development and training of BIM modelers in Asia for Aurecon.

Marty has 8 years' experience in the management of BIM (Revit software and Navisworks software) implementation on building projects, including management of up to 30 structural/MEP (mechanical, electrical, and plumbing) Revit software modelers, also coordinating the engineering design team.

Marty has an understanding of the requirements of projects drawn from his on-site experience in Bangkok and elsewhere. He communicates with teams in different locations to optimize the result, and provides management for all BIM-related elements of the projects.

Appreciate the power of Revit and learn how we pushed Revit to its limit.

File Management

237274 Eiffel_STR 2014_Central.rvt	325,220 KB
237274 Eiffel_STR Link Bridge_2014.rvt	45,300 KB
237274 Eiffel_STR SINGLE LEG_2014.rvt	335,716 KB
237274 Eiffel_STR stair.rvt	25,244 KB

Main model and all Document drawings are in Central file with the models listed before linked into this model.

Link Bridge file

Link bridge part model in this file and linked to Central file

Single Leg file

Quarter of Tower model in this file and linked to Central file

Stair file

Stair model and stair support are in this file and linked to Central file

The models were split in this fashion to allow for different geographies in the company to work on the different parts of the project at any one time. An example of this would be that initially the link bridge model was started in our Hong Kong office.

This project was before our company had access to Revit server, Bim360 and Collaboration for Revit.

Modelling planning

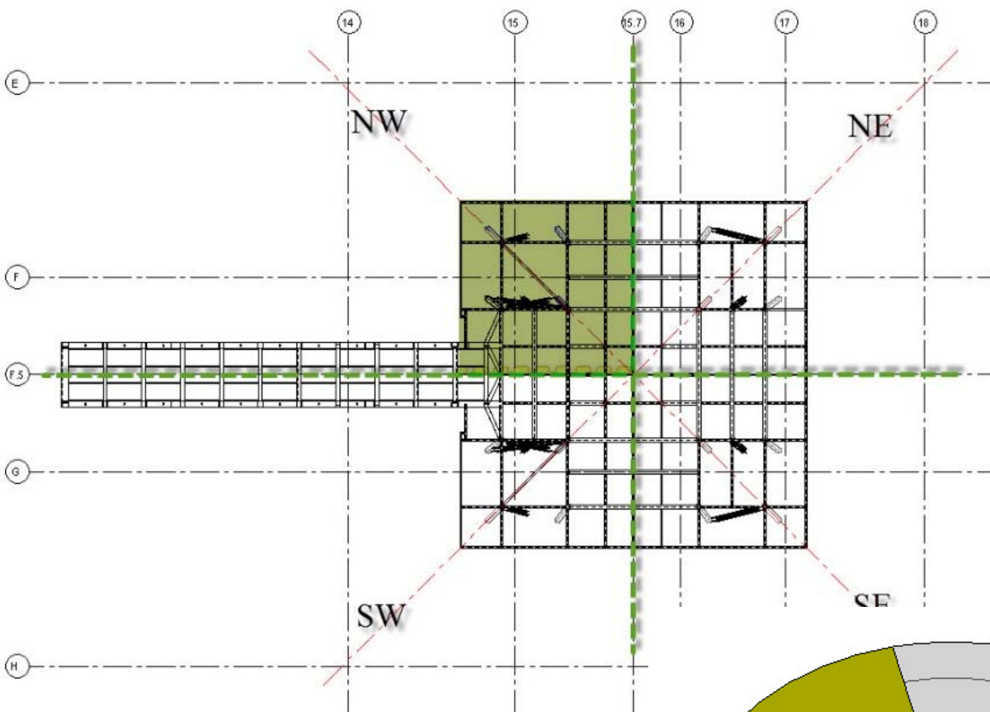
Modelling Part of Quarter

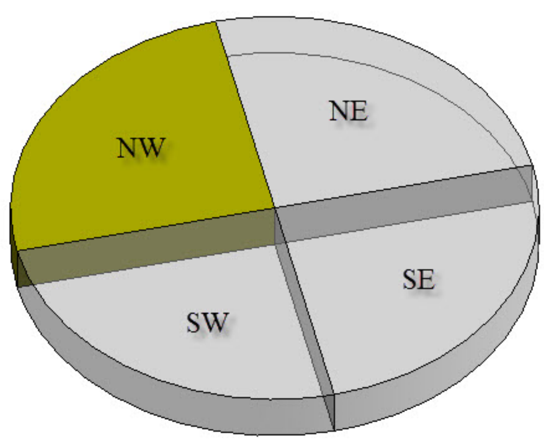
Each side of the Eiffel Tower are quite similar except Link Bridge joined to one side

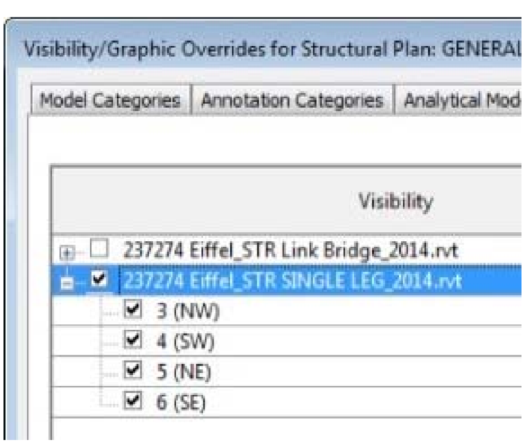
The best way to model, was to model only one quarter, this cut our modelling time down immensely, we then used shared locations to produce a full model.

Share location site

- Quarter of Tower model in this file then link to Central file
- Duplicate with Mirror for each quarter of tower
- Setup Shared Site in the leg model



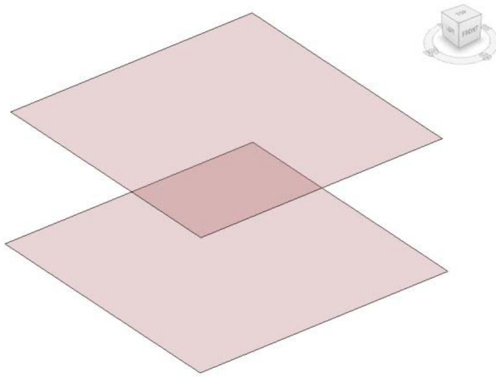


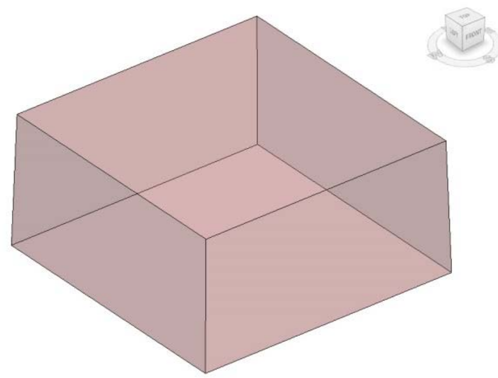


Solid Mass

In Revit and other 3D software you need reference plane when working, for the Eiffel Tower the Mass model is good to use for referencing columns and framing beams. To do this, do the following steps

- Create plane from Plan View for Bottom and Top Plane
- Then create solid mass from Bottom and Top Plane
- Solid Mass surface can be used for Work plane
- Lock top and bottom plane to Reference Level at elevation view
- And do the same process for each level

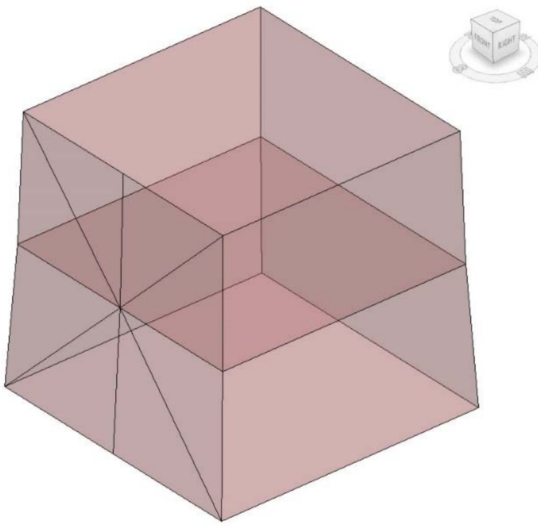


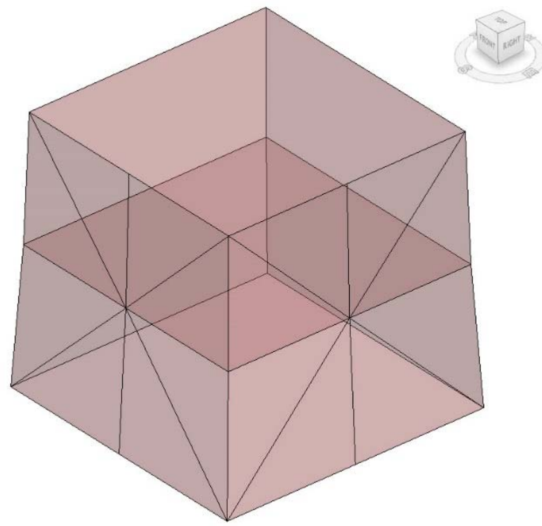


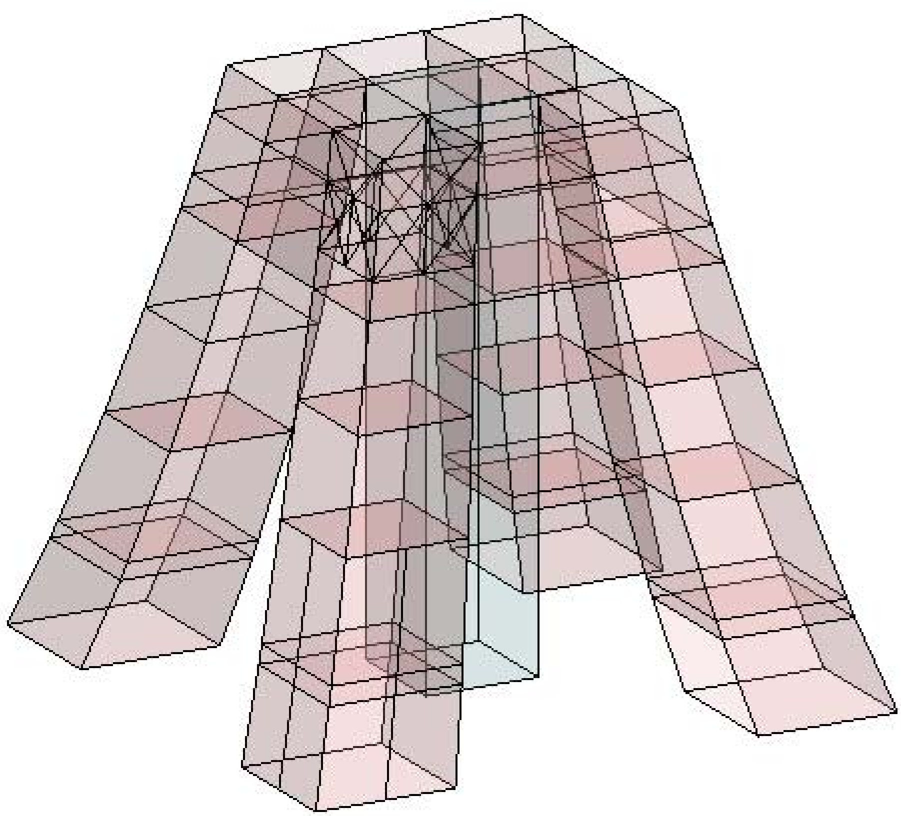
Add Mass line

Edit Mass model and add Mass line used for guide of Columns and Lattice Beams

Once the planes and nodes lines were established, we were able to set the work plane required and then pick the guidelines to start building the model up.

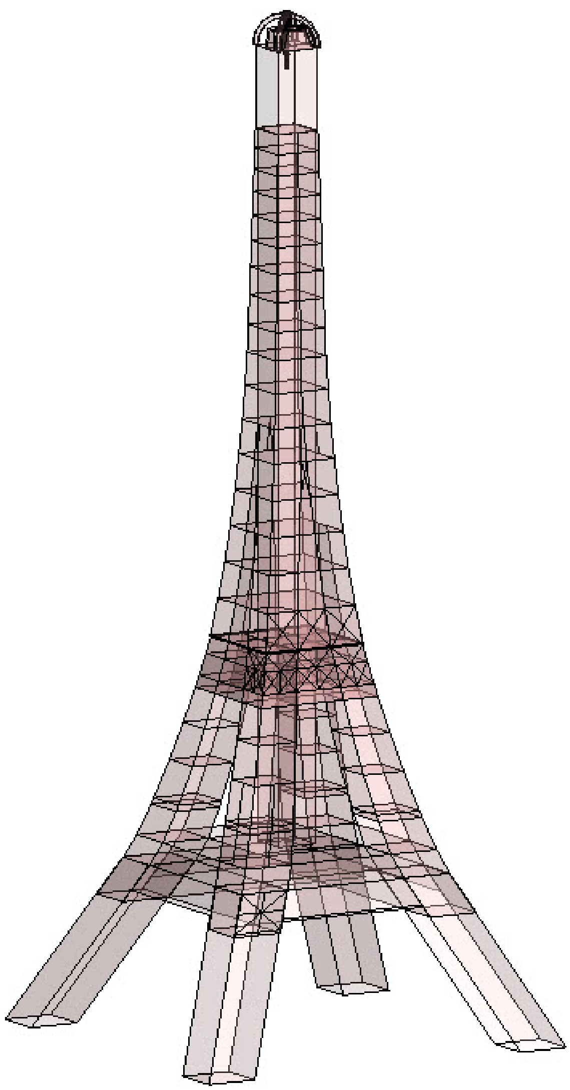






Here is the finished mass model alongside the finished model.

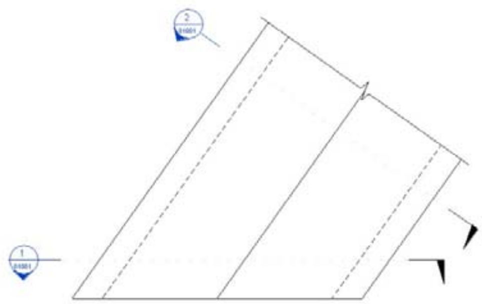
Each horizontal plane you can see illustrated below represents a change of angle. There are approximately 30 of these going up the tower. This caused the geometry of each level to be slightly different, in terms of column sections, angles of bracing and connection configurations.

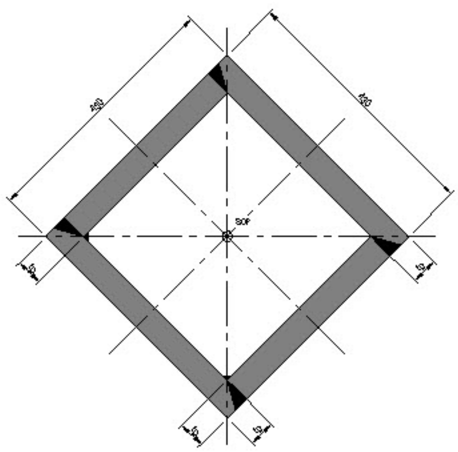


Main Columns

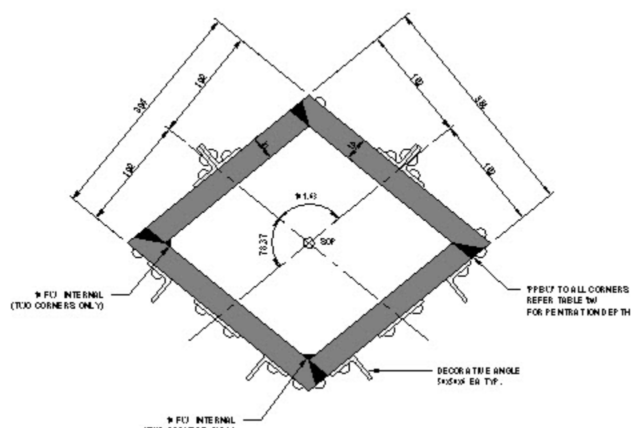
Built-Up Columns

Main columns of Eiffel Tower are not square when cut in true projection and need to be square when cut in horizontal projection, every level we had to provide a new built up column section to satisfy the different slopes. Because of the facetted nature of the model vertical the columns were modelled in place. Doing it this way, it was a lot easier to get the geometry correct. Normally we strive to create families, but in this case modelling in place was the best and easiest way. For each facetted section all four columns were modelled in place at the same time, ensuring the same geometry was achieved.

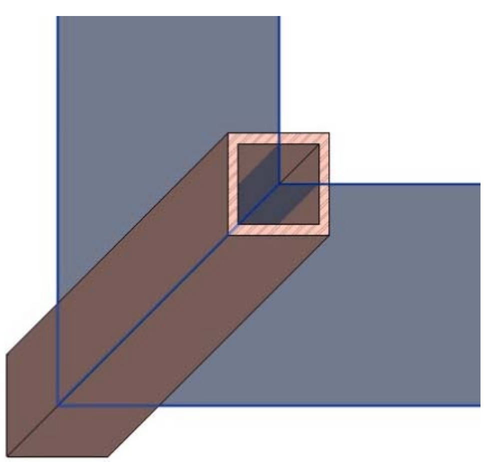


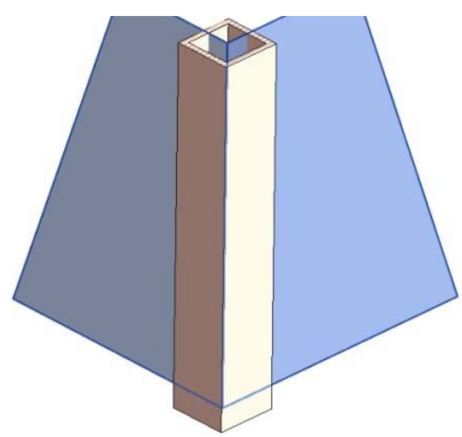


SECTION 1 HORIZONTAL PROJECTION
1 : 5



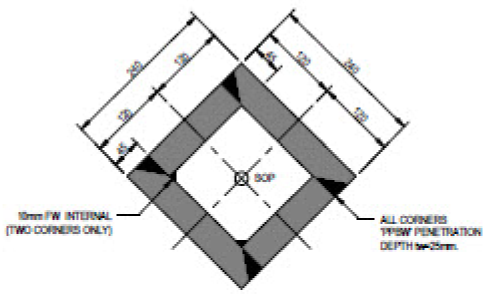
SECTION 2 TRUE PROJECTION
1 : 5



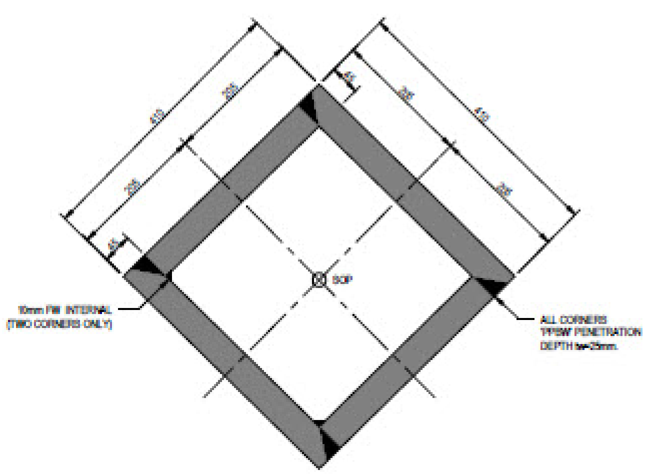


Built-Up Reduced size of Columns

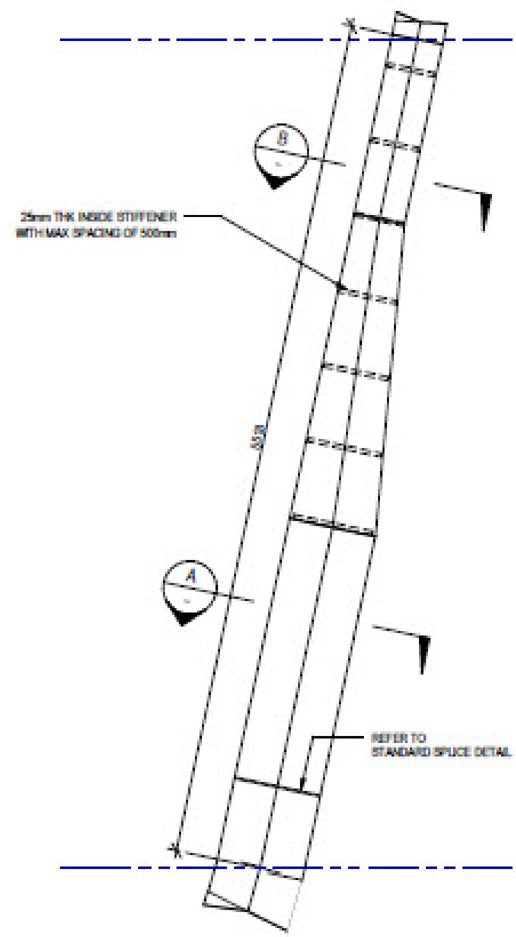
When Main column sizing reduced at middle and top of tower, we had to provide column details for shown set out dimensions and angle



VP4-13A SECTION B



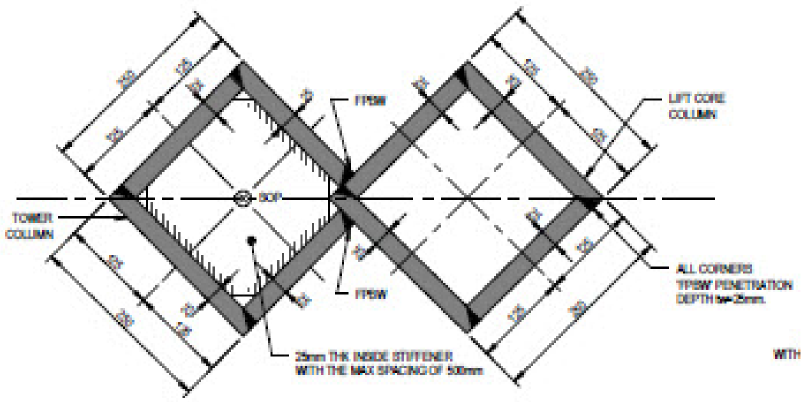
VP4-13A SECTION A



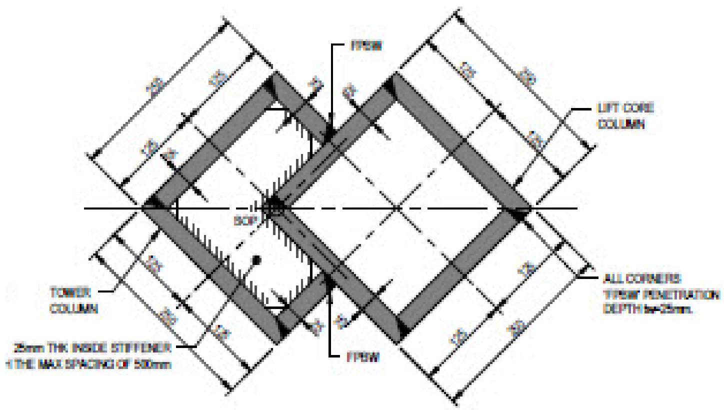
VP4-13A ELEVATION
1 : 25

Built-Up Combined Columns

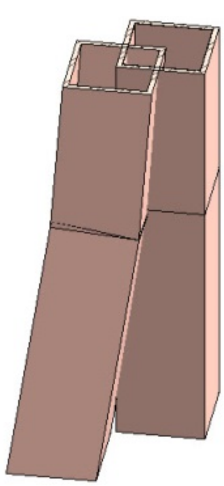
We also had to provide column details for where Main columns joined with vertical columns, again this was also modelled in place.

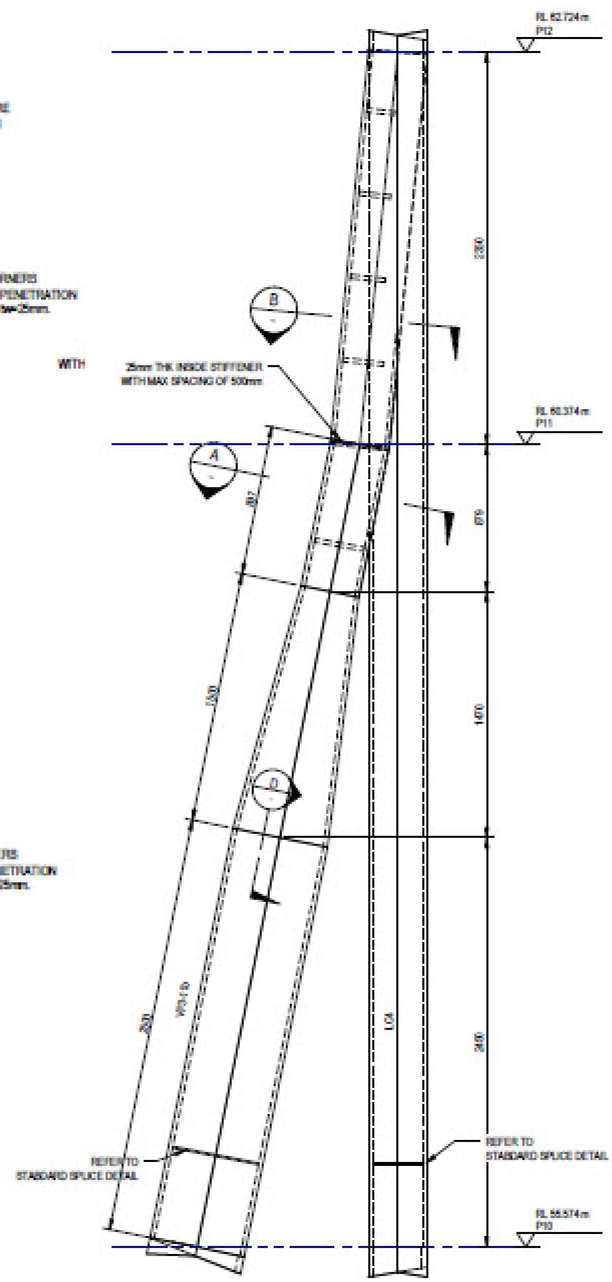


VP3-11C SECTION A



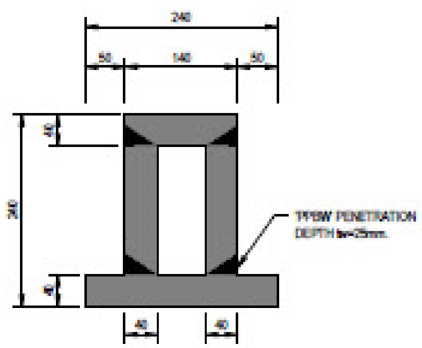
VP3-12C SECTION B

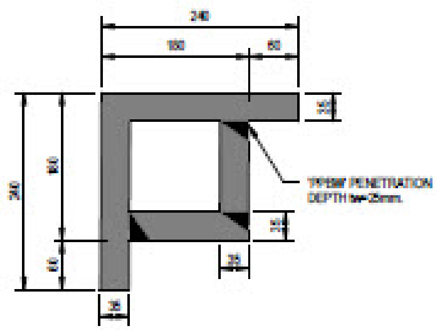


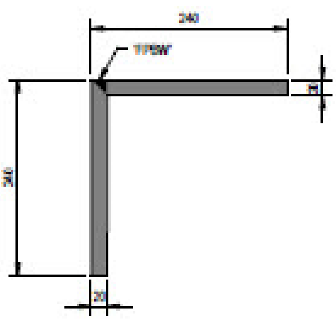


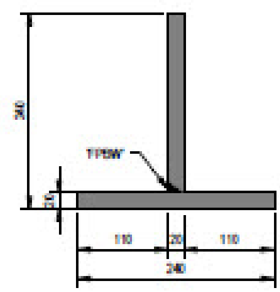
Built-Up Non-Standard Columns

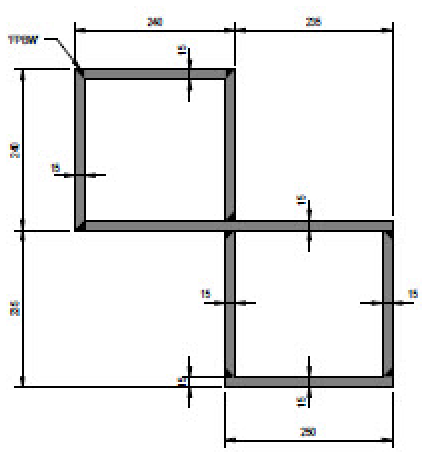
Various column shapes were modelled as shown below

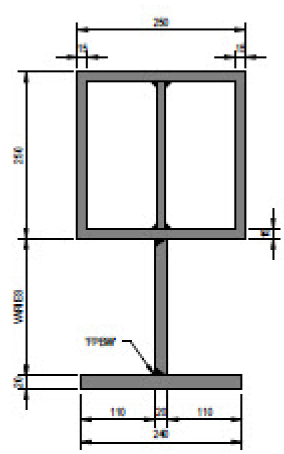








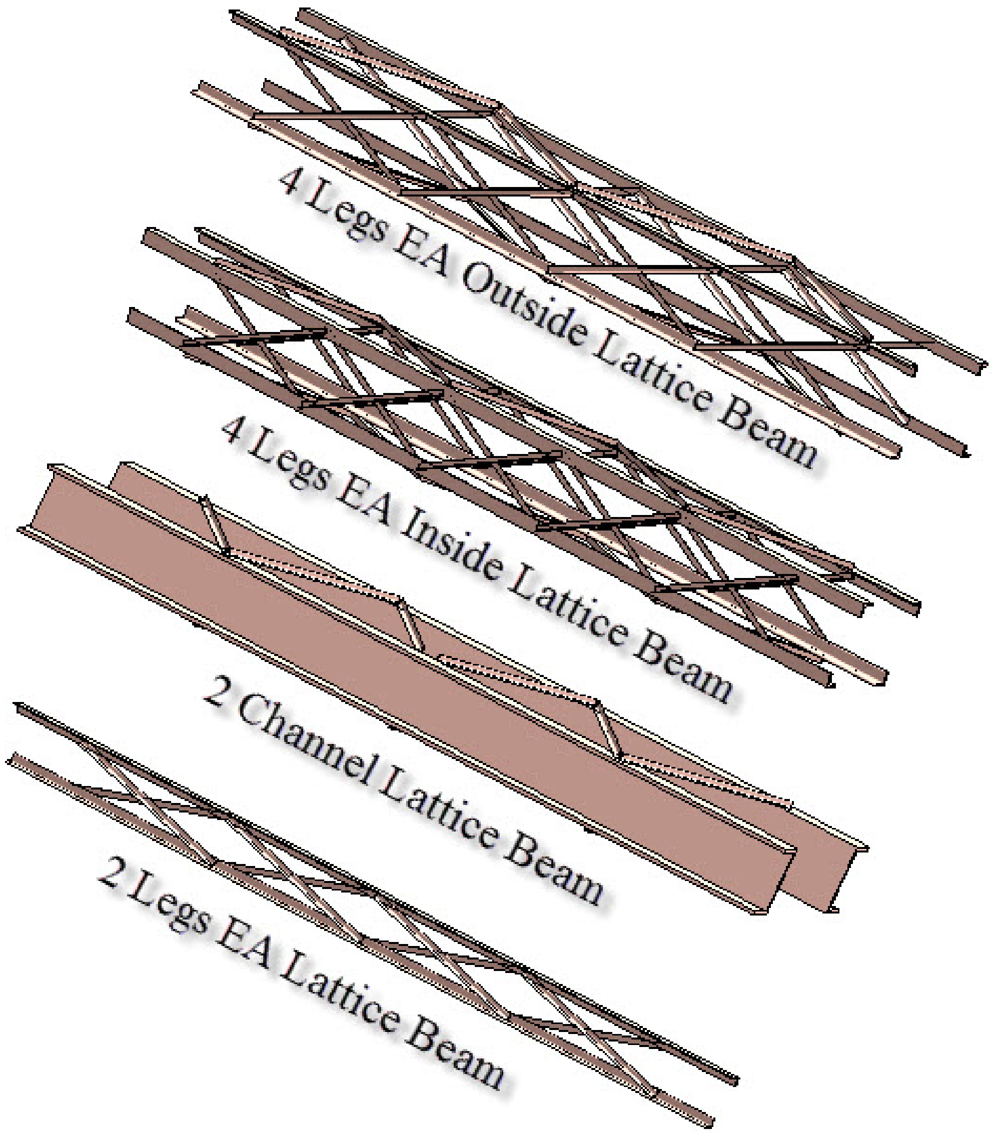




Framing Beams

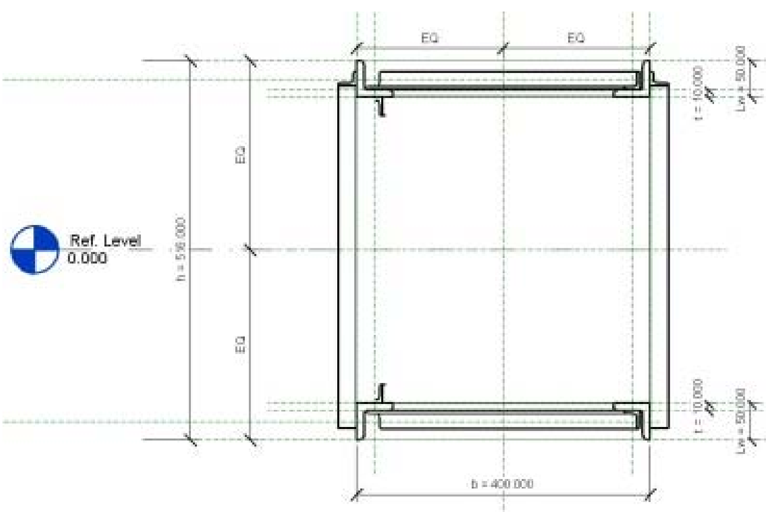
Create families for Lattice Beams and Special Beams

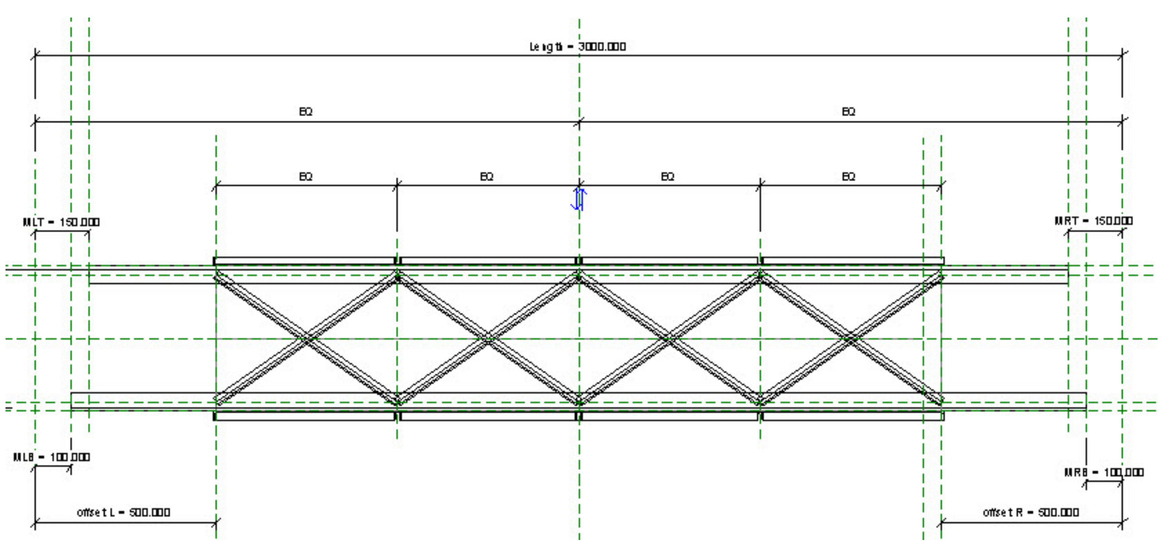
There were many different lattice types required on the project to obtain the look of the original and also to satisfy the design. Below are some examples of the lattice beams.



For the lattice beams we made families using the structural faming template, these were fully controllable so we could go from node to node and the members would flex accordingly.

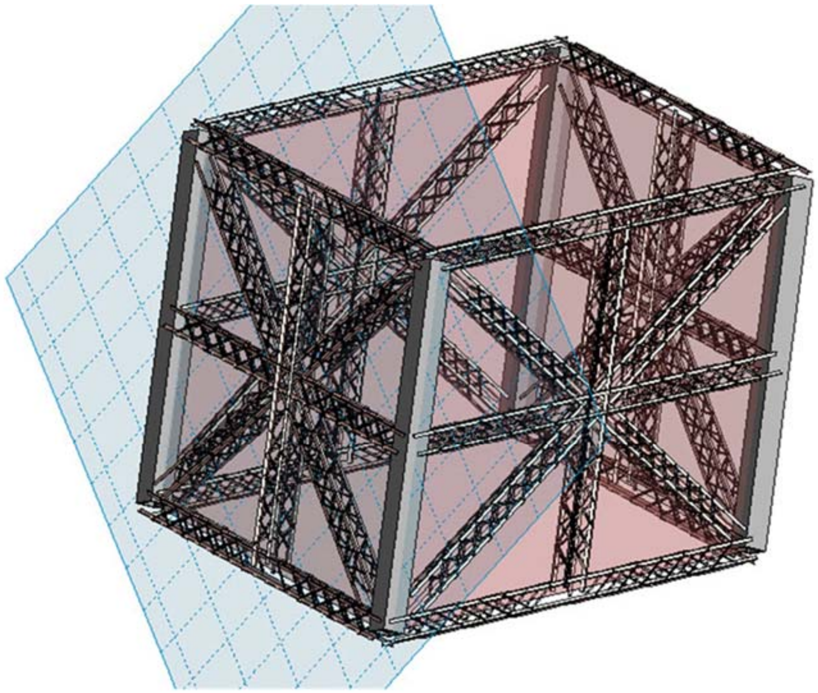
Parameters were used to control member ends and spacing of the lattice bays.

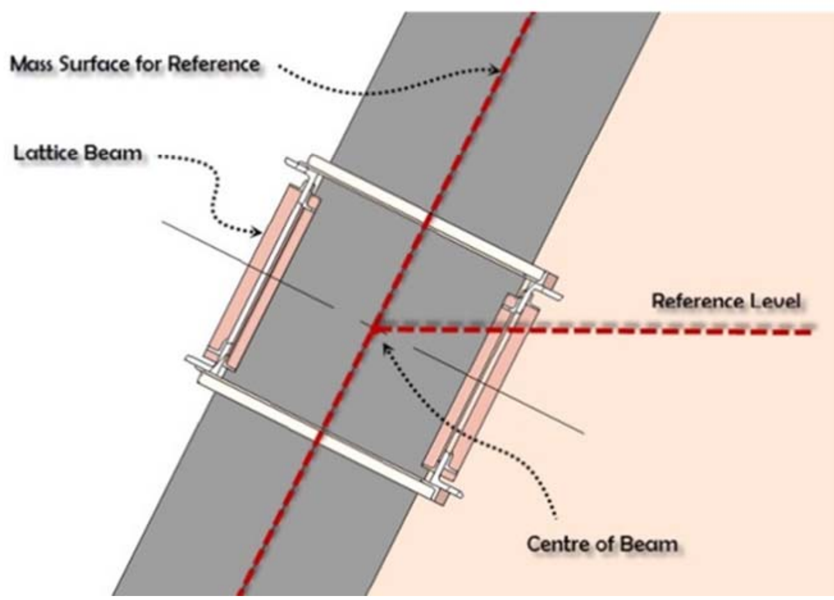




Framing Beams placement procedure.

- Set Work Plane to Mass surface for Framing Reference
- Centre of Beams is Mass Line
- Fixed Node point with Mass Line
- Adjust parameter each end of beam to match with connection plate details





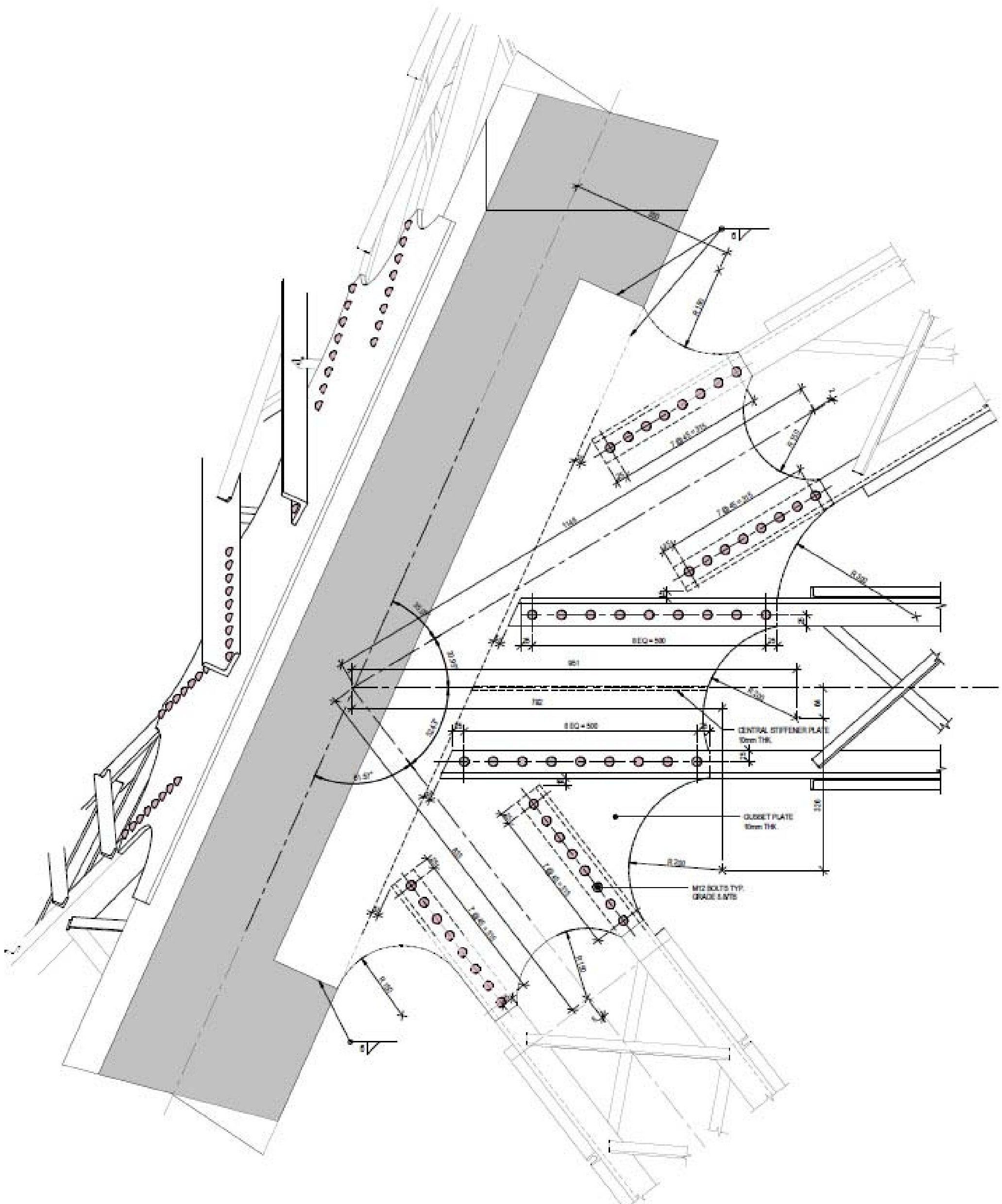
Connection Details

Create families for connection at Lower levels P1-P4

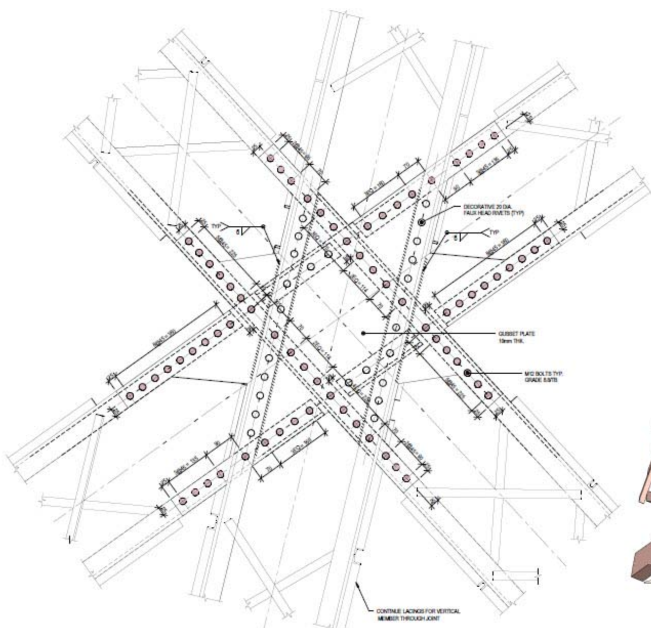
Due to the geometry the tower changing at basically every level it was apparent that we could not use families for this part of the model.

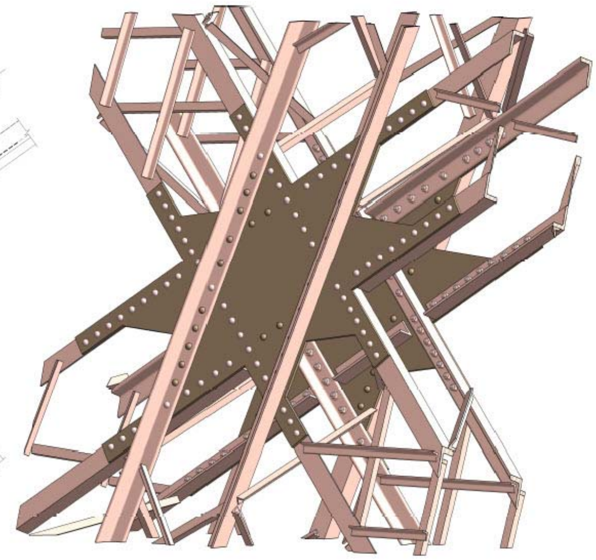
We modelled all the connection plates, in place (including the bolting arrangements). Because we had the centre line geometry of the columns and lattice beams in place in the model already it was just a case of modelling these plate and bolt arrangements to suit this geometry.

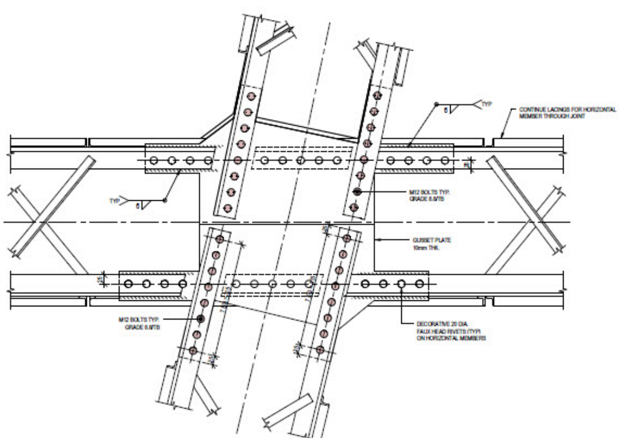
If we had of tried transpose this already in place geometry to create the families required it would have been very challenging and awkward trying establish the special geometry in the tower to the families.

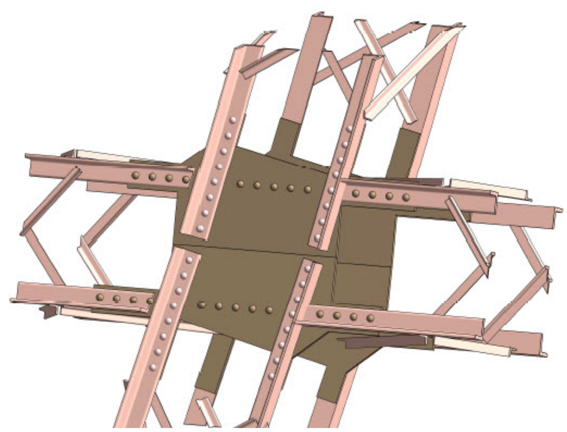


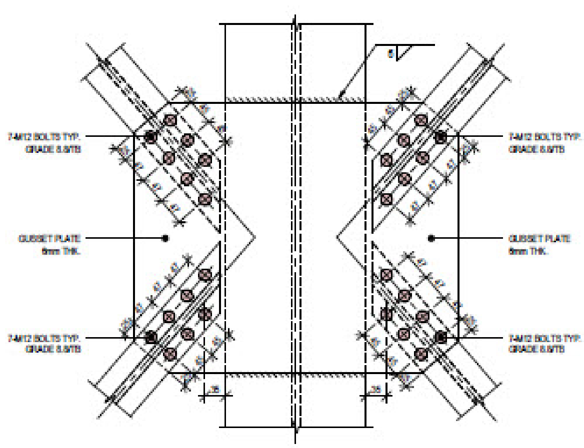
Create Model in place for connections at upper Levels

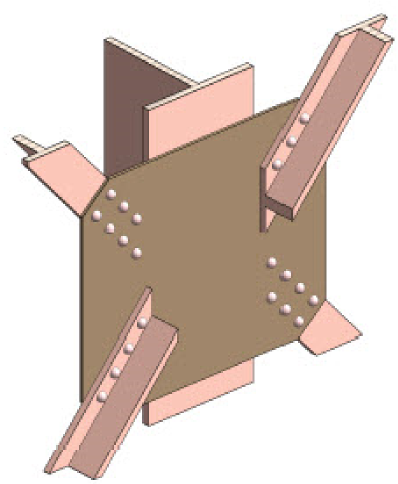






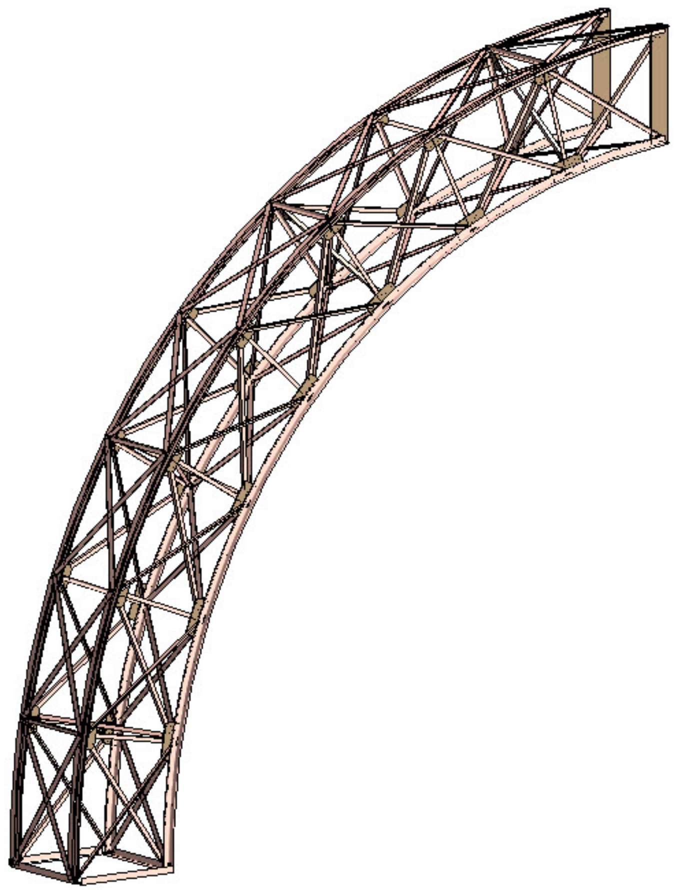


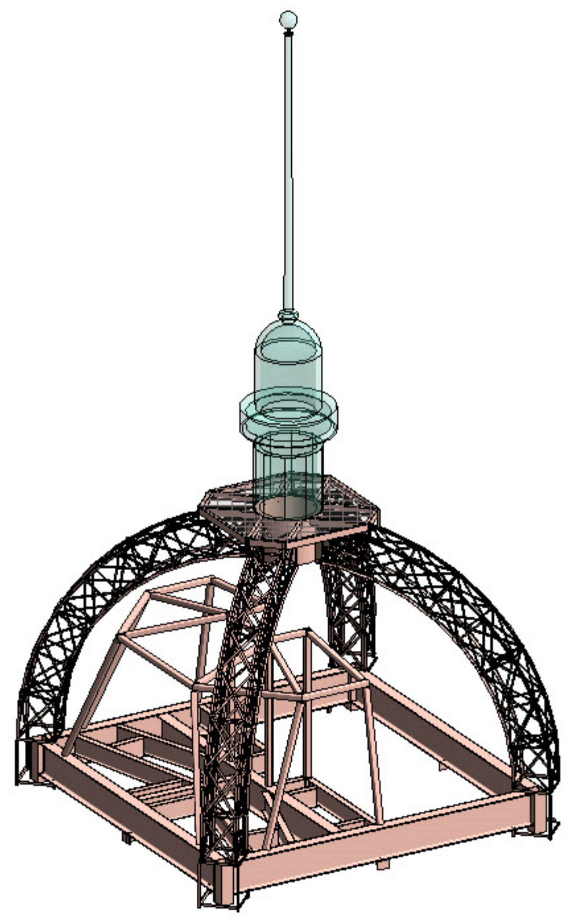


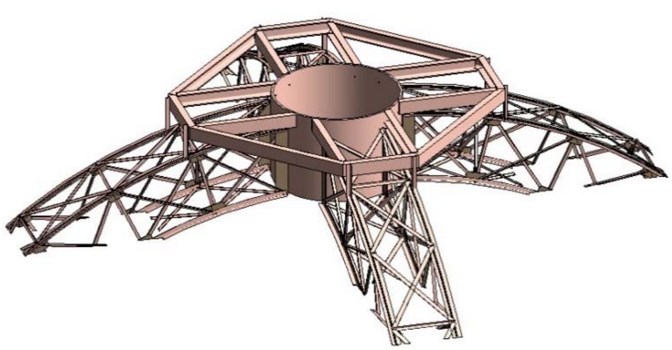


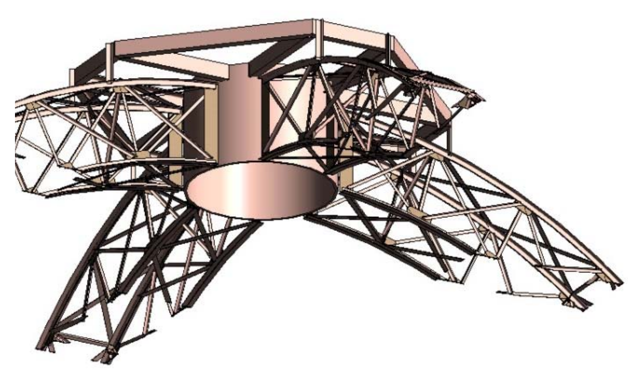
Top roof Structure

A lot of upper structure was again modelled in place due to the nonstandard geometry.









Modelling summary

To summarize, Revit performed very well, we believe we pushed the programme to the limits and our modellers went somewhere they had not been before in terms of the techniques they used.
With the complicated nature of the geometry it was like nothing we had attempted before. Prior to modelling and documenting this great structure, we had only done traditional building structures that Revit is usually associated with. This just proved to us that Revit can and does do the more difficult types of modelling.

Furthermore with the newer technology with have at our disposal now the likes of dynamo and so on. Doing these sorts of things are getting easier and easier as each version of Revit is released.

The future is an exciting, hopefully with the way Revit is going that there will be no need to jump to other supplier's programmes to develop construction models and the Autodesk suite will be up to do everything required. From concept, to design intent, to production models fit for construction.

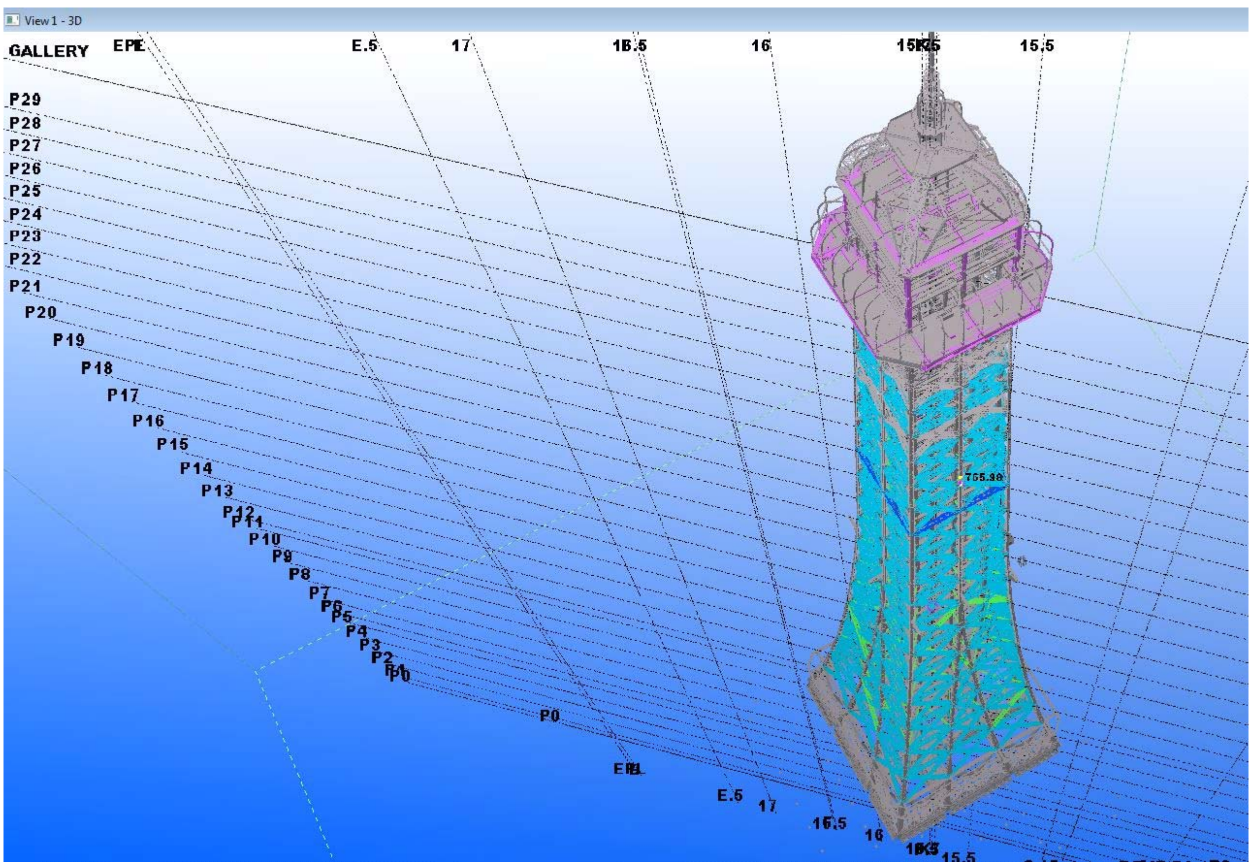
From Design intent model to site

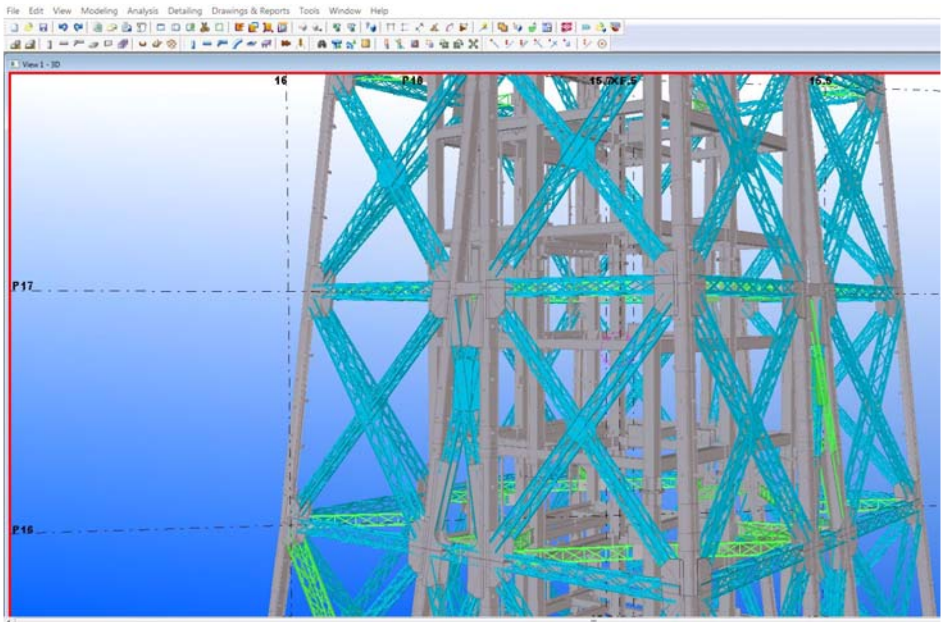
Although the transition from our Design intent model to construction model was not entirely seamless, our exported IFC model from Revit served the construction model detailers well.

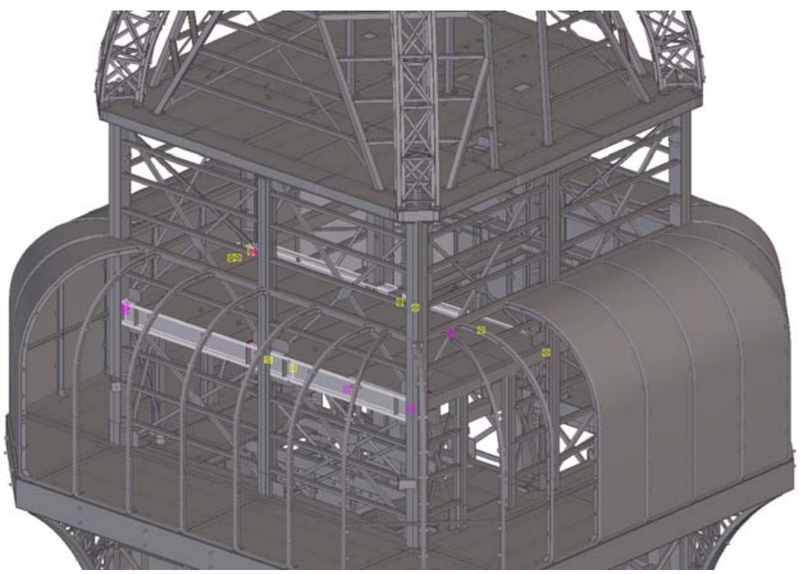
Using our IFC model along with our PDF construction drawings the feedback we got was it speed their process up.
This was because they used our model as a guide for their geometry, instead of them building the model from scratch they had a model they could trust in terms of geometry and simply modelled on over ours.

Obviously the Tekla model was far more detailed than our design intent model. It had to be for the purpose it served.

The Tekla Model

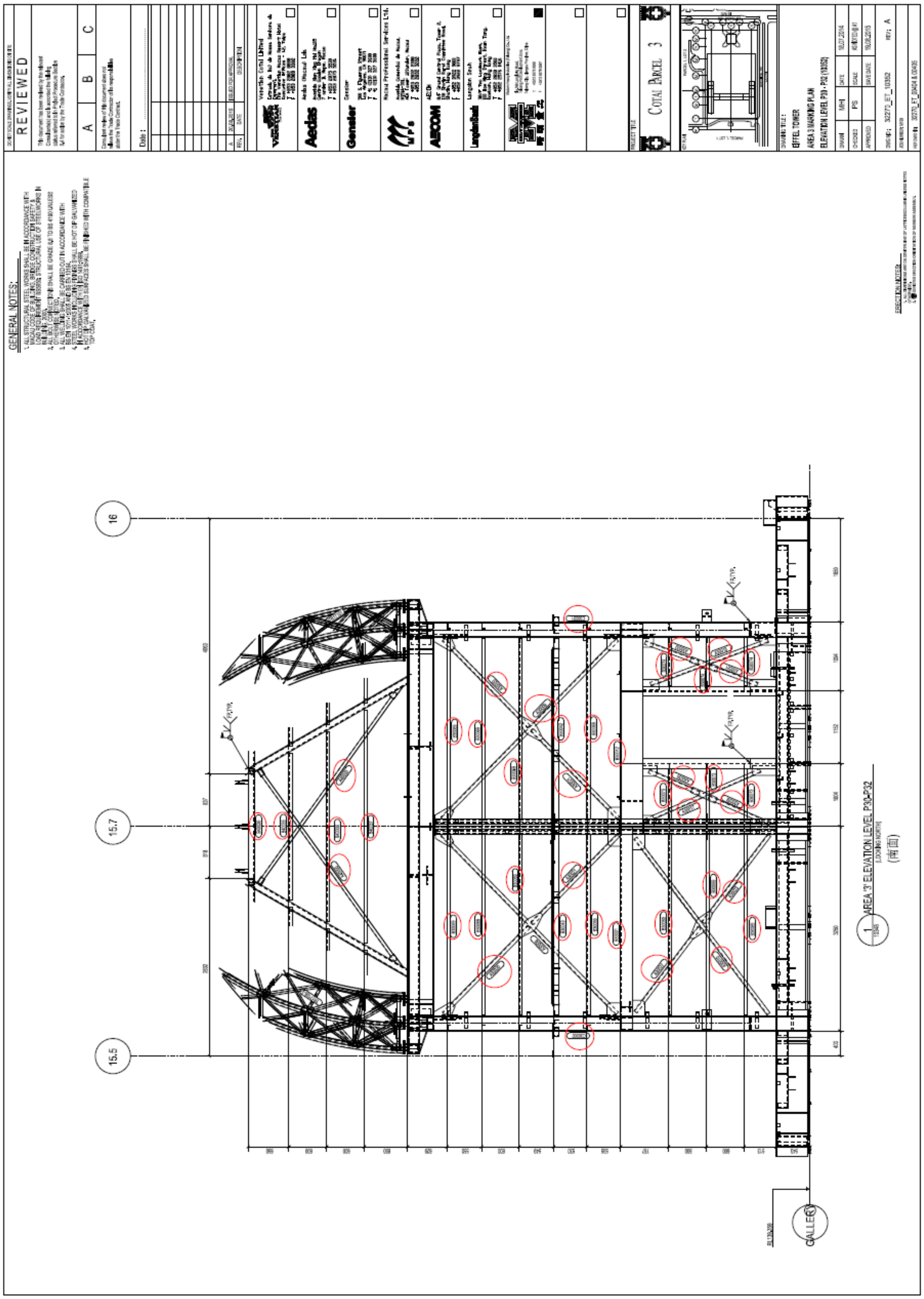


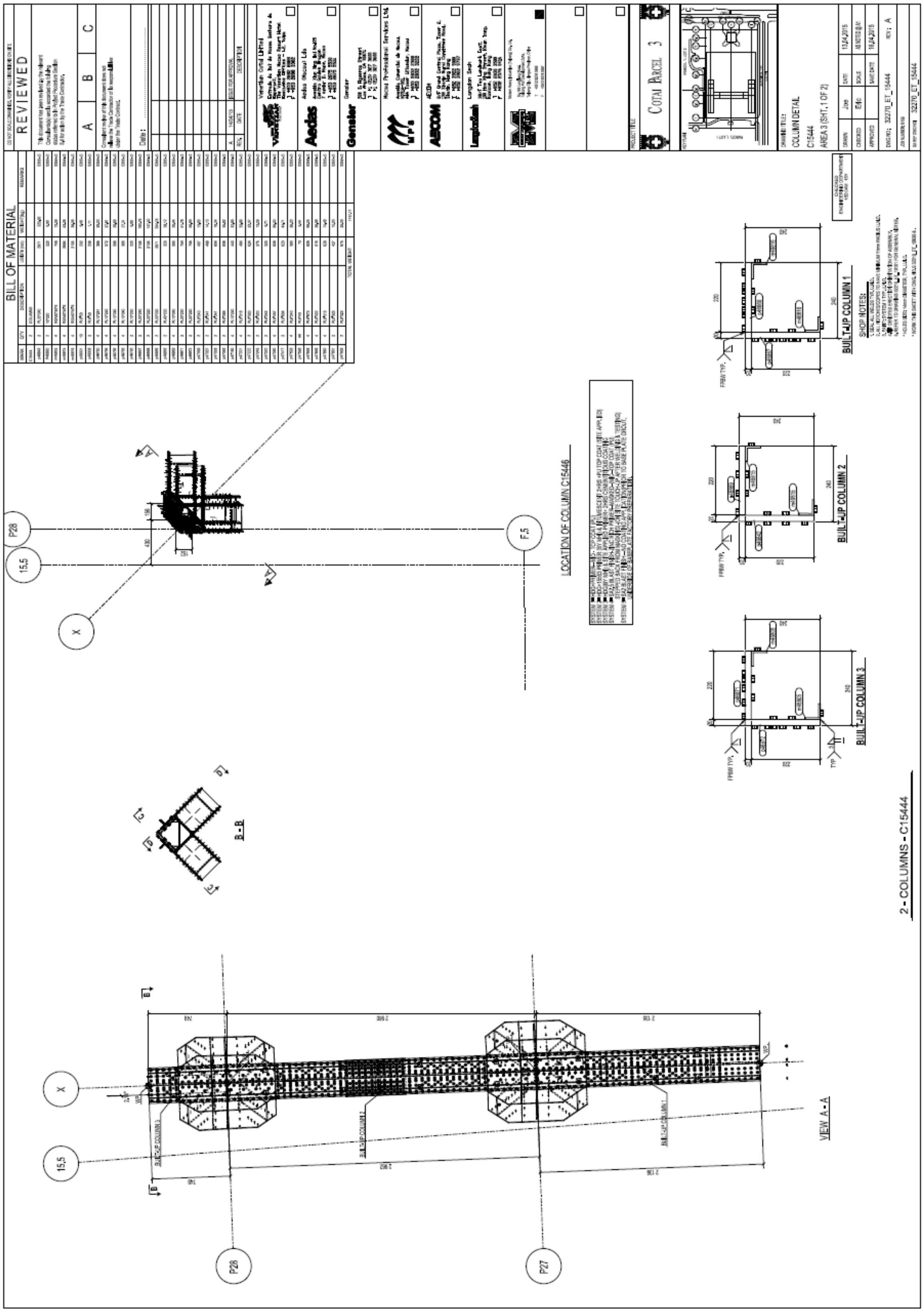




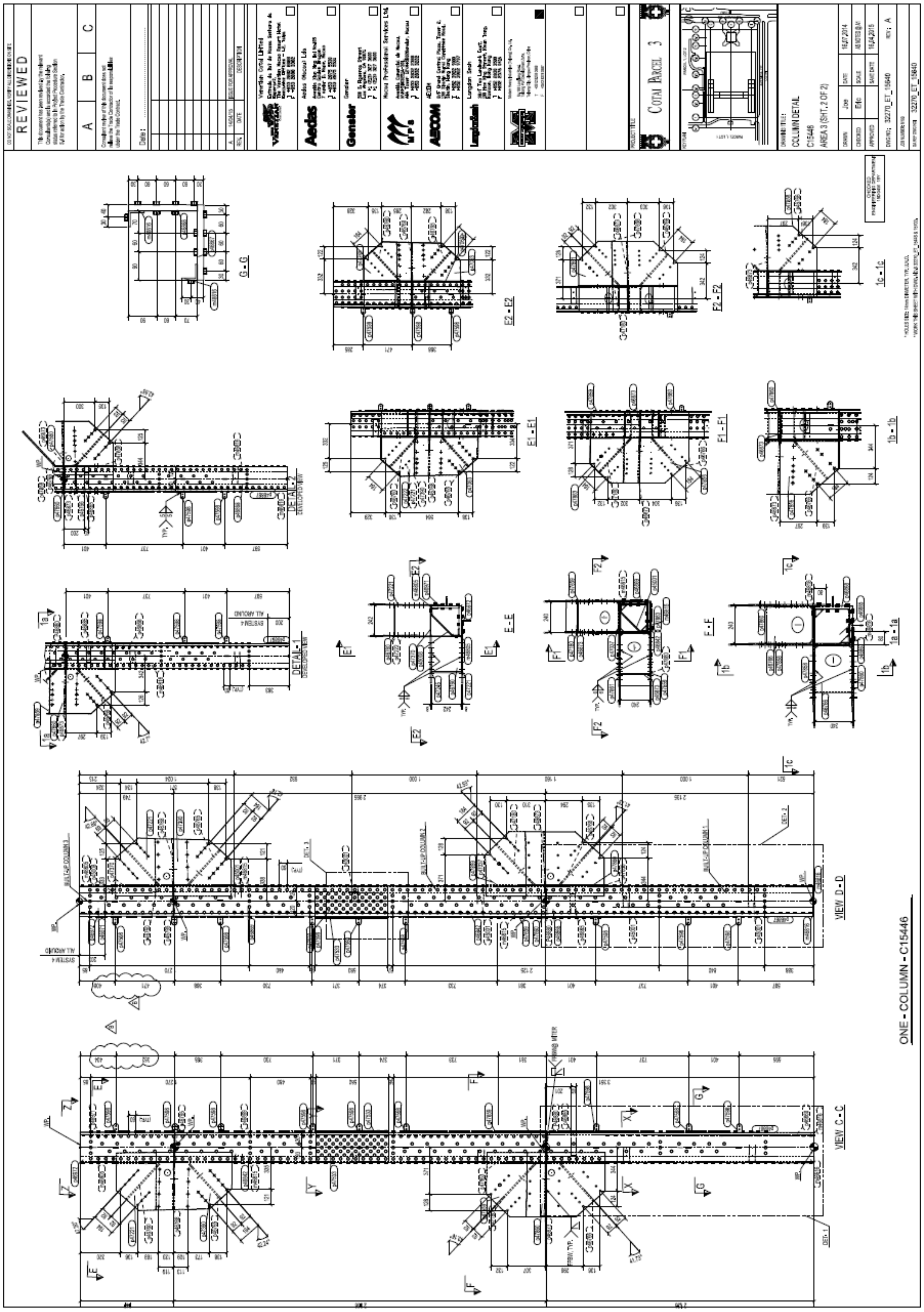
Shop drawings were then created from the Tekla Model

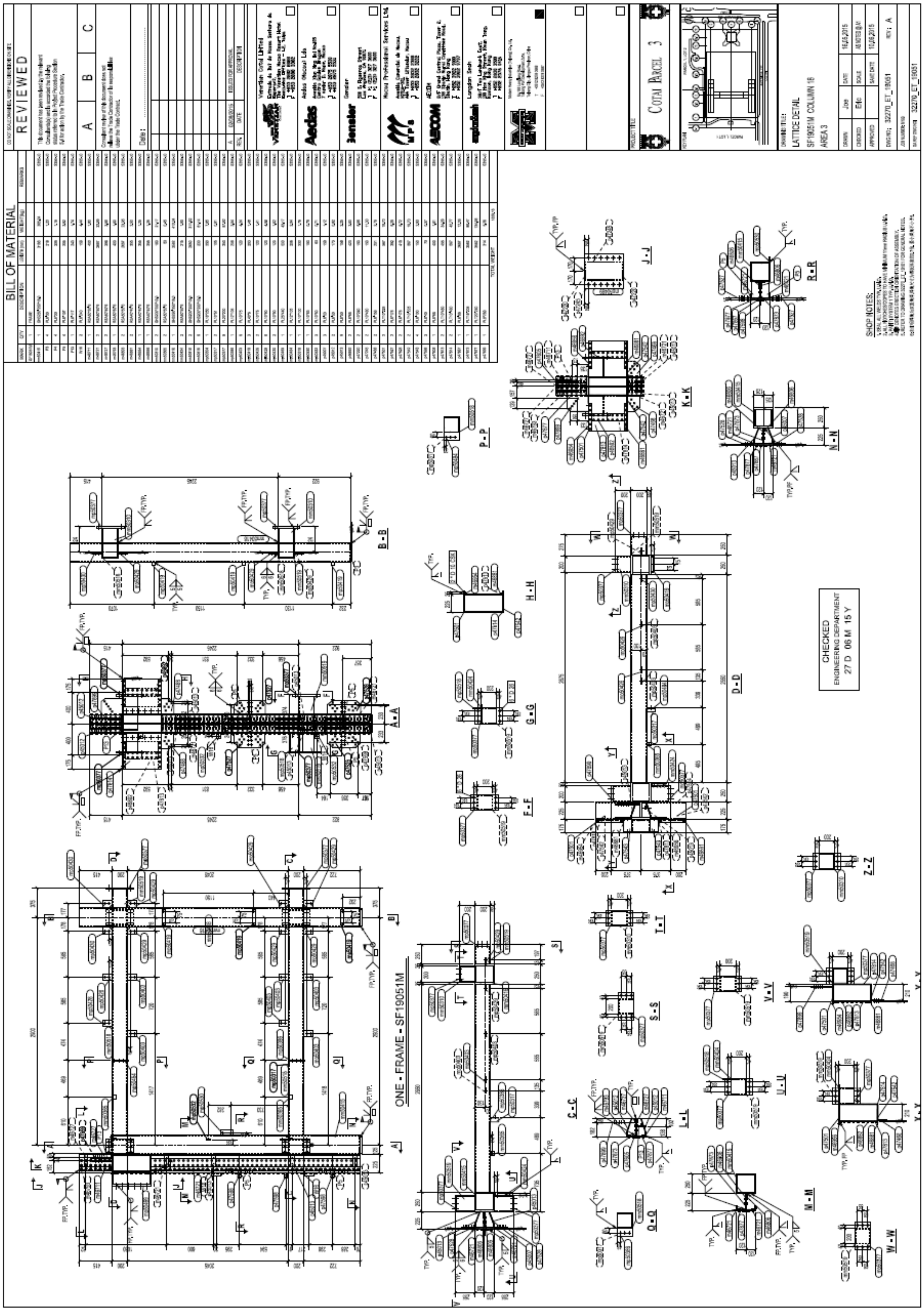
Example Drawings





BILL OF MATERIAL
REVIEWED
LOCATION OF COLUMN C15446
BUILT-UP COLUMN 1
BUILT-UP COLUMN 2
BUILT-UP COLUMN 3
SHOP NOTES:
B - B
VIEW A - A
2 - COLUMNS - C15444
COLUMN DETAIL


REVIEWED
COTAI PARCEL 3
COLUMN DETAIL
C15446
G - G
E2 - E2
F2 - F2
1c - 1c
E1 - E1
F1 - F1
1b - 1b
E - E
F - F
1a - 1a
VIEW D - D
VIEW C - C
ONE - COLUMN - C15446


BILL OF MATERIAL
REVIEWED
ONE - FRAME - SF19051M
CHECKED
ENGINEERING DEPARTMENT
27 D 06 M 15 Y
SHOP NOTES:
LATTICE DETAIL
AREA 3

Lessons learned on the Project

The Modelling Team not only successfully completed the project but also walked away with golden nuggets of lessons learnt from this experience, some of these were:

- Since the model was only a couple of levels above the actual construction time line, planning was imperative to the success of the project. We needed to know the deliverables prior to modelling to avoid abortive work, as what you modelled on levels below may have effects on further modelling going up.
- By standing back and looking at what we had done previously on "standard" revit projects we were able to adapt these techniques and use these to speed up the process of modelling this complicated structure. A great example of this would be the shared location technique stated previously, reducing the time of modelling by at least 65%
- During the project we were under pressure to get documents out, and sometimes this made us break out into 2D detailing. Most of the time, this led to problems, with more queries from the contractor and the shop detailer. If we had our time again we would avoid standard connection details. Bottom line DO NOT take short cuts.
- If you are determined enough, you can make Revit do just about anything. You just have to plan, adapt and test, patience is also required at times.
- All and all Revit performed very well, which is a tribute to the software and the modellers driving the software.