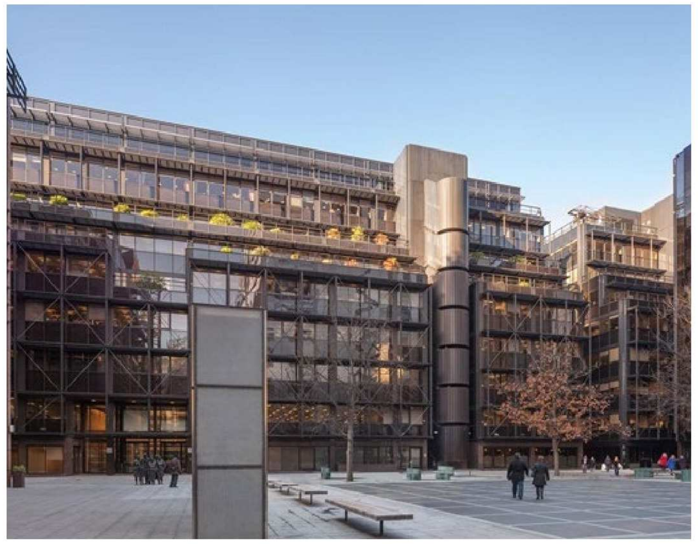
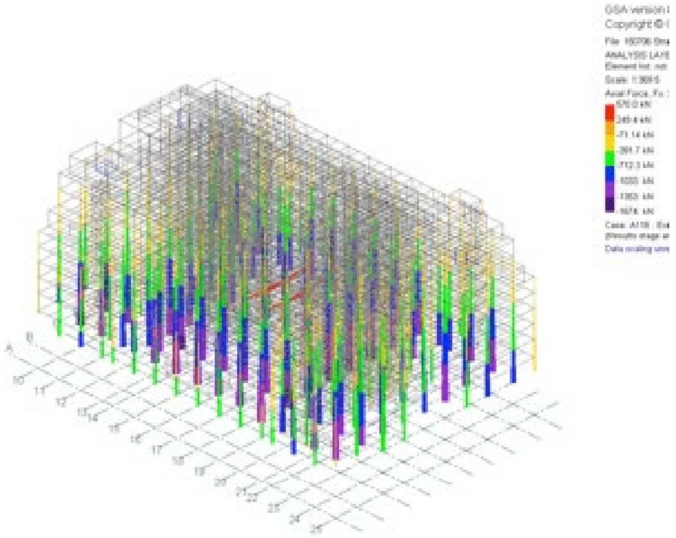
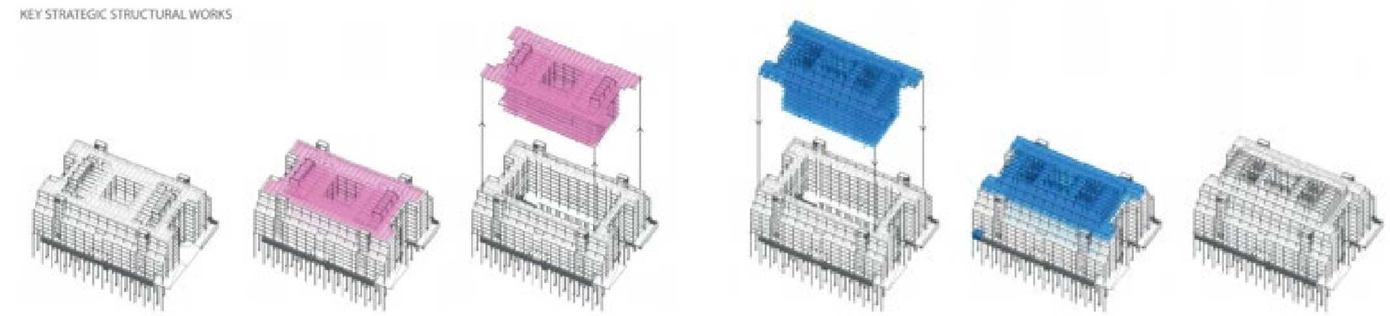
SSN Digital Design

1 Finsbury Avenue



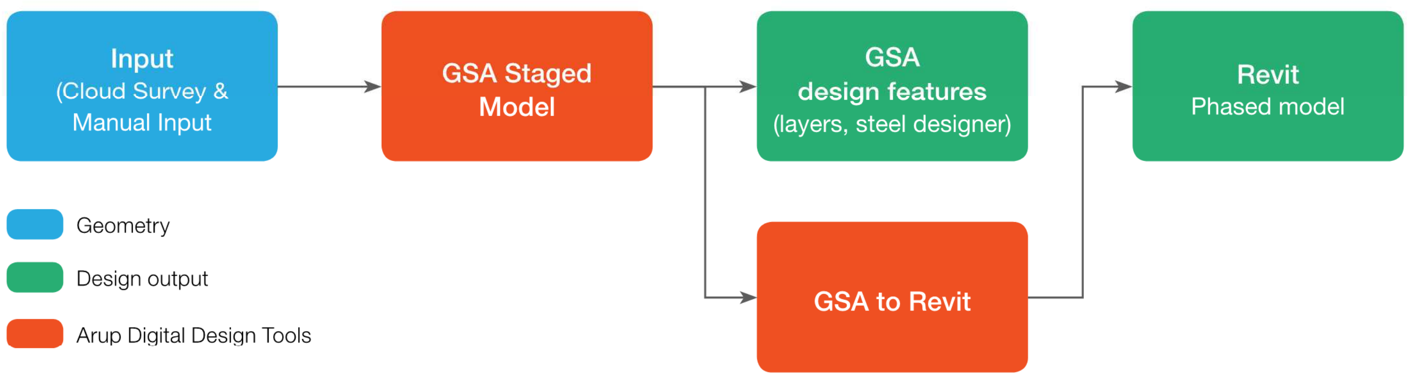




Summary
- Existing building: addition of 3 new storeys and internal structural reconfiguration
- Geometry controlled from GSA, regularly updated in Revit to reflect design changes
- Staged (GSA) / Phased (Revit) model key for the existing building process

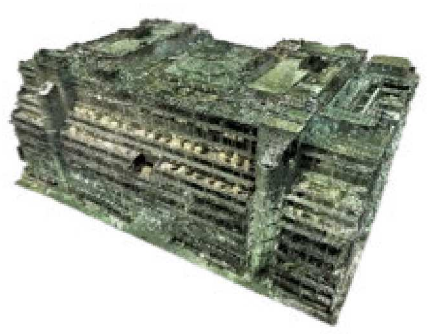
Tools used
GSA, Revit (2016)

Workflow

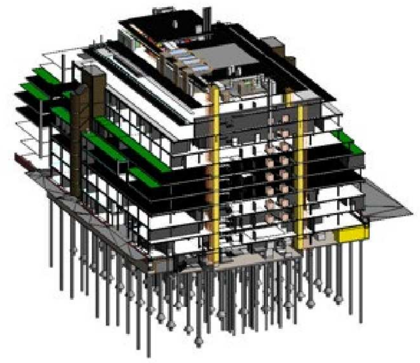


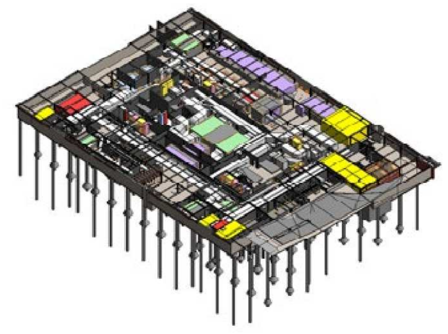
Project
Retro-fit of the 1980s eight storey Grade-II listed commercial office in the City of London, by Arup Associates. Addition of three new storeys and replacement of internal steel-framed stability systems behind the listed façade. Integration of old and new structure is required, with foundation re-use a key design driver. The Revit steel frame is continuously controlled from GSA, to avoid duplication of modelling effort and ensure accurate and live co-ordination.

Process
The orthogonal structural steel geometry was generated in GSA from original construction drawings. Digital surveys of the existing structural frame were not possible, but the external listed façade, which is to be upgraded, has been modelled by importing point cloud data. The modelling process is engineer-controlled with a single (staged) GSA model to drive the steel frame. Design calculations are done in the GSA Design layer, or checks made visually in GSA at the early stages. Concrete elements were modelled once in Revit, being subject to less modification and not being required in the analysis model.



Point cloud survey of external fabric





The steel frame is phased into existing, demolished and new stages, and is continuously exported into Revit, for live 3D ASMEP co-ordination and 2D drawing production. Regular updates from GSA are used to update the steel frame in the Revit model without the loss of phasing data, dimensions, member size annotation and other drawing production work.

Value
As structural design iterations are progressed in GSA, the resulting geometry is instantly available in the Revit model for 3D ASMEP co-ordination (below), which is occurring at a fast pace co-located with Arup Associates. Technician time is not spent re-modelling geometry already devised by the engineer as part of the structural design process.

Next time
There is still a manual process to pause and export to Revit, which takes approx 15 minutes. A fully functional live 2-way link would improve efficiency – feedback is being provided to the Oasys team on the various small bugs and possible improvements. A comparison with the capabilities and efficiency of the analysis/Robot layer in Revit would be useful.

Key Contacts
Catherine Rankine, Michael Thomson

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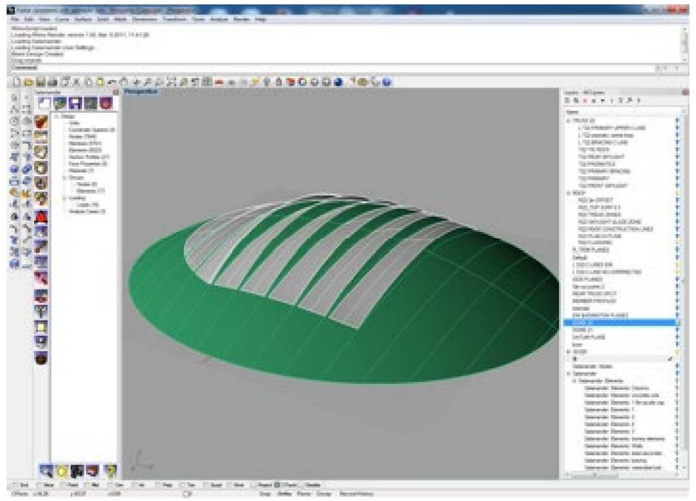
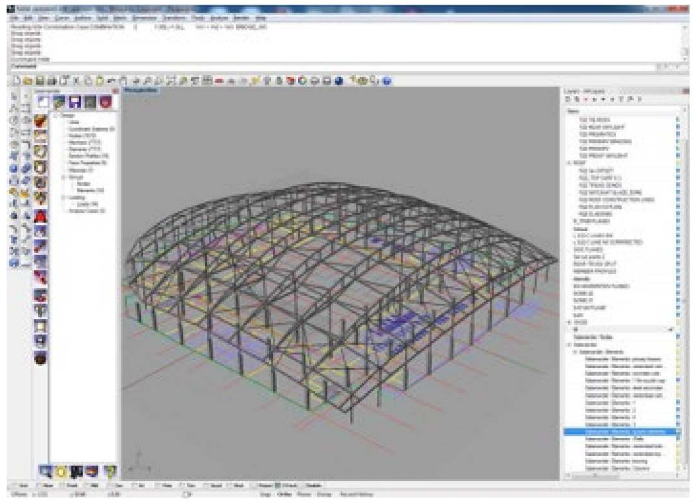
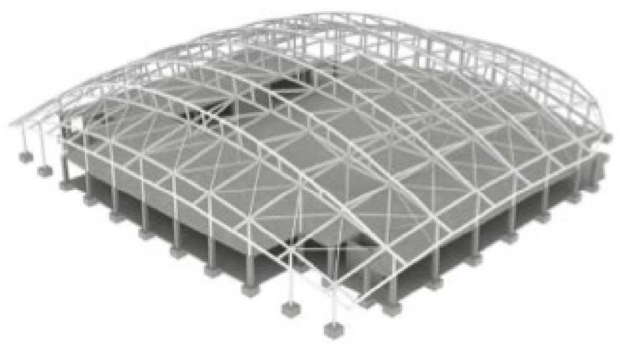
University of Cambridge Sports Centre







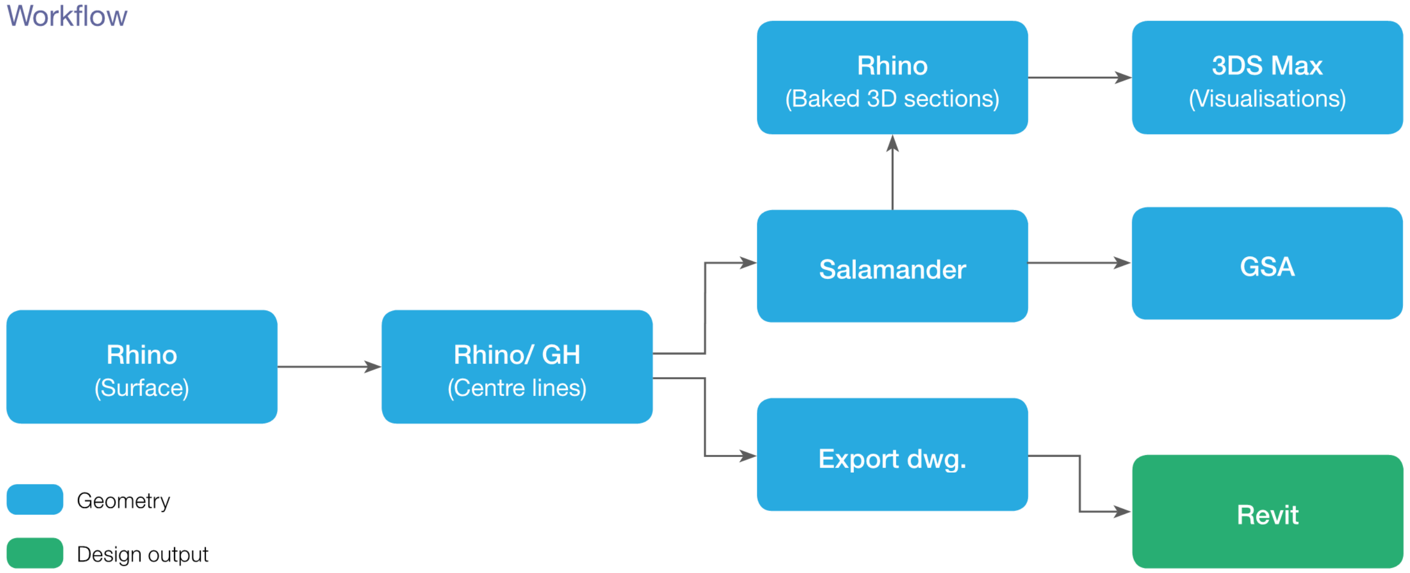
Summary

- Analysis model generated via GH/Salamander to facilitate design iteration
- Geometry generated with parametric scripts used for visualisations in early stages of the project

Tools used

Rhino, Grasshopper (GH), Revit (2008), Salamander, 3DS Max

Workflow



ARUP

Project description

The overall building form for this multi-purpose sports hall is dominated by a continuous curved roof, extending over both the main sports hall and the side accommodation. A toroid surface is used to define the geometry of the roof, with a series of curved, tapered vierendeel steel trusses spanning over the hall. The trusses frame a series of north facing roof apertures that give daylight and ventilation to the space below. Secondary beams and rafters run perpendicular to restrain the top and bottom chords of the trusses and generate the saw tooth profile of the roof.

Process

The structural geometry for the roof was generated in GH using a series of agreed offsets from the architectural surface geometry. This generated a parametrically defined centreline geometry model for the steelwork which could be used for both modelling and analysis. The GSA model was generated using Salamander, with curved centrelines facetted for the purposes of analysis. Loading, materials and constraints were applied manually using Salamander and/or GSA.

A Revit model was not created for Concept design stage. Instead, the GSA model was baked into Rhino using Salamander, and then exported to 3DS Max for 3D visualisations, which were used in the Concept Design report to help describe the scheme, alongside a series of hand sketches. Rhino was also used for Concept stage coordination with architectural and services 2D and 3D information.

The centreline geometry was imported into Revit for roof modelling during Design Development and beyond.

Value

Using parametrically defined centreline geometry for the roof steelwork enabled a quick assessment of a variety of different geometry and framing options at Concept stage, working closely with the architectural and services teams to assess performance across disciplines. The centreline model was the ‘master’ file, that could easily be used for analysis, visualisation and coordination purposes, and then also for modelling in Revit.

Next time

The definition of material and section properties, constraints, and loading could also have been done using Salamander functions in GH, to make a fully parametric workflow for creating the analysis model from surface geometry. However, the time investment for generating this script was not felt to be worthwhile in this case.

Key Contacts

Paul Jeffries

ARUP

SSN Digital Design

China Zun — Z15 Tower

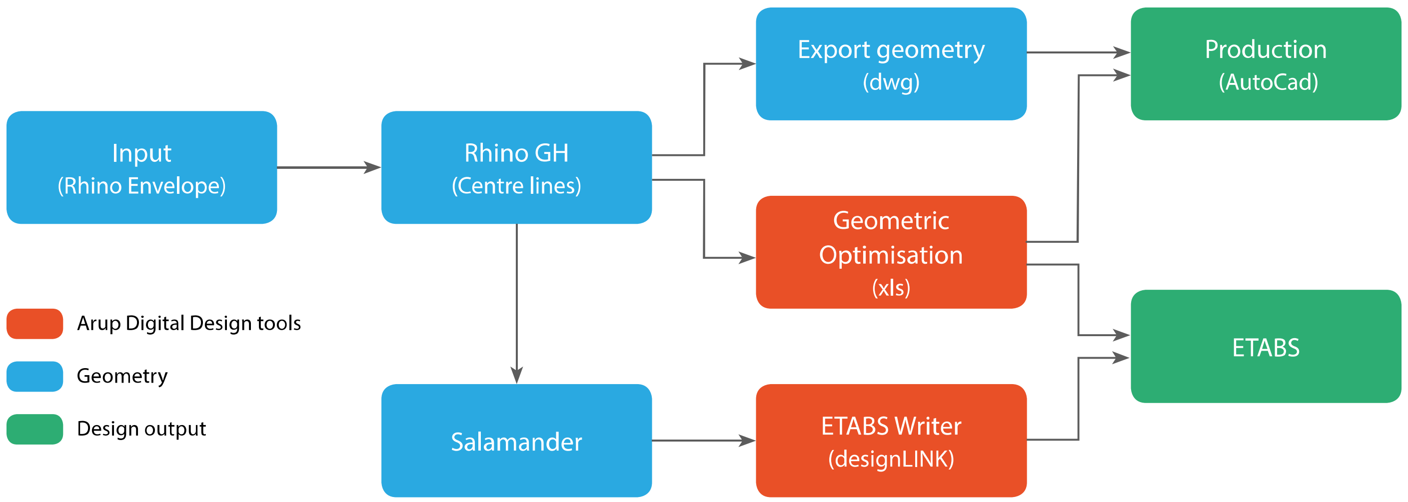
Tools used

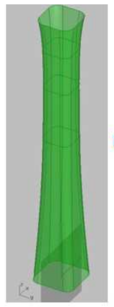
Rhino, Grasshopper (GH), Salamander, ETABS Writer, ETABS (Version?), designLink

Summary

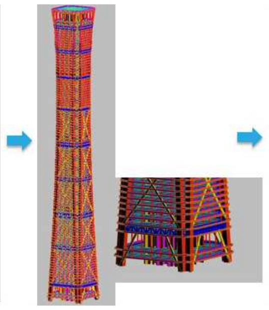
- Development of a new tool to link Rhino/GH and ETABS analysis software
- Use of a central parametric model to export information to analysis and production

Workflow

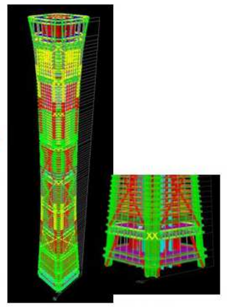




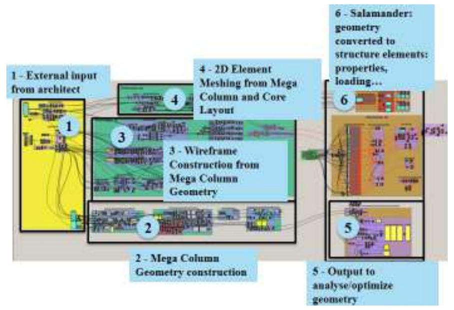
KPF Massing

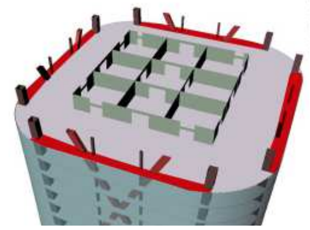


Salamander parametric modelling



ETABS Model for 2nd EPR





Project description

The 536m tower has square floor plates, varying from 78m wide at the base, to 54m at the waist line and finally 69m at the top. The floor plates have rounded corners with variable radius. The total Gross Floor Area is 350,000m^2.

The structural scheme is made of 4 four pairs of corner mega columns, linked by bracing on the façade. Due to the curved profile of the tower the mega columns are inclined and their spacing varies with the height.

Process

The tower profile was a freeform curve. For structural efficiency, the mega-columns centrelines were to be a segmented line included in a unique vertical plane with minimum number of "kinks" located at belt trusses levels. The architectural and functional requirements regarding the mega column geometry were sometimes working against the structural performance, e.g. the rounded corners reducing the lever arm. The parametric workflow was used to explore a wide range of geometrical and structural solutions. The solutions were compared for their relative structural performance (ie analysis results), construction complexity/cost (eg number of kinks), and their impact on project value (distance structure to façade creating dead area on the upper floors).

The ETABS Writer link was developed to integrate the structural analysis software ETABS into the parametric design workflow, using the DesignLink platform: this reduced the modelling time for an ETABS model from a few weeks to a few days.

Value

This has given us a better knowledge of the key parameters driving the structural behaviour and of their relative importance. We focused on the critical issues of the structure and replaced the highly time-consuming tasks of analysis model production with ETABS by a fine optimization process, leading to a more efficient and economical design.

Using this workflow, we were able to weigh the structural performance benefits against construction cost implications or floor plate efficiency. The advice given to the client was thus more accurate and quantifiable.

We were also able to update the structural model according to the late design changes, such as overall tower height or stacking chart modification.

Next time

We want to integrate in this workflow optimisation tools that have been developped in parallel for high rise towers. We also want to extract parts of the parametric model to create some GH components re-usable on other high rise projects.

Supporting Docs

1. ETABS Writer program and link to documentation
2. Sample file for link from Salamander to ETABS

Key contacts

Dorothee Citerne — dorothee.citerne@arup.com
Liu Peng
Yun-Bo Liu
Jecht Ma

SSN Digital Design

Coal Drops Yard

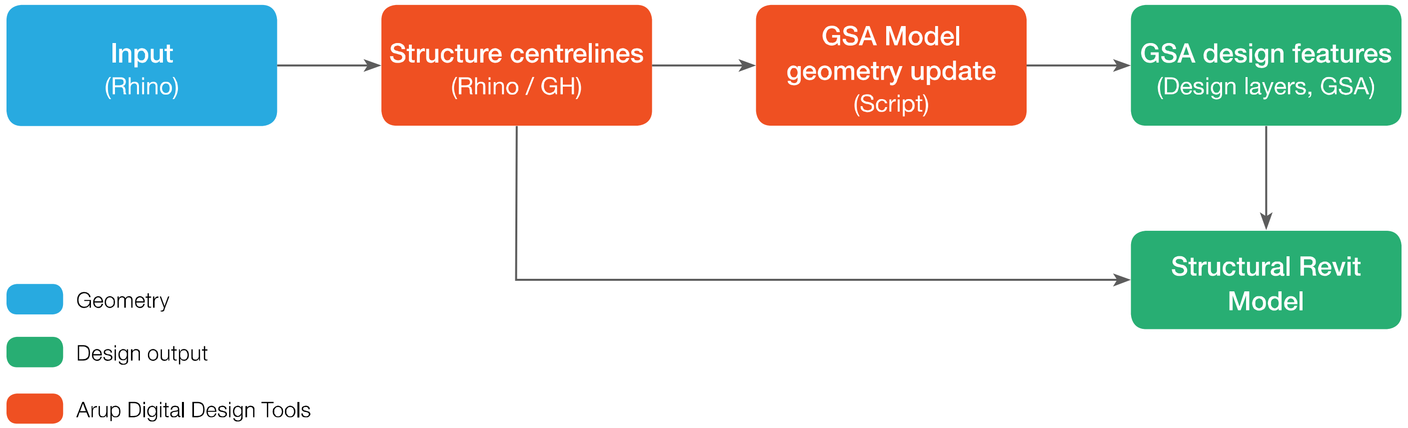
Summary

- Master parametric model (Rhino/GH) used to generate multiple models for analysis, setting-out information, and accommodate changes throughout the design process
- GSA model update from GH parametric script output (geometry, property tables)
- GSA design layer used to run structural code checks on steelwork and RC diaphragm and cores

Tools used

Rhino, Grasshopper (GH), GSA, GSA Design Layers, GSA Steel Design, GSA RC Design, Compos

Workflow



ARUP

Project

The project consists of an iconic roof sitting atop two historic warehouses in the Kings Cross re-development. The structure is composed of a curved steel truss supported off new steelwork within the warehouses and a large steel frame spanning directly between the two buildings.

Process

The architectural geometry of the roof was provided by the architects as a number of surfaces and curves in a Rhino file format. This geometry was regularly changing, so using Rhino in combination with GH a parametric script was created in which centrelines for primary structure could be generated rapidly for using these architectural inputs. These centrelines and RC boundaries where then fed into GSA where elements where meshed (using the design layer), section properties, releases, loading and combinations where applied. The use of layering in Rhino, and property tables in GSA allowed for minimal rework to update the centreline geometry to a fully functioning GSA model once a first iteration had been complete.

The GSA design layers where used to rapidly verify the structural design to EC codes. This information was then used to inform the best structural solution and ultimately used to provide Revit with the right sectional sizes and properties.

Revit Geometry was initially derived from the parametric Rhino/GH file, and was later fully co-ordinated and set-out in Revit alone.

Value

The parametric model allowed for the quick generation and manipulation of GSA analysis models. Due to the faster generation of analysis models a large number of structural models were able to be considered without the fear of spending lengthy periods of time re-generating analysis models, ultimately allowing for the most structurally efficient solution to be tested and verified.

The parametric model was also able to be used as an initial set out file for primary structure during the early stages of the job.

Next time

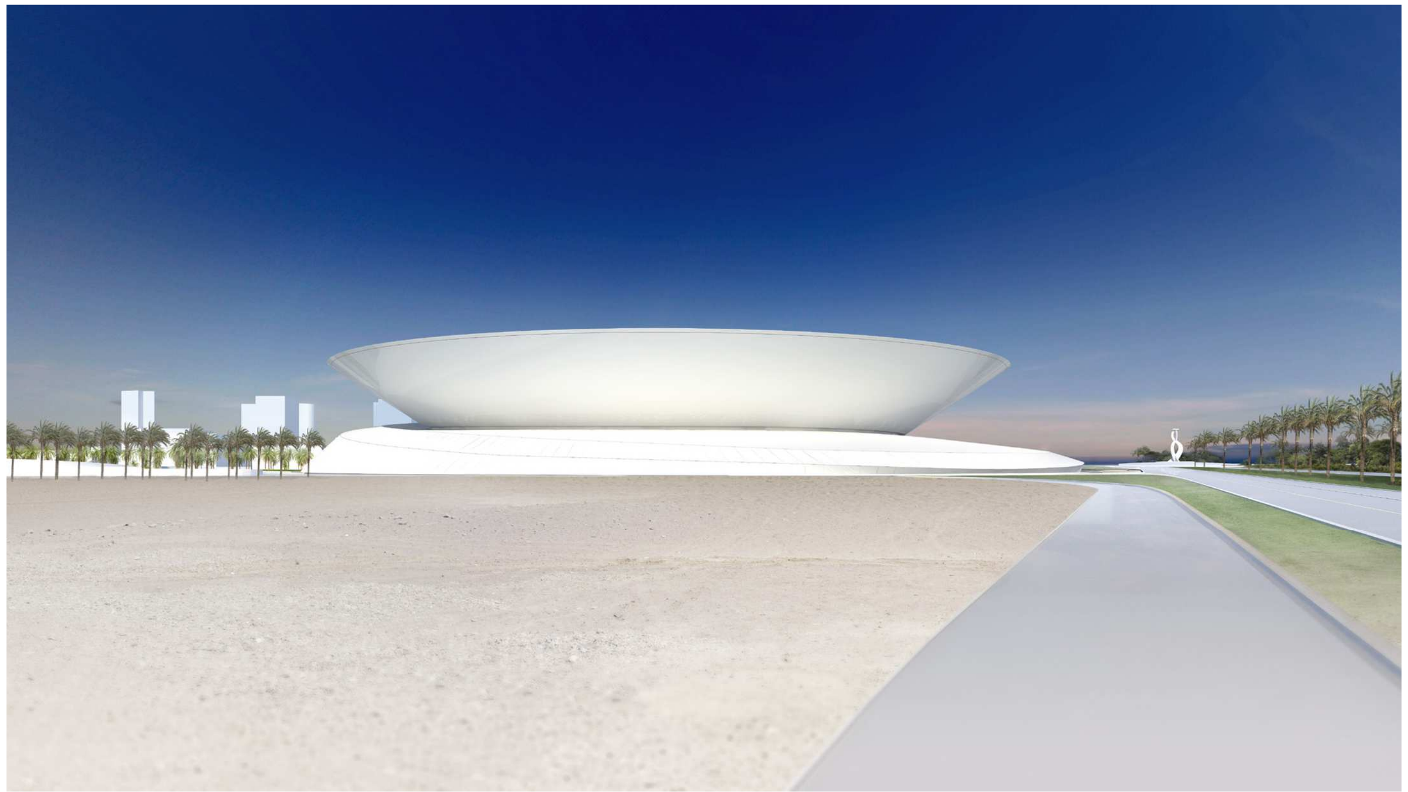
- Parametric scripts can take a long time to generate, and can become unwieldy if too many metrics are considered, decide what parameters are most important and only include those in the script.
- A parametric model providing geometric set-out for drawings (Revit) needs to be much more refined than one setting out for analysis (GSA). Whilst it was beneficial to be able to use the parametric model to provide set out for Revit, the added level of detail required slowed down and ultimately hindered the speed and adaptability of the design approach in the later stages of design. Next time I would find another means of providing accurate set-out for geometry, or a technician who can use parametric tools at an earlier stage in the design.
- The use of a structural optimiser (VBA based or otherwise), defined by utilisation and deflection performance requirements would be of much use in closing in on the best structural solution in the quickest time.
- Better Rhino to Revit and GSA to Revit links would improve workflows.

Key contact

Stuart Chambers, Rick Benjamin

ARUP

Doha New Tennis Stadium at Khalifa Tennis Complex



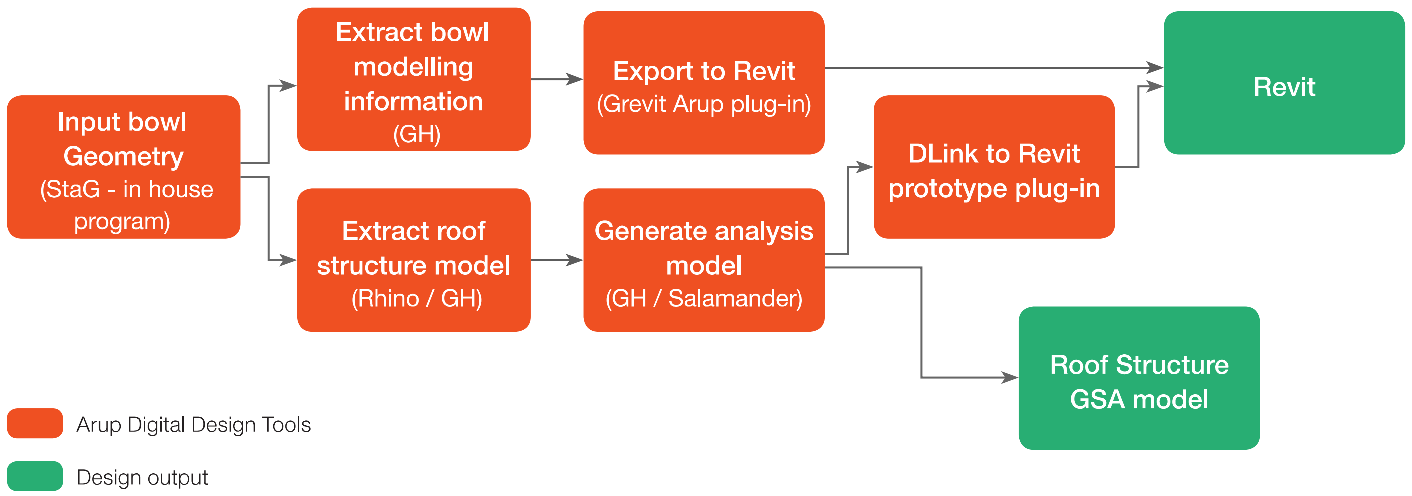
Summary

- Use of custom made parametric tools to define complex stadium geometry and export to Revit
- Use of Salamander to generate GSA model
- Use of a prototype Arup plugin exporting DesignLink file to Revit

Tools used

Rhino, StaG, Salamander, Grasshopper, Grevit, GSA, Revit, DesignLink-Revit Import Plugin

Workflow



Project

A new 12,000-seat capacity tennis stadium in Doha, Qatar. The roof has a 160m overall diameter, with 120m span between support points. Additionally the centre of the roof has a 50m diameter opening, coverable by two semi-circular moving roof segments supported by three tracks running across the roof. The roof is supported by several trusses, reciprocally supporting one another in a star-like arrangement.

Process

The bowl geometry at the heart of the project has been designed and modelled using StaG (Stadium Generator), a specialised seating bowl generation tool developed in-house by Arup Associates. The bowl geometry that this produced was then passed through a Grasshopper definition that converted it into a suitable form to then be exported, through the Grevit plugin, into Revit.

Further architectural geometry, driven by the bowl geometry, was created using Rhino and Grasshopper. All aspects of the structural analysis model were defined parametrically for both the main roof model and the moving roof model.

The Salamander model was exported to GSA for analysis and to Revit, through a prototype DesignLink-Revit import plugin, for documentation.

Value

The structural and architectural workflows were tightly integrated, ensuring clear communication between architectural and structural teams and facilitating rapid response to changes in the design.

Using StaG allowed different options for the seating bowl geometry to be defined, generated and analysed. The geometry of the bowl is also an important driver for the surrounding structural and architectural geometry meaning that the improvement in the speed of design of this region allows the design of other parts of the building to also progress more rapidly. Passing the bowl plank geometry from Rhino to Revit eliminates the need for time-consuming re-modelling of the complex bowl geometry in Revit.

Parametrically defining the roof arrangement gave the opportunity to evaluate different arrangements (radius, number of trusses, angles of connection).

Because the entirety of the structural analysis data was defined in the GH/Salamander model there was no additional overhead to changing parameters and outputting new models for analysis.

Use of the Salamander-Revit link allowed curved geometry to be translated across from Rhino to Revit and for the definition of continuous members (whereas the equivalent GSA-Revit link would have necessitated splitting and faceting those members).

Next time

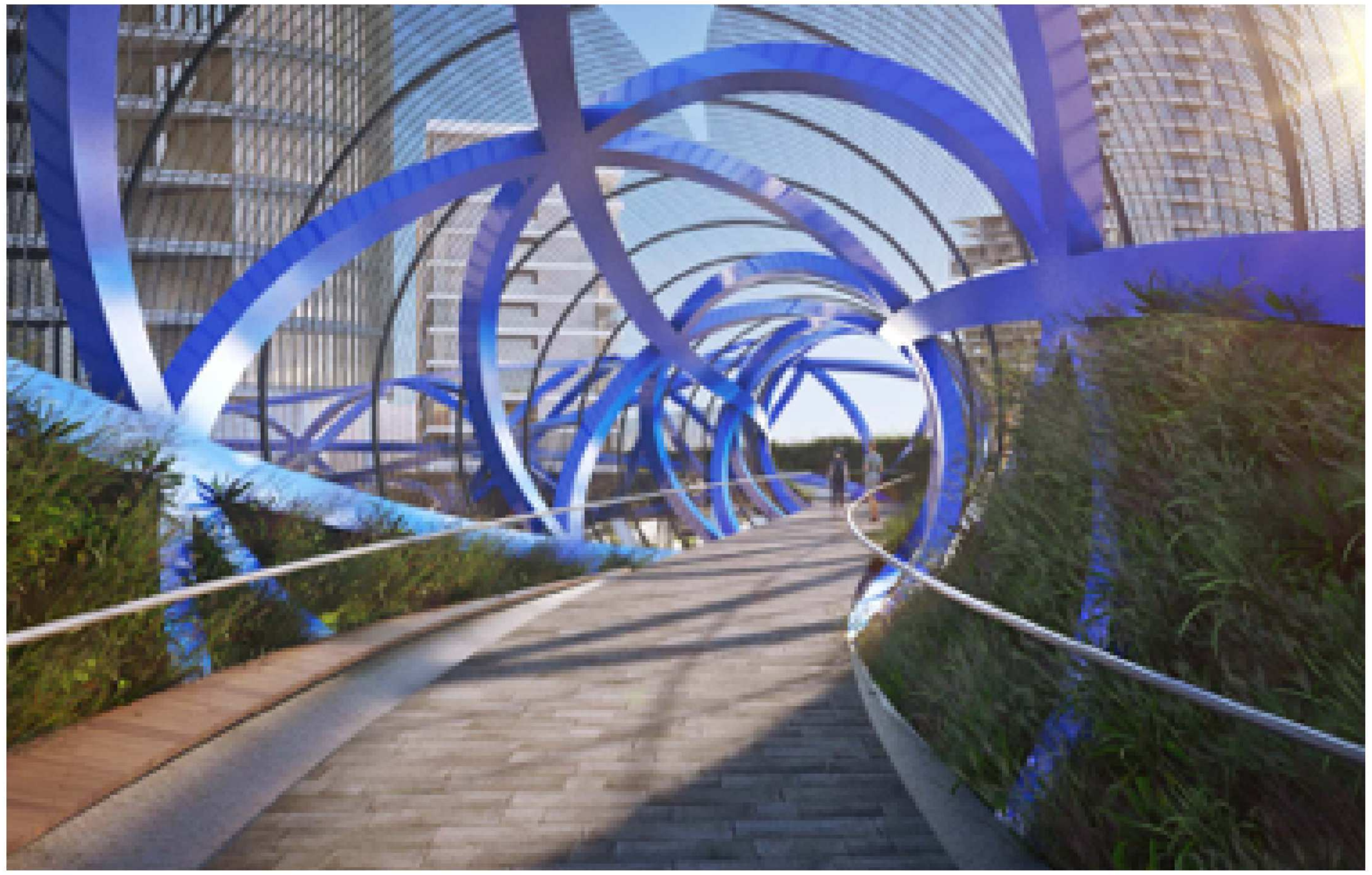
Some experiments were done with automating section sizing through Salamander. This identified some necessary improvements which have since been made, however there has not yet been time to re-attempt this procedure.

Key contact

Paul Jeffries

SSN Digital Design

Lachlan's Line Pedestrian Bridge



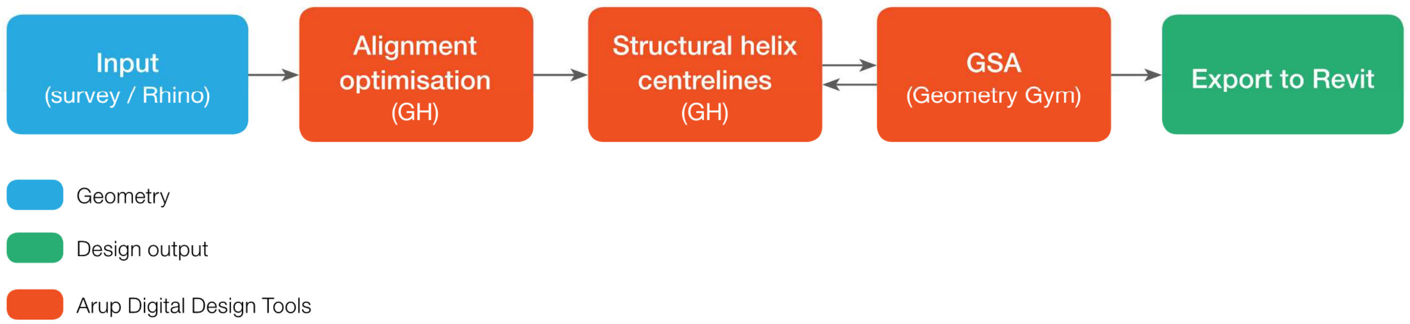
Summary

- Optimise bridge alignment to minimise total length
- Automate complex geometrical space structure in Rhino / GH
- Export directly into GSA for automated design
- Exported directly into Revit for automated documentation

Tools used

Rhino, Grasshopper, Geometry Gym, GSA

Workflow



Project

Lachlan's Line (Concept Phase). Complex geometrical steel helix pedestrian bridge structure

Process

- Import survey and define alignment constraints in Rhino (ie road clearances)
- Grasshopper allows parametric adjustment to bridge CL to optimise total length for given constraints
- Grasshopper generates helix CL
- Import CL into GSA for analysis. Readjust geometry (in grasshopper) and re-import (into GSA) helix CL to develop optimum structural solution
- Export to Revit for documentation

Value

- Provided an optimised bridge alignment
- Allowed a complex form to be rapidly developed and analysed
- Model imported directly into Revit so no re-modelling for documentation purposes (as .dwg)

Next time

Iterate parametrically through helix geometry parameters rather than manually.

Import steel helix into Revit as native Revit members rather than .dwg.

Key contact

Xavier Nuttall – Andrew Johnson

Keywords

Grasshopper, GSA, Geometry Gym

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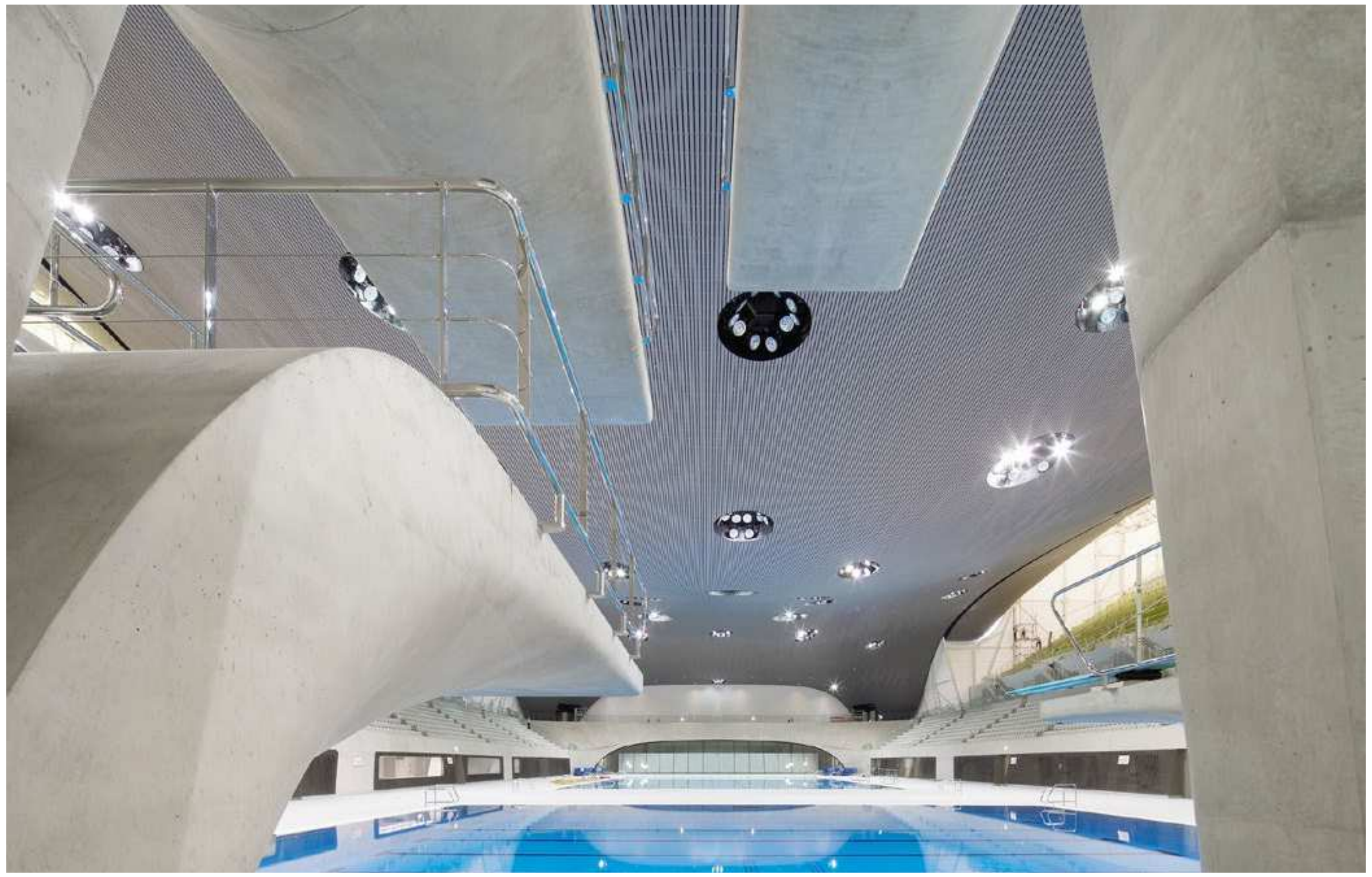
London Aquatics Centre Dive Towers



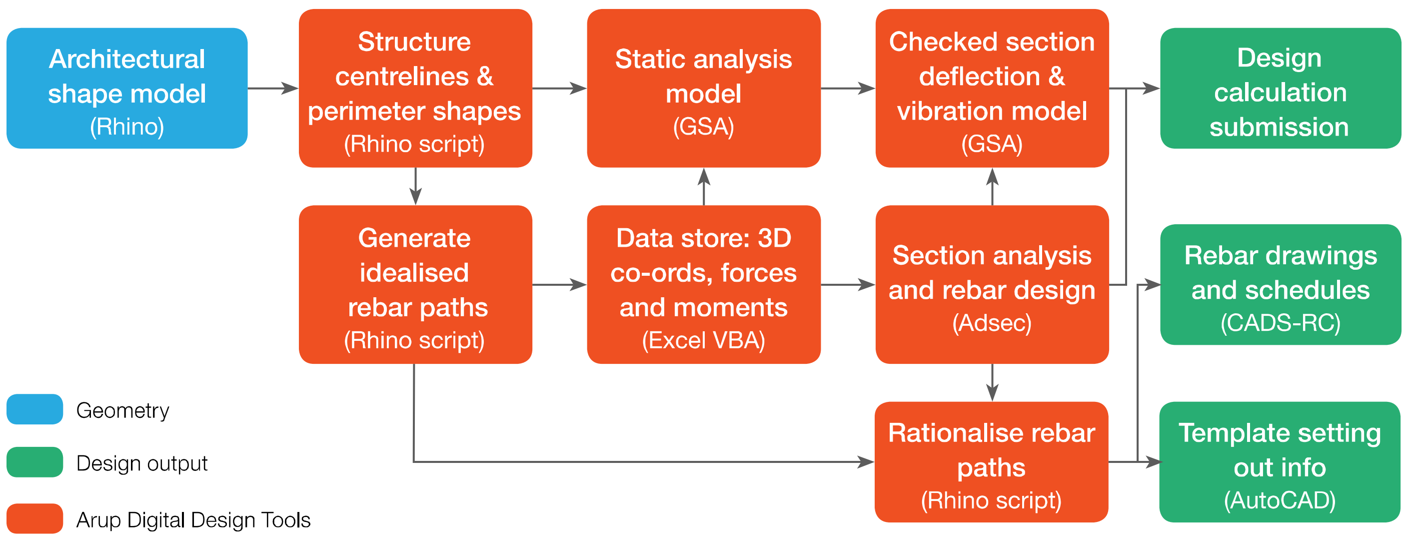
Summary

- Creation of tools to rationalise and convert freeform surface geometry to centreline analysis and design
- Rationalisation of freeform reinforcement paths into standard shape code components using Rhino Scripts

Tools used

Rhino, RhinoScript, Excel VBA, GSA, AdSec, CADS-RC

Workflow



ARUP

Project

The diving platforms are a bespoke design which form the centrepiece of the pool hall for the 2012 Olympics and have an exposed concrete finish in keeping with much of the centre. The platforms do not follow the traditional solution of short rectangular platforms supported by a structural frame. Instead they have a continually changing profile. Arup delivered the design and reinforcement detailing of the platforms on time and on budget.

Process

Rhino scripts were written to accurately and repeatably 'slice up' the freeform shape generated by Zaha Hadid Architects. The script then ran a centreline through these perimeter slices which could be exported to GSA. The perimeters were offset inwards and the curves divided to create an idealised reinforcement layout for each slice. The properties of each slice and the reinforcement were then written out to Excel where they were combined with the forces and moments from GSA to generate AdSec models. This process allowed iterations of overall shape and reinforcement size and spacing to be computed efficiently until the final form was derived.

Once the bar sizes and spacing had been finalised the process of generating the reinforcement fabrication information could begin. Knowing what bar size was required at each section allowed the bars to be plotted in 3D considering lap locations, maximum bar lengths and buildability. The resulting bar paths were freeform with double curvature so further scripting rationalised these to single curvature, standard shape code bars while checking that the deviation from the idealised bar path was acceptable. These rationalised bar shapes were then fed into CADS-RC which produced the layouts and schedules.

Value

Arup's skills de-risked a key part to this high profile, award winning project which had an immovable deadline. This gave the Client and Architect reassurance and allowed the Contractor to focus on achieving the high quality concrete finish required without worrying about how to reinforce such complex shapes. The use of standard shape codes reduced costs and ensured certainty of supply as any rebar bender could fulfil the order. Not a single site query was received from site for this part of the works.

Next time

The intent was to avoid the need to rationalise the reinforcement shapes into standard shape codes by feeding the exact geometry into the bar bending machines but this was a step too far at the time.

We have won lots of work on the back of what was achieved at the LAC and now we do it in Grasshopper rather than script.

Supporting docs

1. Rhino scripts and models
2. AutoCAD scripts for bulking drawing name and number control
3. AdSec pro-forma
4. Example drawings

Key contact

Mark Fyson / Gordon Mungall – Newcastle, UK

Keywords

Rhino, scripting, automation, interoperability

ARUP

SSN Digital Design

Bombay Sapphire Greenhouses (Project Manta)

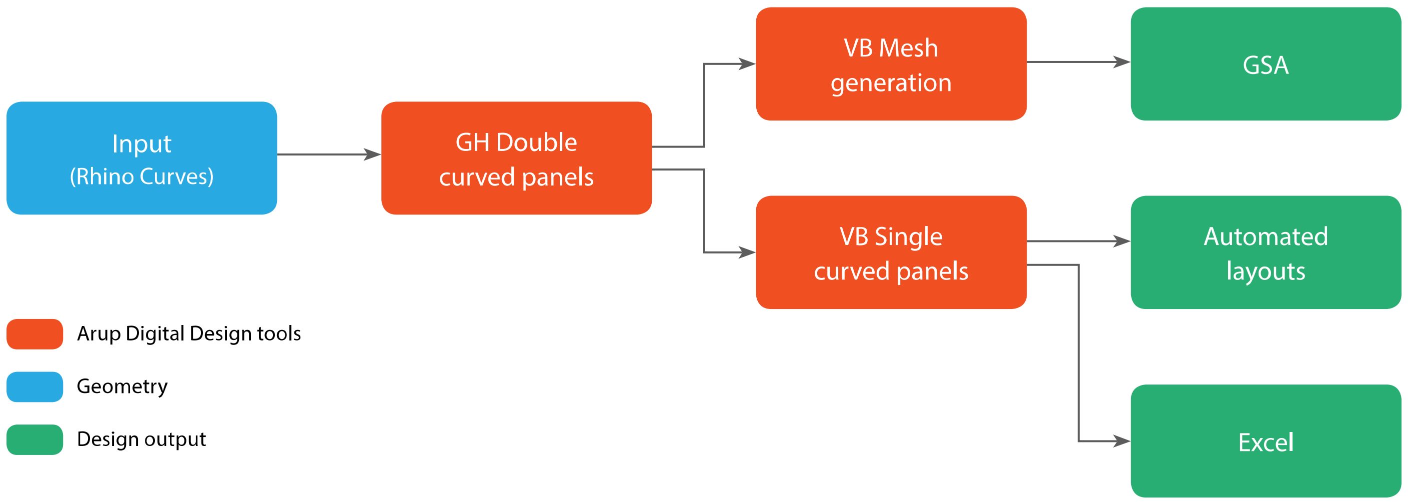
Tools used

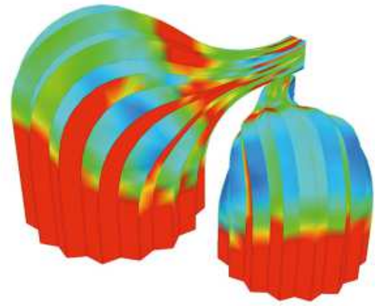
Rhino, Grasshopper (GH), RhinoScript, VB.Net, GSA, Salamander

Summary

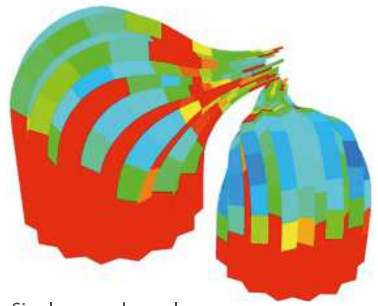
- Optimisation of the project geometry to build the double curvature surface with cylindrical shapes
- Creation of automation tools to export panels geometry to analysis and production

Workflow





Doubly curved strips



Singly curved panels

Project description

Two iconic greenhouses were designed by Heatherwick Studio for Bombay Sapphire and are built adjacent to a small river on an old mill site in Laverstoke, Hampshire. The freeform volumes with tropical and Mediterranean climate feature pleated glass skins, ideal to be used as a structural skin. Arup supported Heatherwick Studio with geometrical optimisation, structural and detailed design of the glass structures.

Process

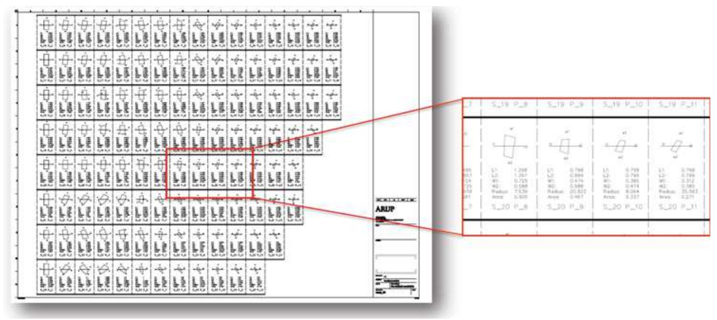
As cost was a major driver on the project, the geometry of the individual glass panels was a critical element in the design process. Studies were undertaken to understand whether subtle modifications to the overall geometry would reduce the amount of double curvature.

Initial studies looked at creating long developable strips along the full length of the 'flow' lines. It quickly became apparent that such constraints drastically changed the overall setout of the project and panels would still have varying curvature along their length.

The design team also explored the possibility that individual panels could be cold bent to approximate the architectural form. Cold bent panels have restrictions on the amount of curvature that can be achieved which is dependent on the overall glass build up. We developed a process to approximate the panels as pure cylindrical shapes with constant curvature per panel to allow the design team to describe each individual panel with a defined setting out rule and therefore allow greater confidence in the tendering process.

Value

A list of all glass panels with their size, production radius and amount of on-site bending was automatically generated to support the tendering companies' discussions with their glass suppliers. Without optimising the glass panels it would have been nearly impossible to accurately describe the geometry and complexity of the individual panels.



Next time

Calculating the stresses applied to the glass by the cold bending technique was not fully resolved and two panels had to be slump formed.

Supporting Docs

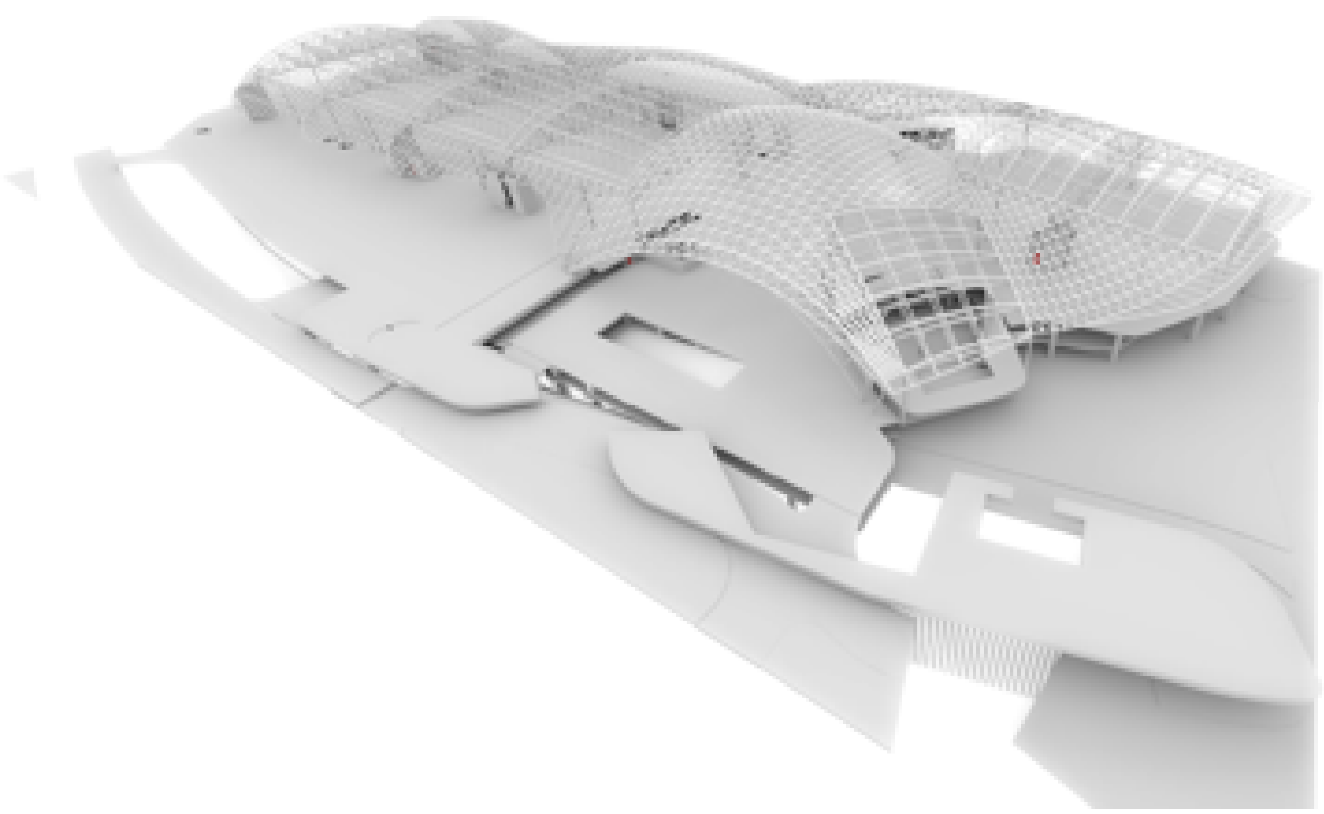
1. GH — Double curved to Single Curved
2. Centre line model

Key contacts

Toby Clark — Toby.Clark@arup.com

SSN Digital Design

Puteri Harbour



Project
Puteri Harbour. Complex geometrical steel space structure

Process
- GH model coordination with architect
- Export centreline model to Strand7
- Create loads, apply restraints and properties
- Use Strand7 steel optimiser to automatically size steel members
- Export to Tekla

Value
- Rapid explorative optimisation of architectural optioneering
- No mark ups

Next time
Integrate property and load application in GH

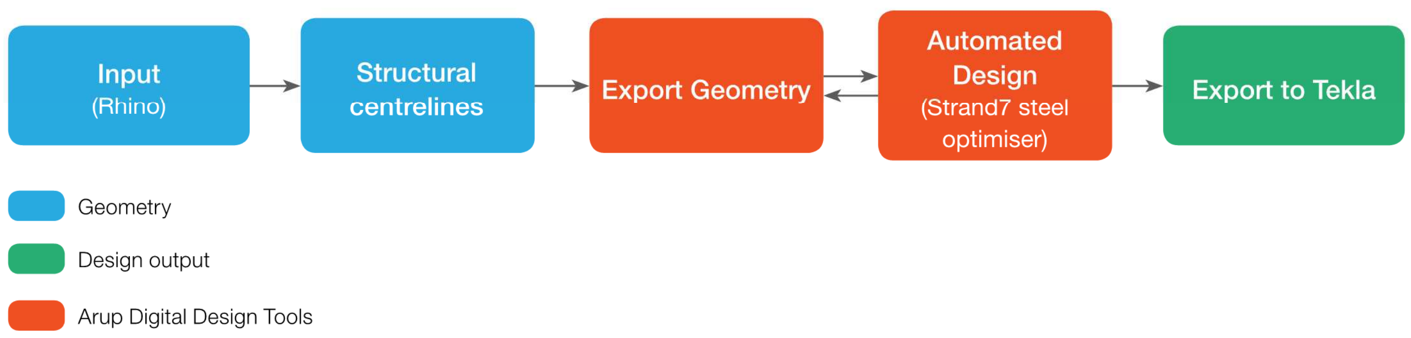
Key contact
James Danatzis, Stephen Corney, James O'Donnell

Keywords
Strand7, Tekla, Steel optimiser

Summary
- Automate complex geometrical space structure in GH
- Export directly into Strand for automated design
- Export directly to Tekla Structures

Tools used
Grasshopper, Strand7, Tekla Structures

Workflow



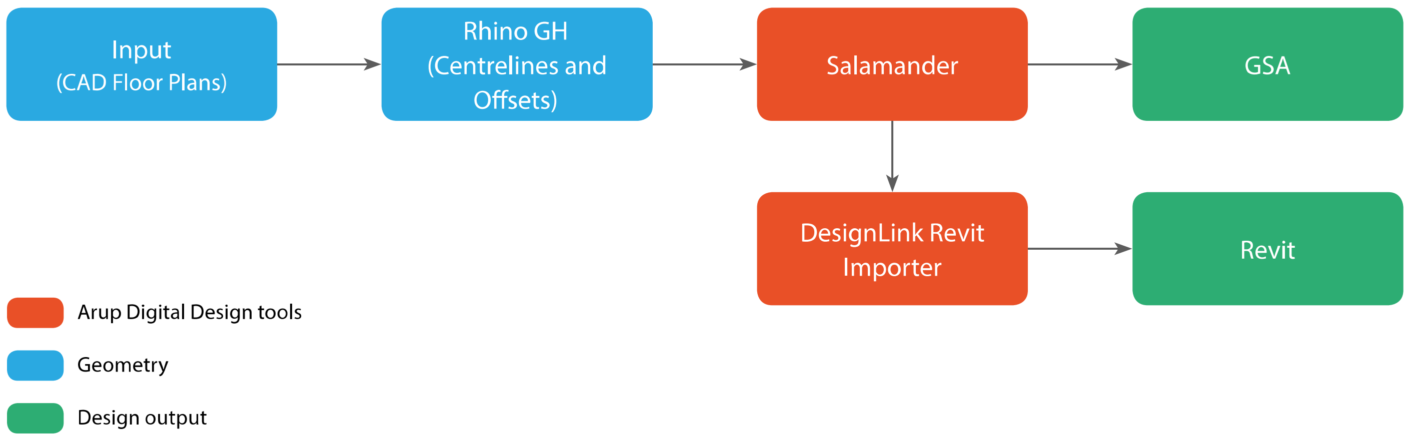
SSN Digital Design

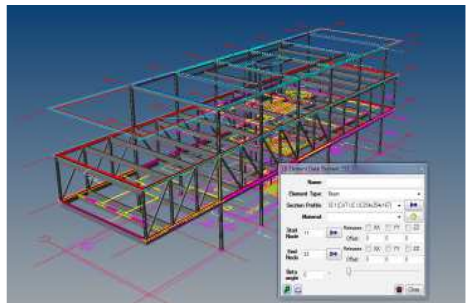
Royal Wharf Marketing Suite

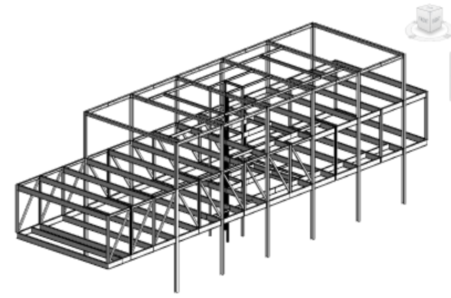
Tools used
Rhino, Salamander, GSA, Revit, VB.NET, DesignLink, Revit API, DesignLink-Revit Importer Prototype

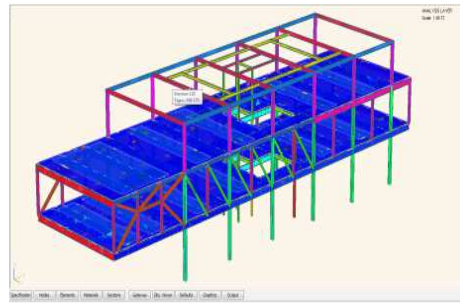
Summary
- Central structural model for export to analysis and production
- Development of a new link between designLink and Revit

Workflow









Project description
Three-storey marketing suite for the Royal Wharf housing development in East London, designed by Arup Associates.

Process
The architectural CAD floorplans and elevations were brought into Rhino via DWG and positioned and aligned correctly in 3D space. Salamander was then used to create the 3D structural analysis model by 'tracing over' this geometry, including the specification of sections, offsets, meshing regions and loads.

The GSA model was then written out directly from Salamander, while the same model was also brought into Revit through exporting from Salamander to DesignLink format which was then imported into Revit through a newly created DesignLink Revit Importer written in VB.NET using the Revit API and the DesignLink SDK (currently only a prototype, but available for use on request).

Value
A list of all glass panels with their size, production radius and amount of on-site bending was automatically generated to support the tendering companies' discussions with their glass suppliers. Without optimising the glass panels it would have been nearly impossible to accurately describe the geometry and complexity of the individual panels.

Modelling the structural analysis model in Rhino/Salamander in conjunction with the architectural geometry enabled the structural model to be produced much faster with significantly less opportunity for error than directly modelling in GSA would have allowed. Potential clashes between the structural and architectural and service geometry were made more obvious at an early stage. Later, when the architectural geometry changed the bi-directional link between Salamander and GSA made it much easier and faster to modify the geometry using Salamander and then update the linked GSA model.

The new Salamander-Revit link that was developed allowed the complete structural model to be brought across into Revit, including some information (such as offsets) that would have been lost through an import from GSA. By re-using our structural analysis model as the basis of our Revit BIM model, we saved considerable modelling time and effort and were able to complete our Revit model for documentation ourselves as an engineering team without technician assistance.

Next time
Further develop the Salamander-Revit link.

Supporting Docs
1 - Slamander-Revit link

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SSN Digital Design

181 Freemont St & Seattle Civic Square: LS-DYNA Scripting

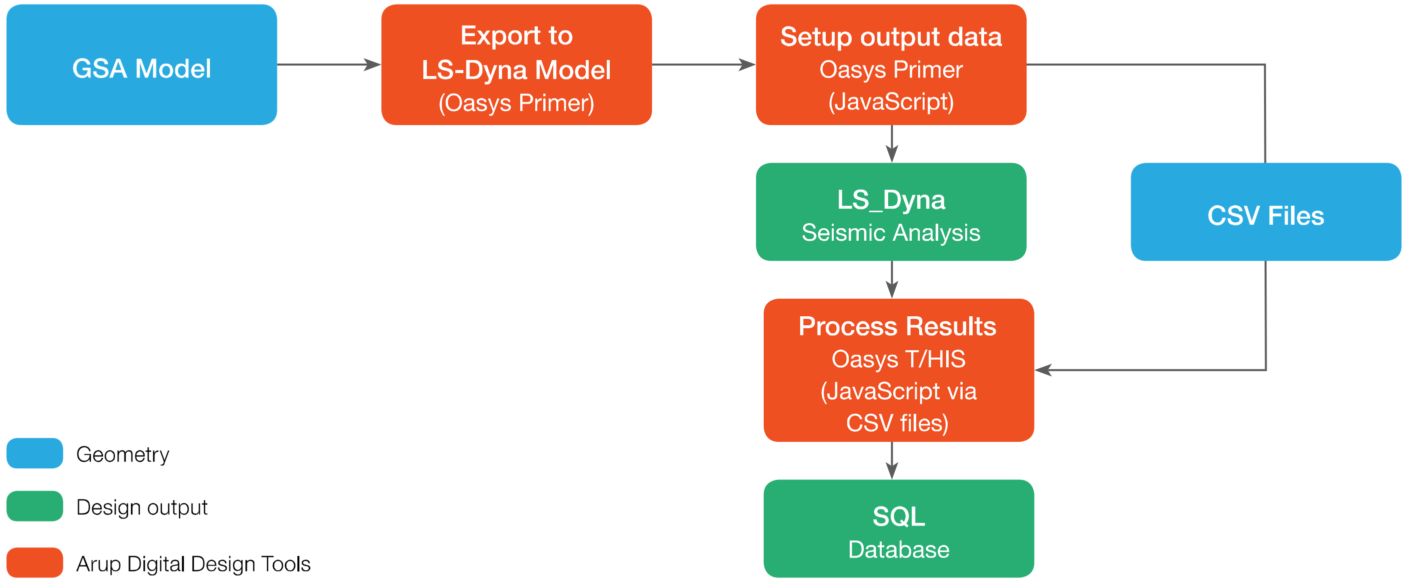
Summary

- Development of tools to convert GSA model to LS-DYNA model for seismic analysis
- Automated post processing of LS-DYNA seismic analysis results to reduce design cycle time
- Use of Java Scripts to export to SQL database

Tools used

LS-DYNA, Oasys PRIMER and T/HIS, JavaScript

Workflow



ARUP

Project

LS-DYNA is a very powerful tool for seismic analysis. However its output contains a large amount of data that has to be post-processed to pull out the various metrics used for design (story drift, floor acceleration etc.). Doing all this manually can take significant amount of time.

We developed a series of JavaScript that can run with the Oasys software to automate this process.

Process

1. Construct the LS-DYNA model from the GSA model via Oasys Primer
2. Setup the relevant output data via Oasys Primer JavaScript outputting CSV files
3. Run the suite of LS-DYNA analyses (There can be up to 11 different ground motions to analyse)
4. Post-process the results via Oasys T/HIS JavaScript – Cycles through the results of each analysis and post-process them in turn and then compiles the results from all analyses
   i. Inputs: LS-DYNA analyses – Oasys Primer CSVs
   ii. Outputs: CSV files of processed results and compiled results
5. Read the results CSV files into a SQL database

Value

The use of these scripts has reduced the post-processing time for a full suite of ground motions from 2-3 days to about 4 hrs.

Next time

We are hoping to further develop the scripts to create a simplified viewer for use in Oasys T/HIS and to automate report generation using Oasys Reporter templates and scripts.

We are also hoping to improve the interface with GSA to reduce the amount of time it takes to create an LS-DYNA model from a GSA model.

Supporting Docs

IiA Value Report - http://invest.intranet.arup.com/?layout=valuerep&projID=10579

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Keywords

LS-DYNA, JavaScript, PRIMER, T/HIS, D3PLOT, Seismic

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