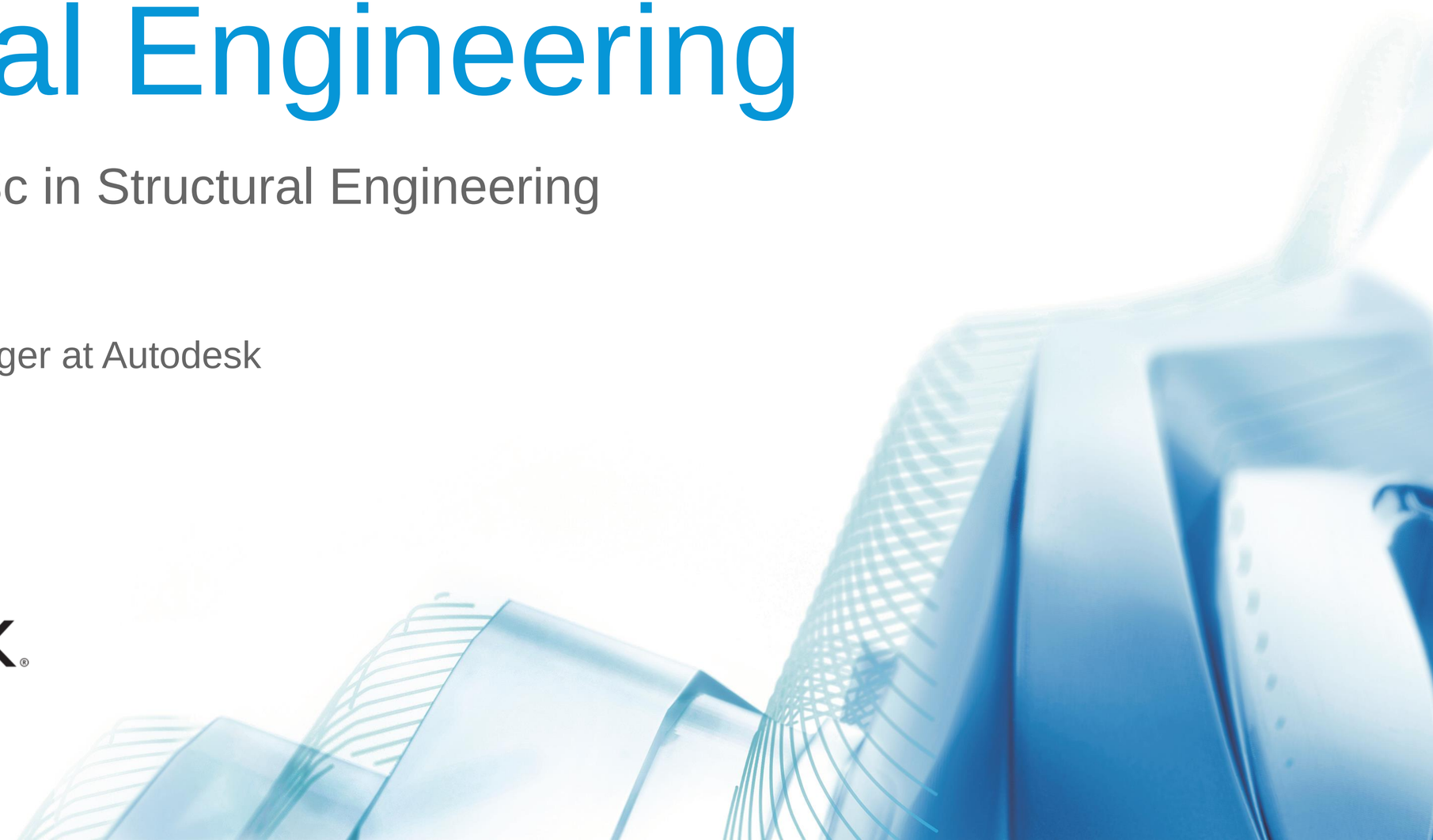
Design Automation for Structural Engineering

Tomasz Fudala, MSc in Structural Engineering

@TomekF

Technical Marketing Manager at Autodesk



AUTODESK. UNIVERSITY

About the speaker

Tomasz Fudala

He has over 16 years of experience in the software industry and a comprehensive background and vast knowledge of structural solutions in the Autodesk portfolio. He achieved a Master of Science degree in Structural Engineering from the Cracow University of Technology, Poland.

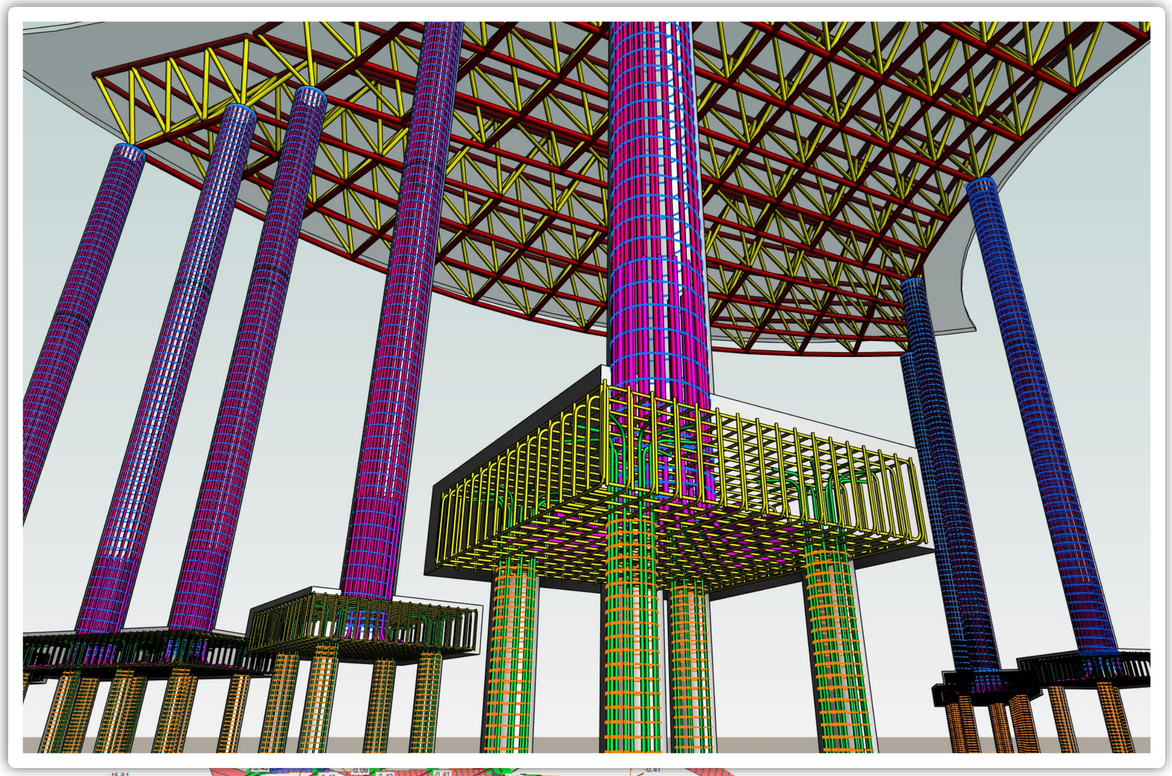
Find him:

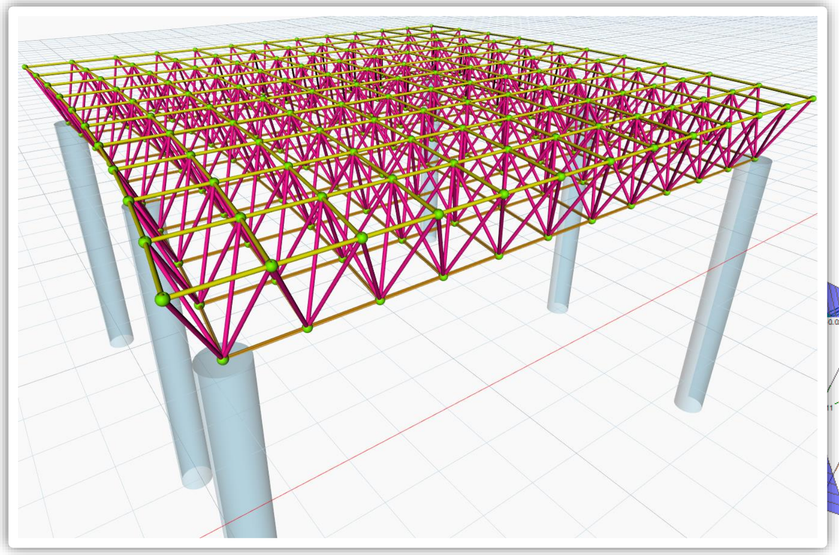
- @TomekF
- www.linkedin.com/in/tomaszfudala/
- blogs.autodesk.com/revit/
- youtube.com/user/AutodeskBuilding/

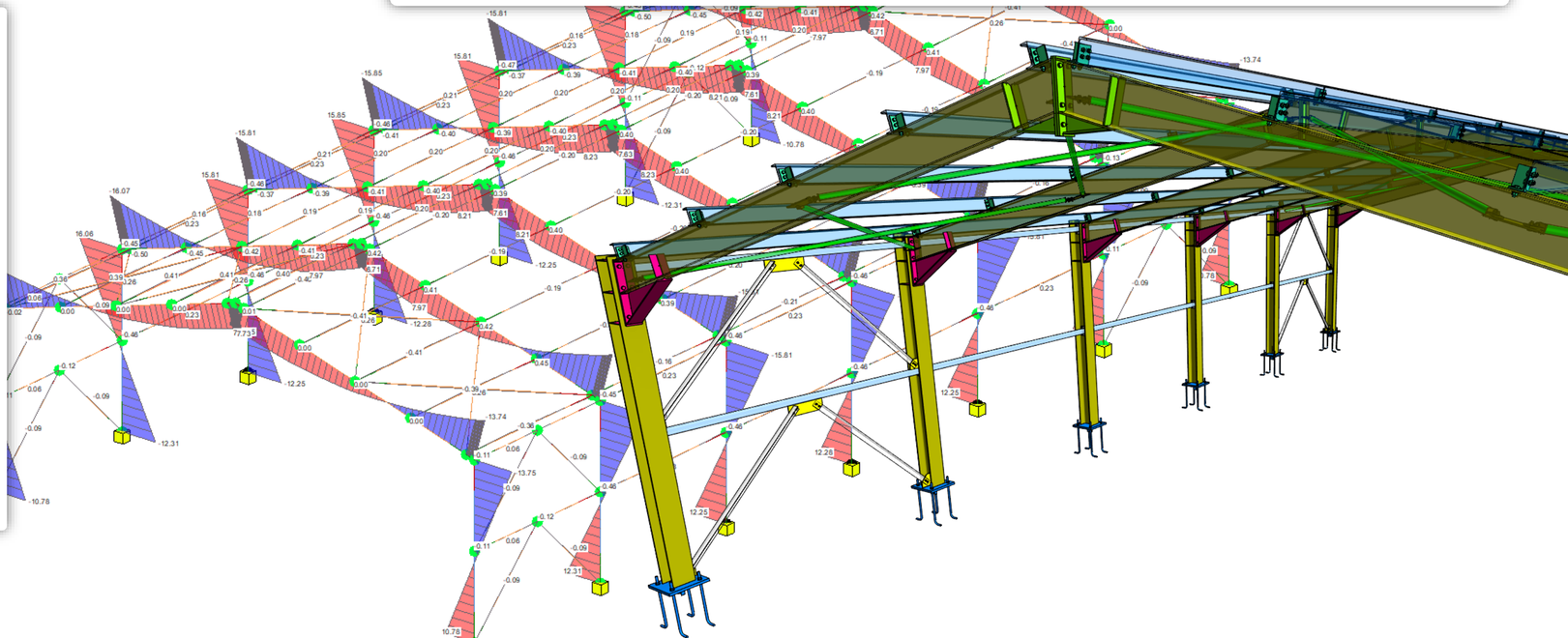
Agenda

Design Automation for Structural Engineering

- Structural Design Dynamo Package
- Structural Analysis for Dynamo Package
- Autodesk Analytical Model Dynamo Package
- Autodesk Steel Connections Dynamo Package







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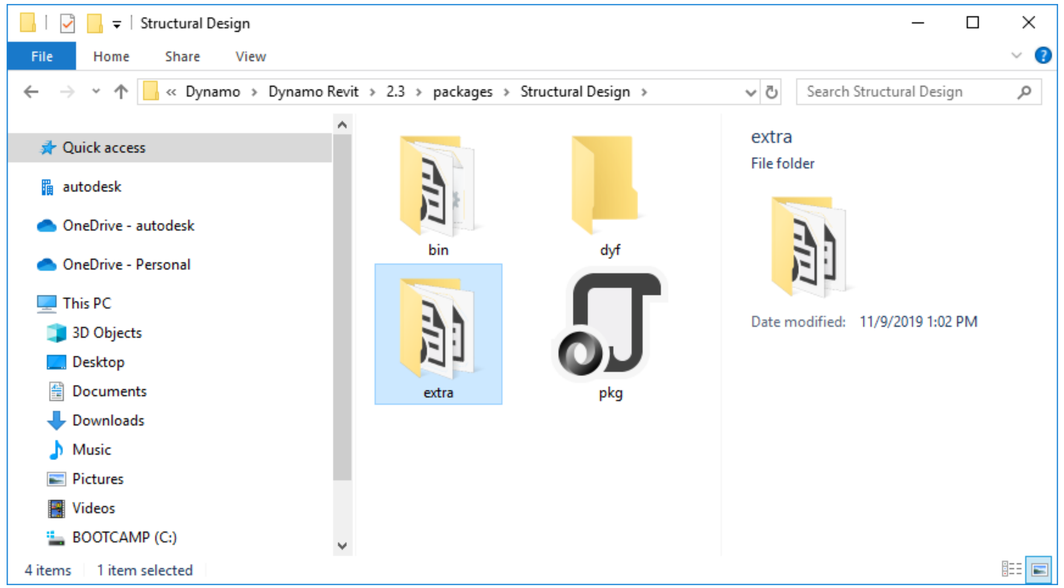
Class Materials

Handout & Example Scripts

- **58 page** document with detailed step by step instructions
- The **“extra”** folder of the **Structural Design** package contains examples that can be used with Dynamo Player

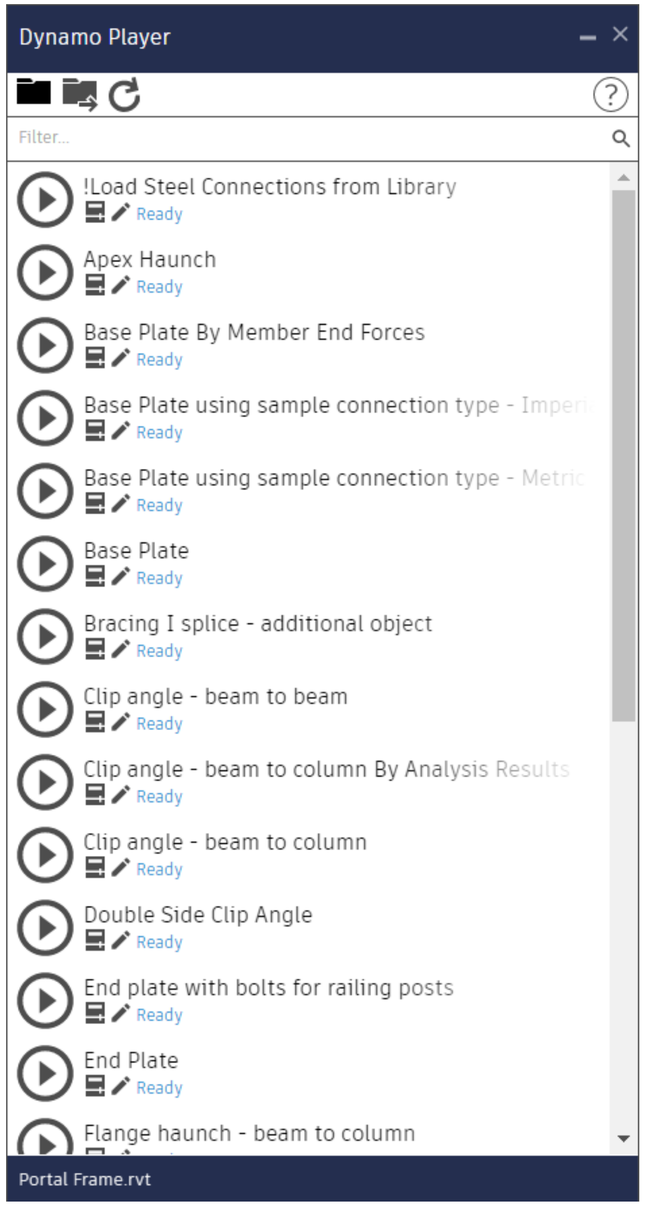


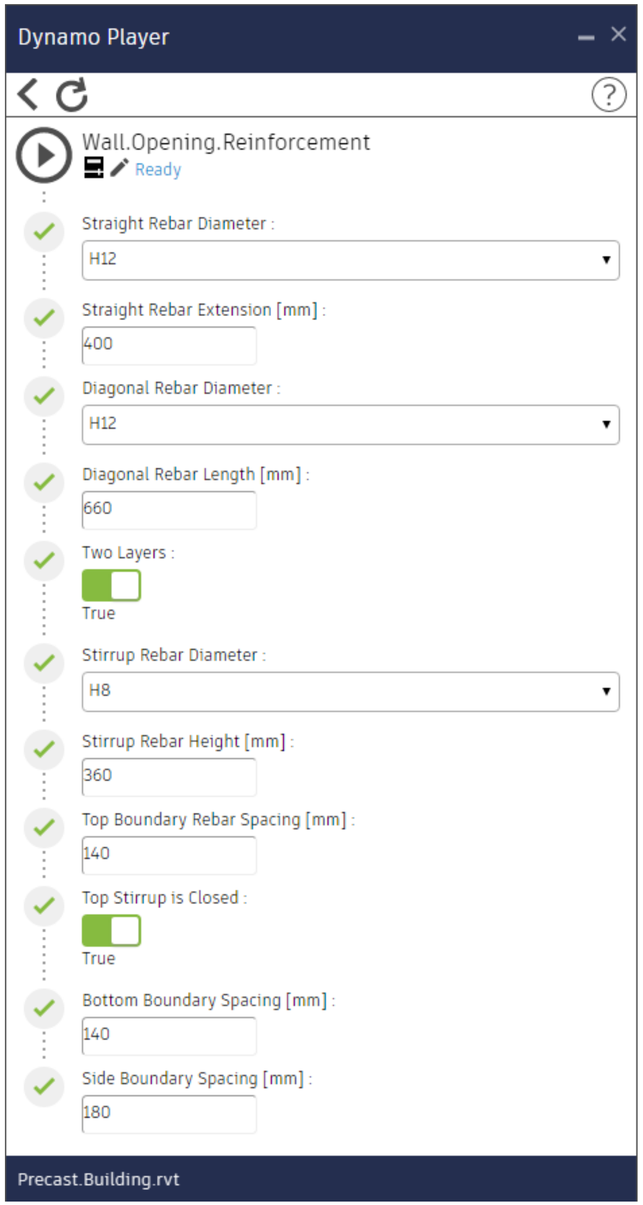
Dynamo Player

Dynamo Player

Simple way to execute Dynamo scripts in Revit

- Default directory for scripts
- Filtering visible scripts
- Viewing the status of current scripts
- Launching a script
- Providing input for scripts in Dynamo Player
- Editing a script in Dynamo

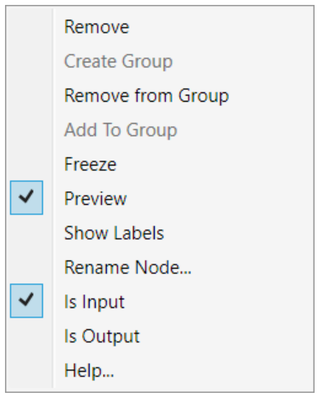


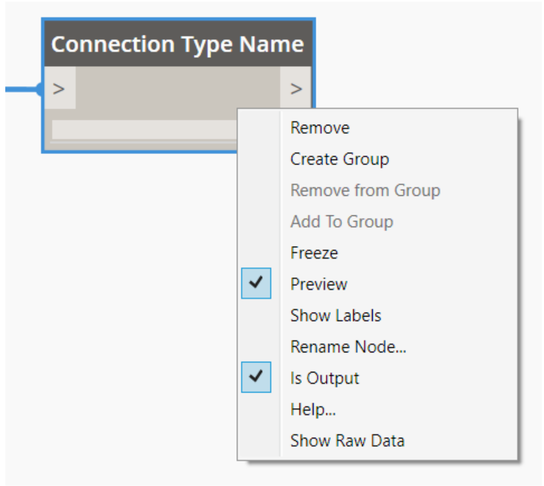


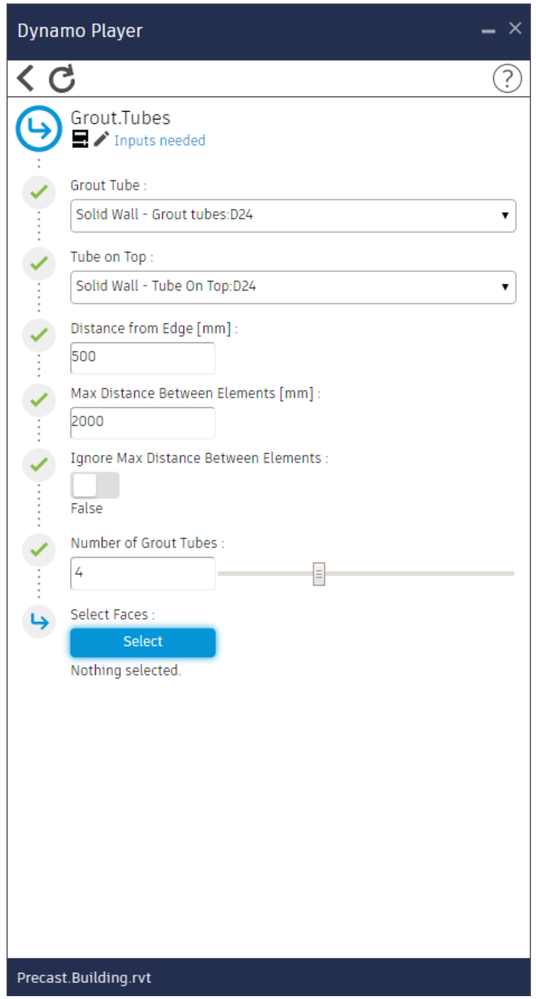
Dynamo Player

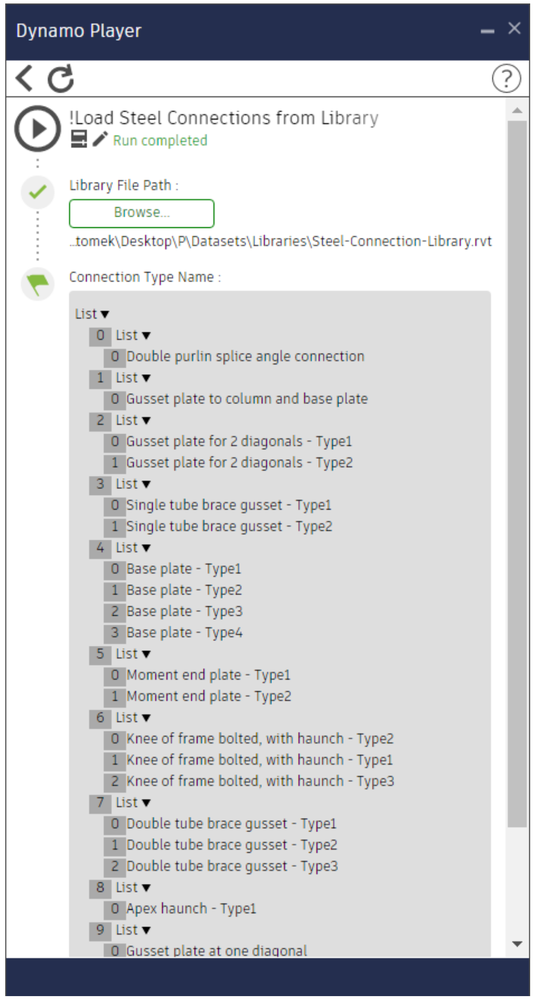
Inputs & Outputs

- Supported input types
  - Select Model Element
  - Select Model Elements
  - Categories
  - Element Types
  - File Path
  - Directory Path
  - String
  - Levels
  - Boolean
  - Number
  - Number Slider
  - Integer Slider
  - Views
  - Number From Feet and Inches
- Outputs
  - Watch nodes









Structural Design Dynamo Package

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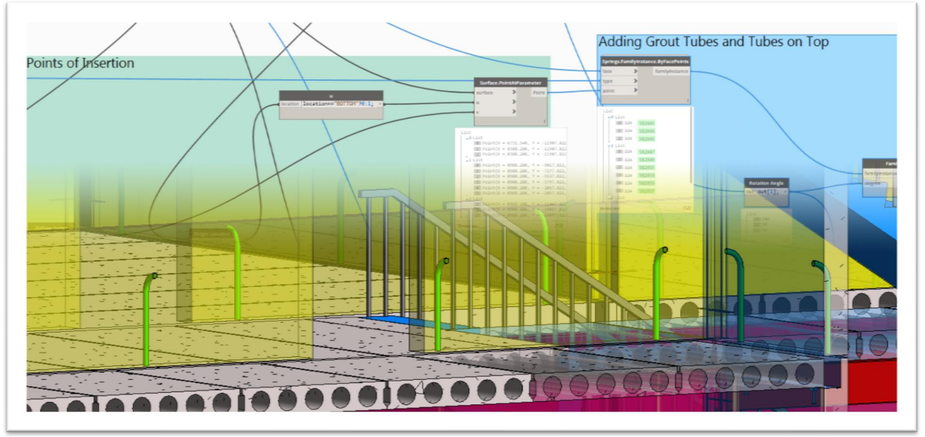
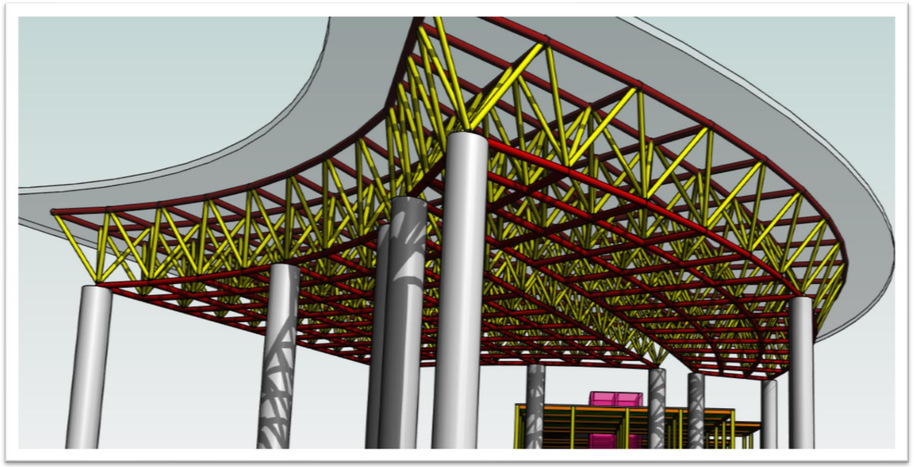
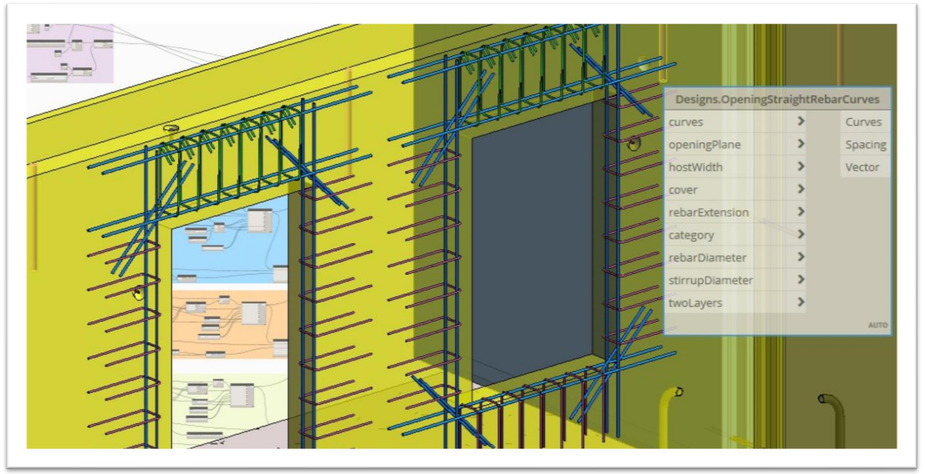
Overview

Structural Design Dynamo Package

- Supports various structural workflows in Dynamo and Revit
- Nodes are shared with example scripts to automate workflows
- Cross-industry nodes
- Compatible with Dynamo 2.3
- 70 nodes and the number is growing…



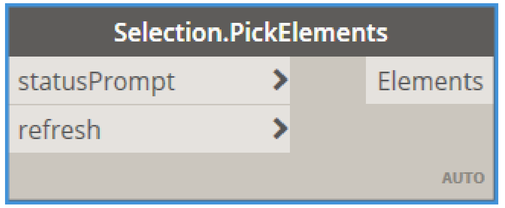


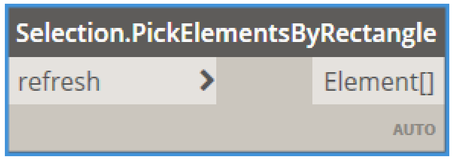


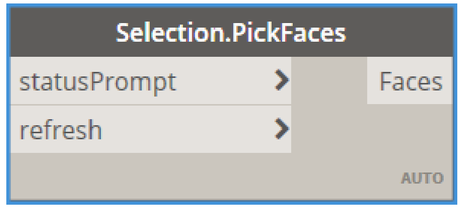
Selection

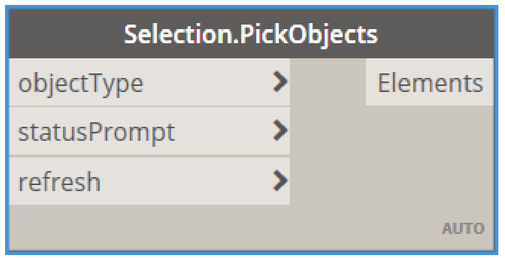
Structural Design Dynamo Package

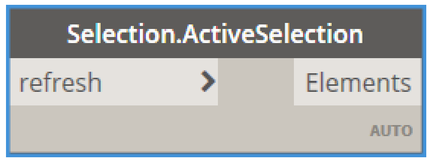
- Selection Nodes
  - 7 nodes to enhance default Dynamo selection of Revit model elements
  - Filter selection by categories
  - Different types of selection
    - Pick Element,
    - Pick Elements by Rectangle
    - Pick Faces

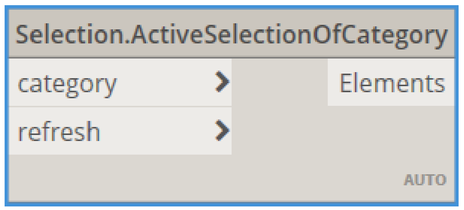


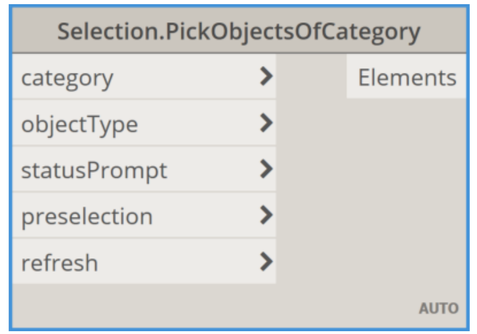


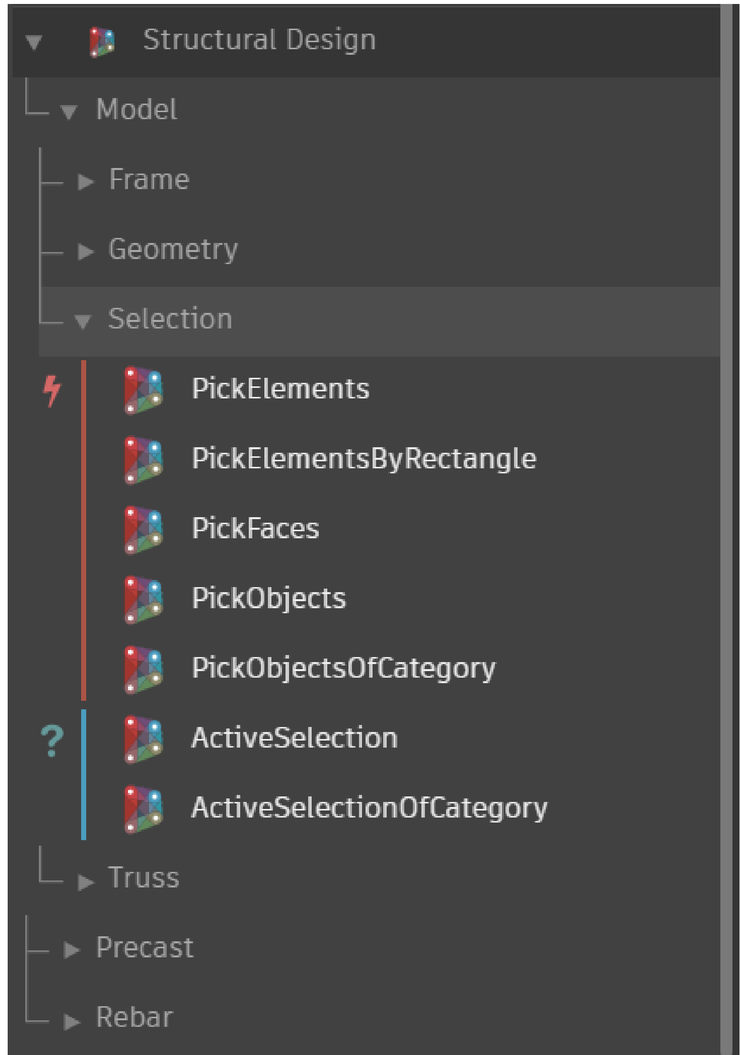












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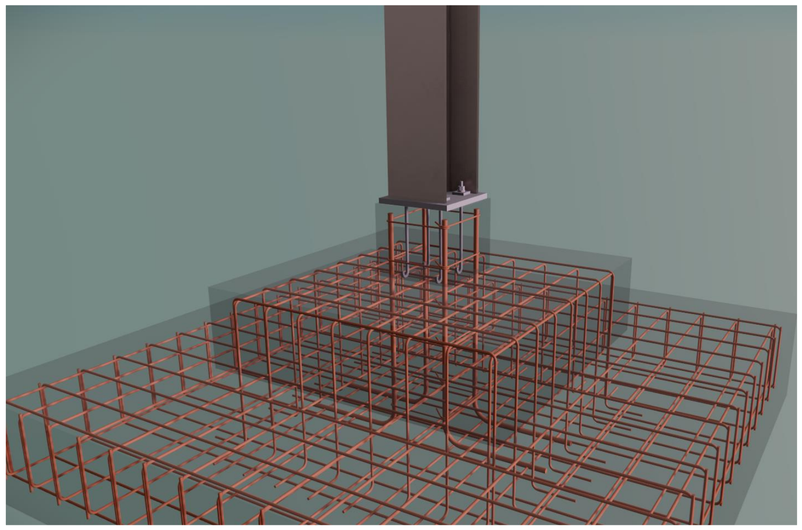
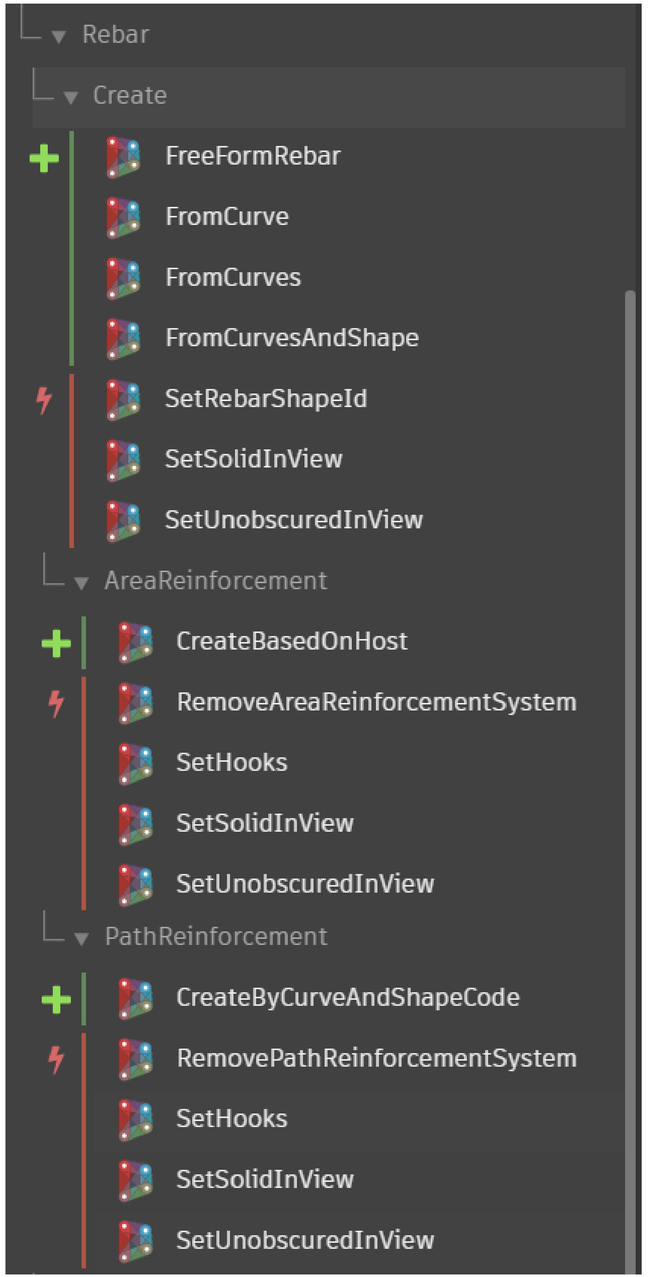
DEMO

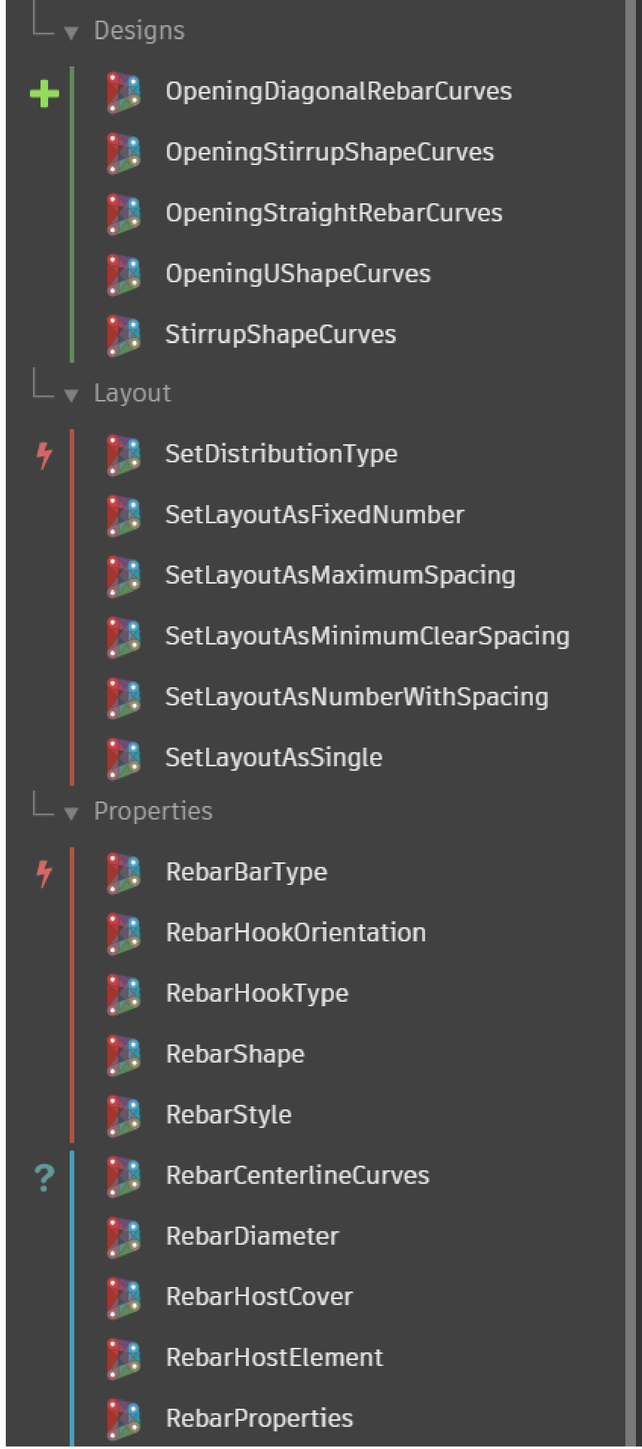
Concrete Detailing

Structural Design Dynamo Package

- Rebar Nodes
  - 38 nodes to automate rebar detailing
  - Area & Path reinforcement
  - Typical Rebar Designs
  - Rebar Visibility Control

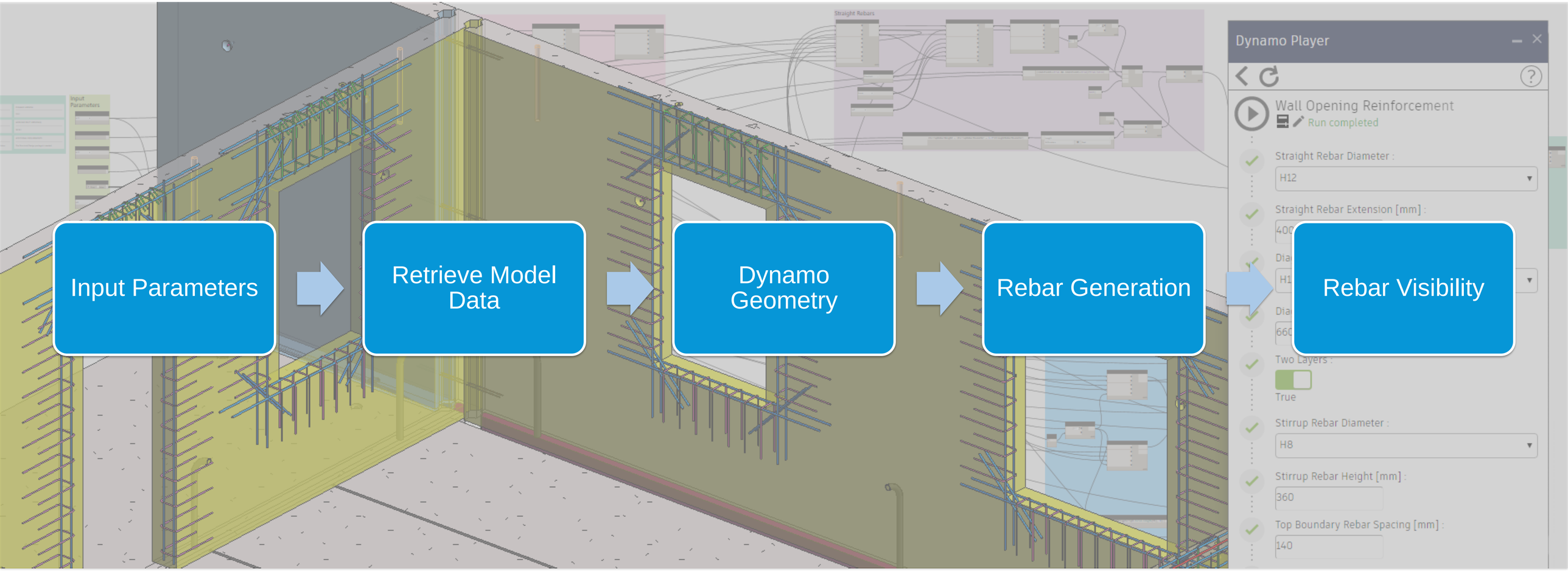






Concrete Detailing: Process

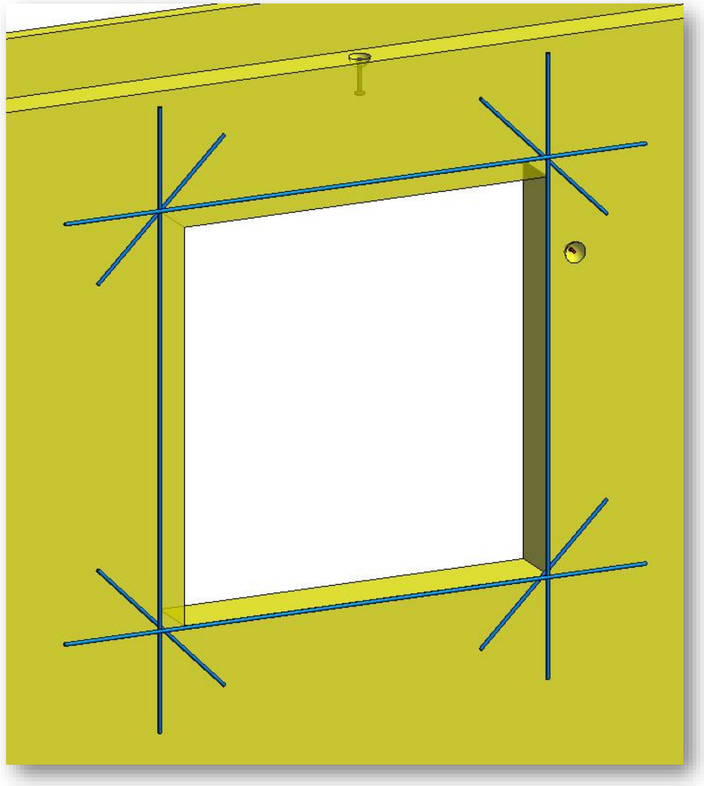
Structural Design Dynamo Package



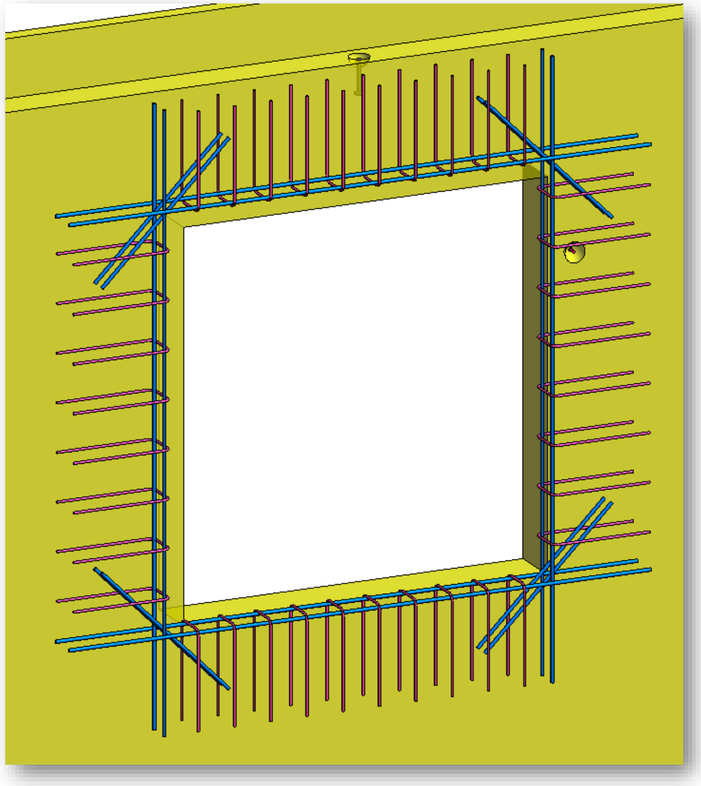
Concrete Detailing

Structural Design Dynamo Package

- Automated process of reinforcement detailing around wall openings

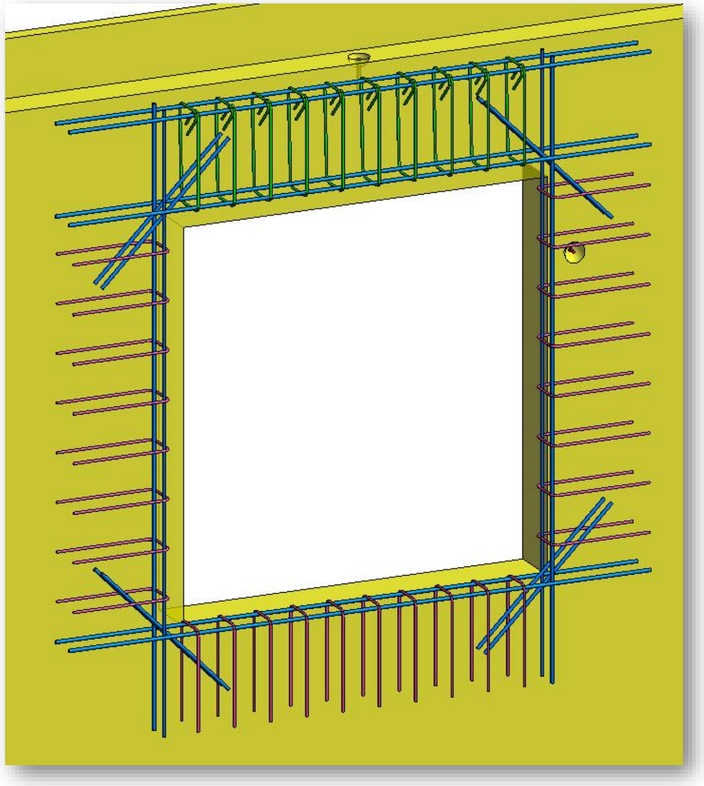


One Layer



Two Layers &

Top Stirrups with U-shape



Two Layers &

Top Stirrups are Closed

Automated Rebar Modeling with Dynamo Player

TIMESAVER

AUTOMATED
VS
MANUAL

Manual Rebar Modeling

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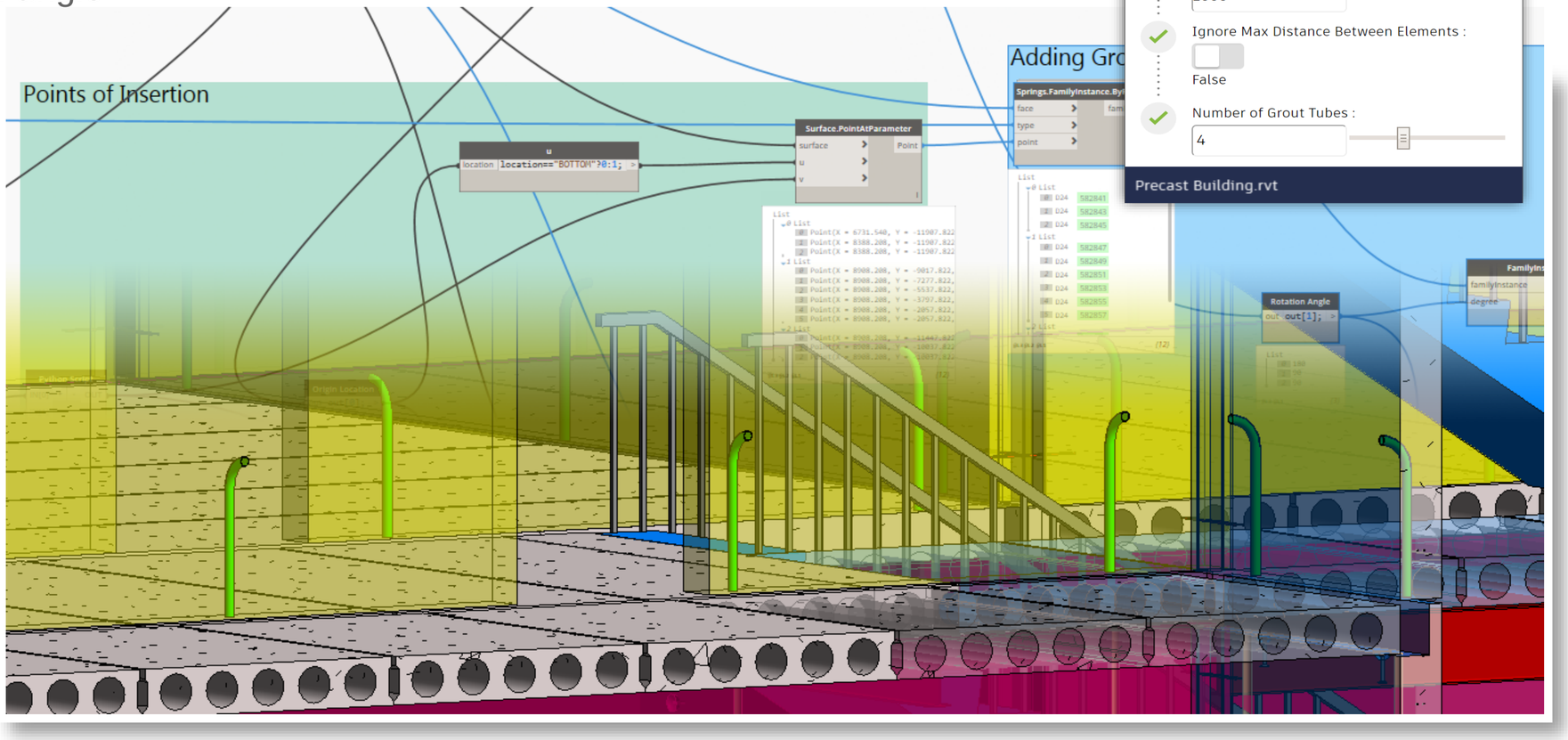
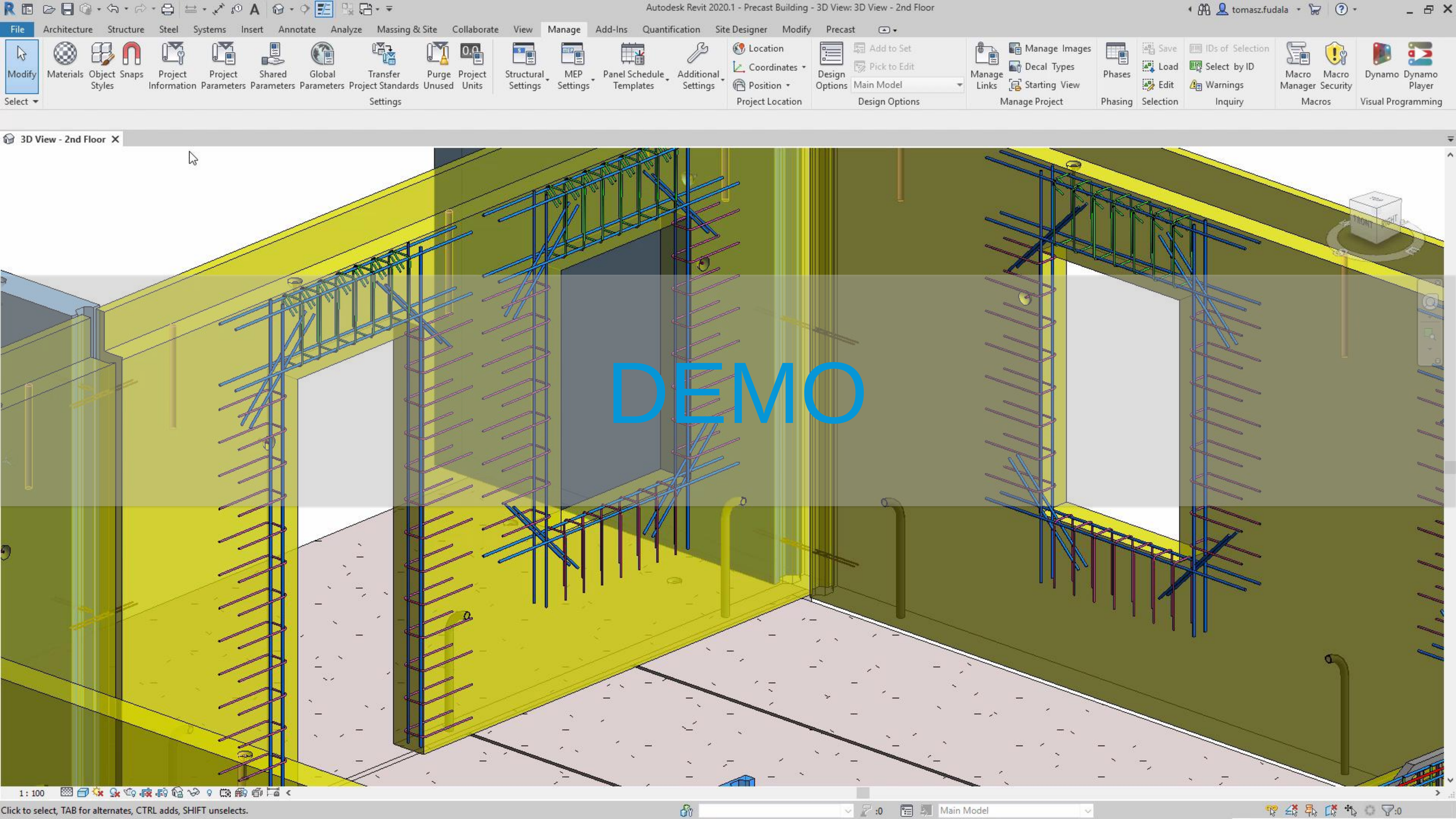
Precast Concrete Detailing

Structural Design Dynamo Package

- Grout Tubes Automation
  - Get point parameters based on specified division
  - Calculate grout tube rotation angle

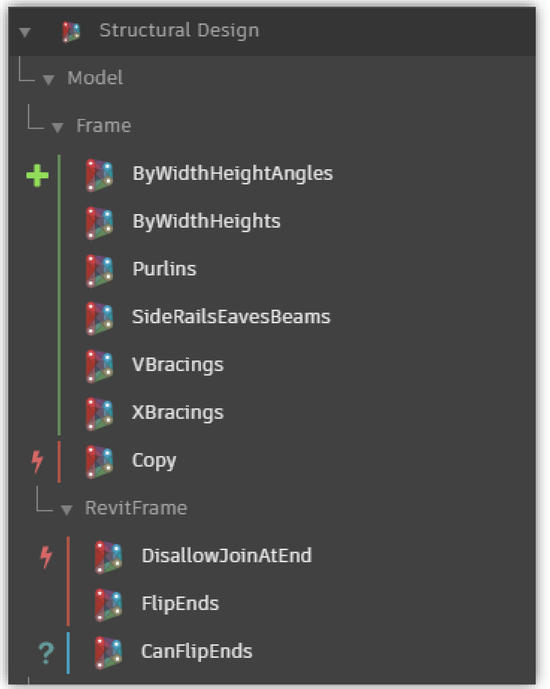


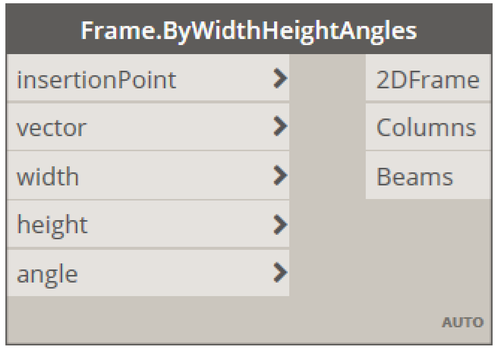

Autodesk Revit 2020.1 - Precast Building - 3D View: 3D View - 2nd Floor
tomasz.fudala
File
Architecture
Structure
Steel
Systems
Insert
Annotate
Analyze
Massing & Site
Collaborate
View
Manage
Add-Ins
Quantification
Site Designer
Modify
Precast
Modify
Select
Materials
Object Styles
Snaps
Project Information
Project Parameters
Shared Parameters
Global Parameters
Transfer Project Standards
Purge Unused
Project Units
Settings
Structural Settings
MEP Settings
Panel Schedule Templates
Additional Settings
Location
Coordinates
Position
Project Location
Design Options
Add to Set
Pick to Edit
Main Model
Design Options
Manage Links
Manage Images
Decal Types
Starting View
Manage Project
Phases
Phasing
Save
Load
Edit
Selection
IDs of Selection
Select by ID
Warnings
Inquiry
Macro Manager
Macro Security
Macros
Dynamo
Dynamo Player
Visual Programming
3D View - 2nd Floor
DEMO
1 : 100
Click to select, TAB for alternates, CTRL adds, SHIFT unselects.
Main Model

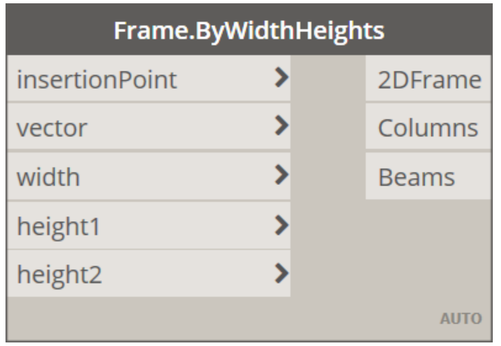
Frame Design

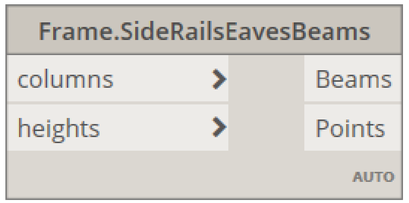
Structural Design Dynamo Package

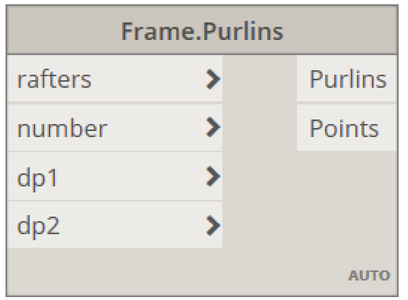
- Frame Design Automation
  - 10 nodes to automate frame design

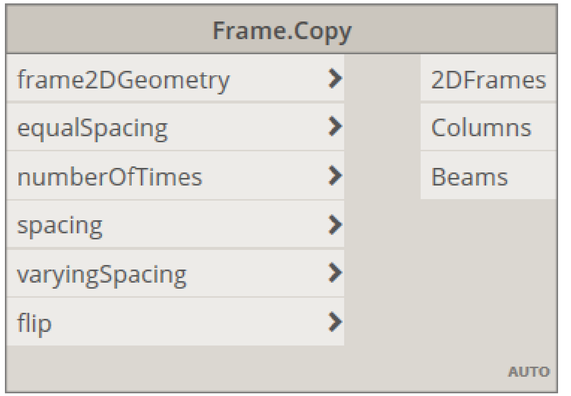


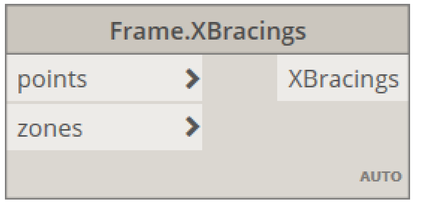


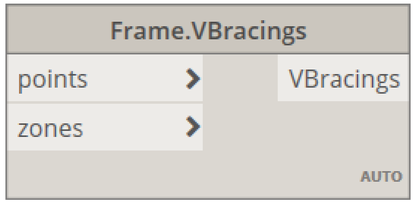


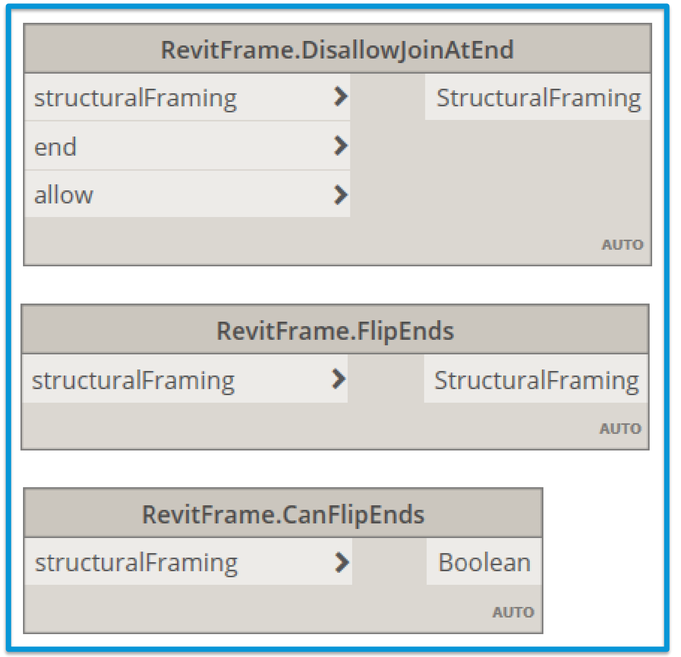






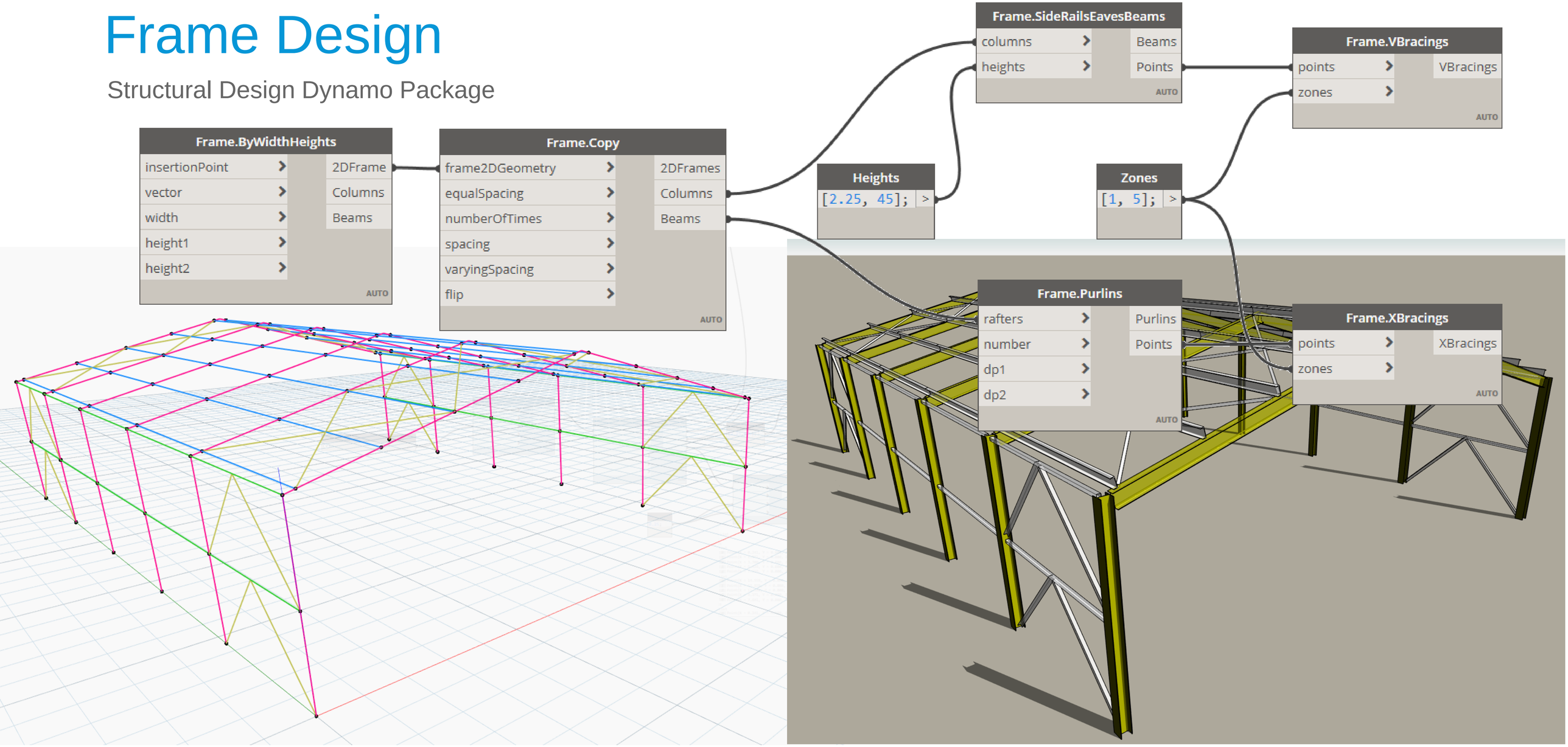






Frame Design

Structural Design Dynamo Package



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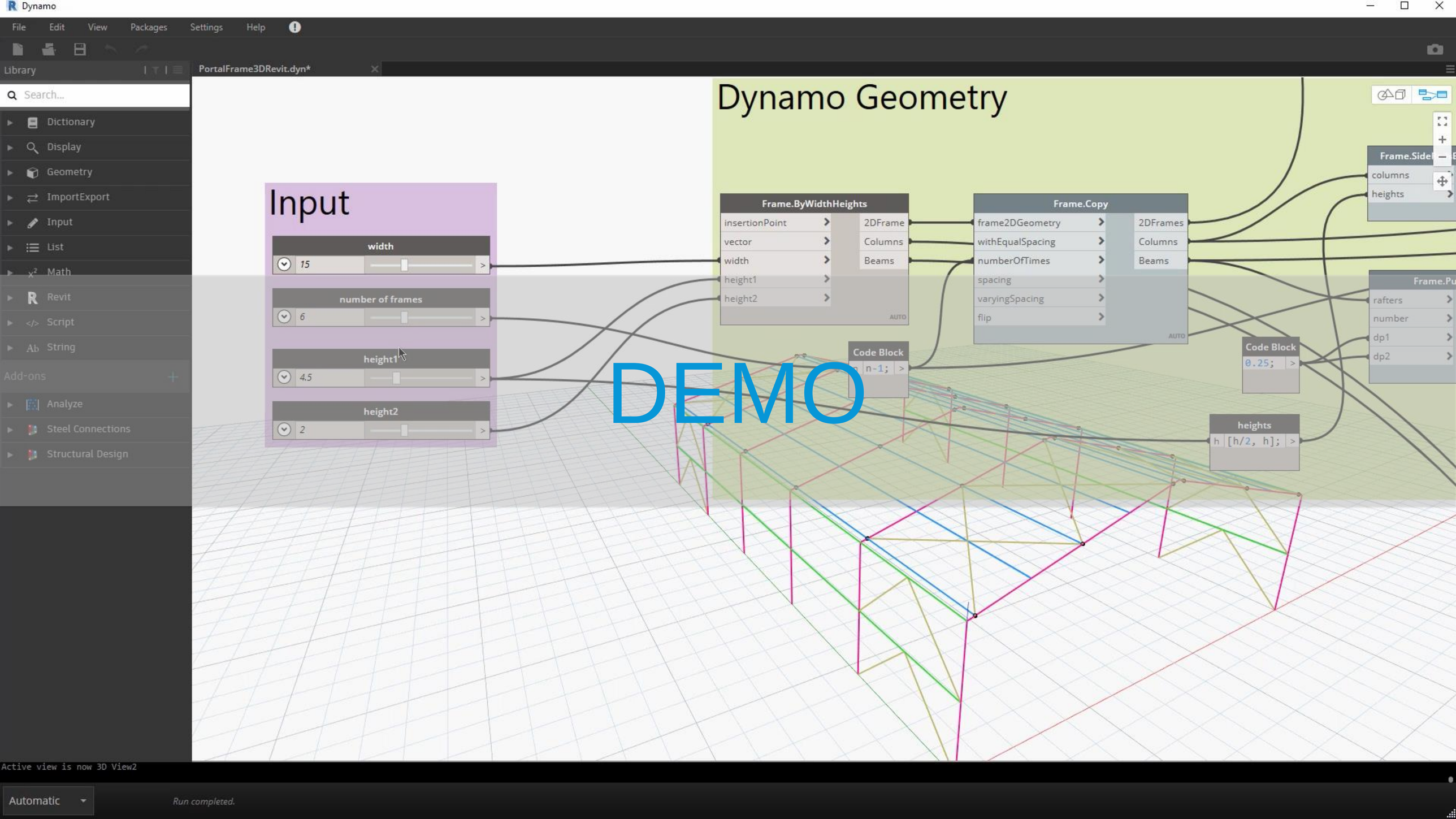
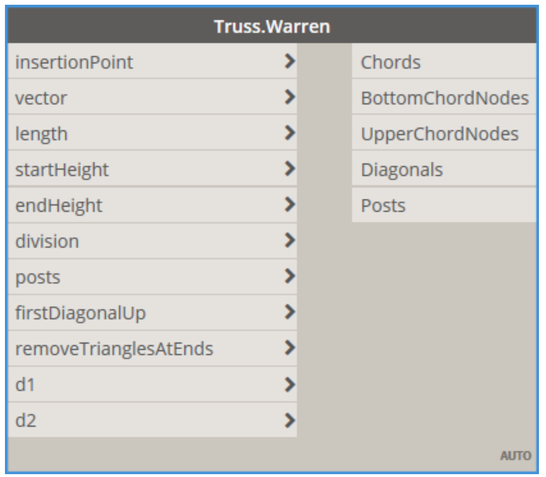
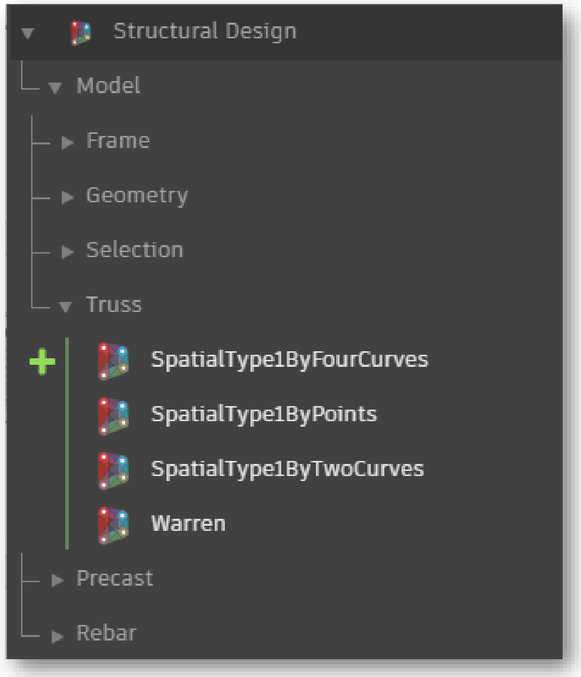

Dynamo
File
Edit
View
Packages
Settings
Help
Library
Search...
Dictionary
Display
Geometry
ImportExport
Input
List
Math
Revit
Script
String
Add-ons
Analyze
Steel Connections
Structural Design
PortalFrame3DRevit.dyn*
Dynamo Geometry
Input
width
15
number of frames
6
height1
4.5
height2
2
Frame.ByWidthHeights
insertionPoint
vector
width
height1
height2
2DFrame
Columns
Beams
AUTO
Frame.Copy
frame2DGeometry
withEqualSpacing
numberOfTimes
spacing
varyingSpacing
flip
2DFrames
Columns
Beams
AUTO
Code Block
n-1;
Code Block
0.25;
heights
h [h/2, h];
Frame.Side
columns
heights
Frame.Pu
rafters
number
dp1
dp2
DEMO
Active view is now 3D View2
Automatic
Run completed.

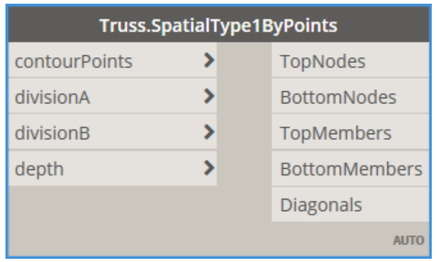
Truss Design

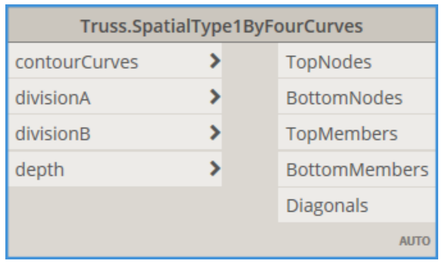
Structural Design Dynamo Package

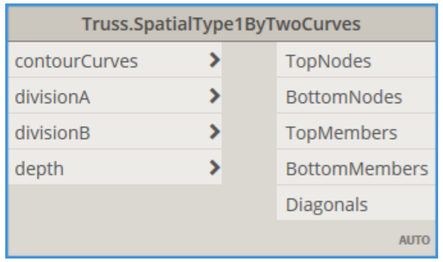
- Truss Design Automation
  - 4 nodes to automate frame design
- Warren truss
- Special truss
  - By boundary points
  - By two curves
  - By four curves
- Easy of usage







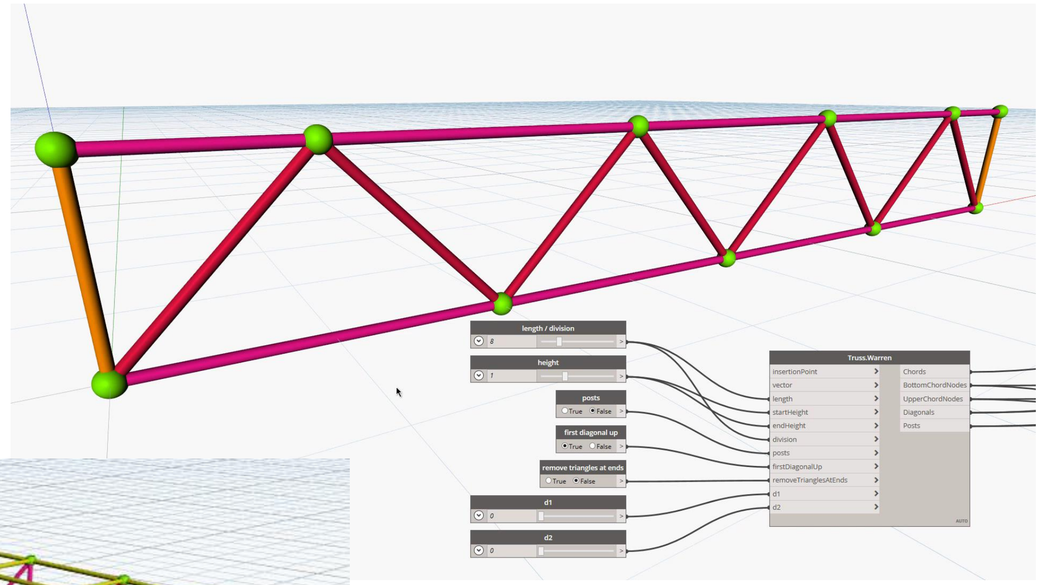


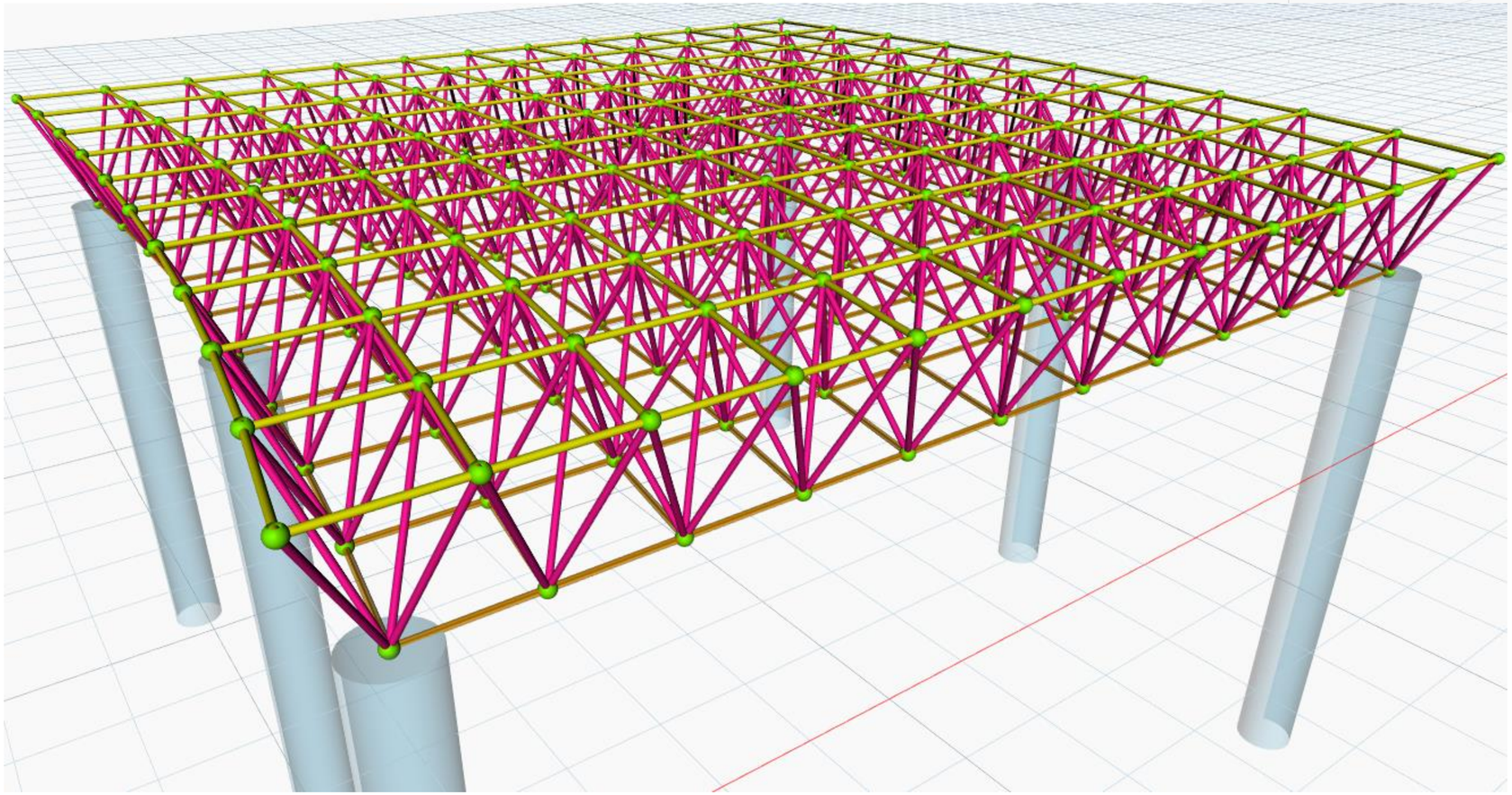


Truss Design

Structural Design Dynamo Package

- Examples

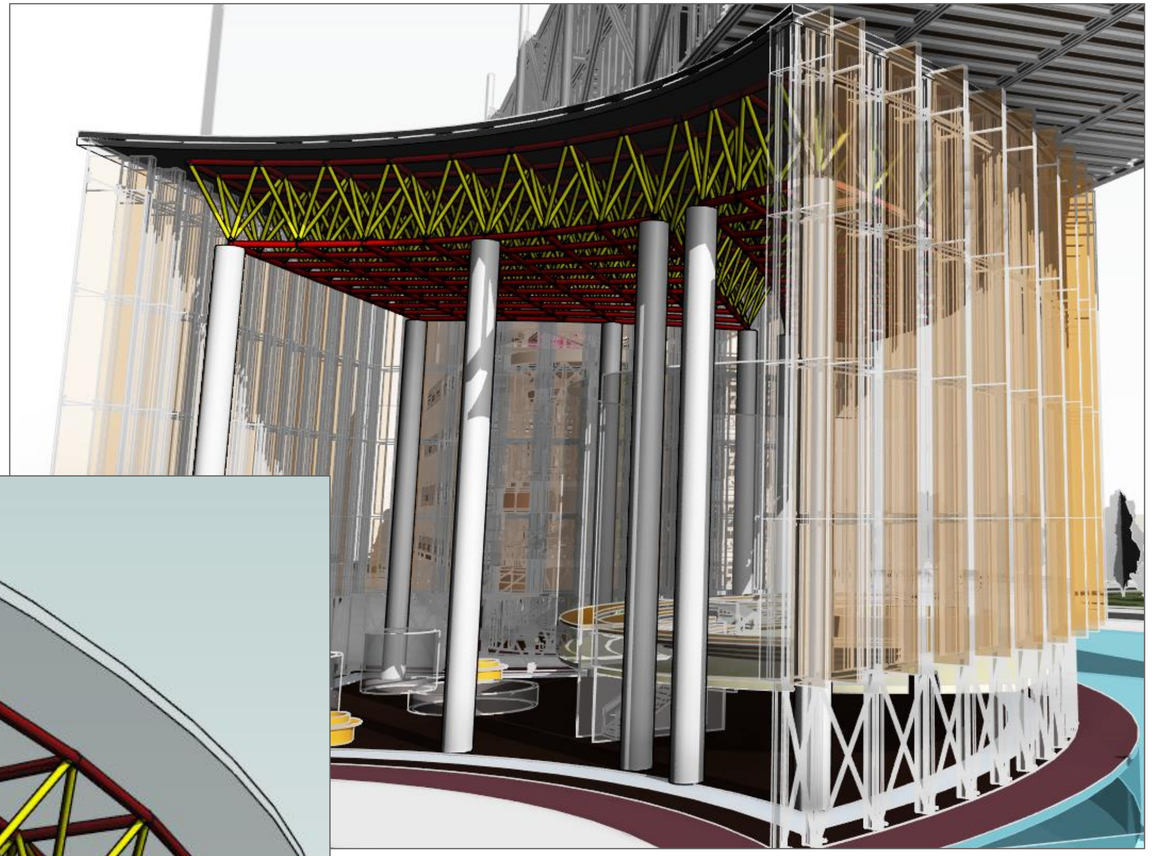


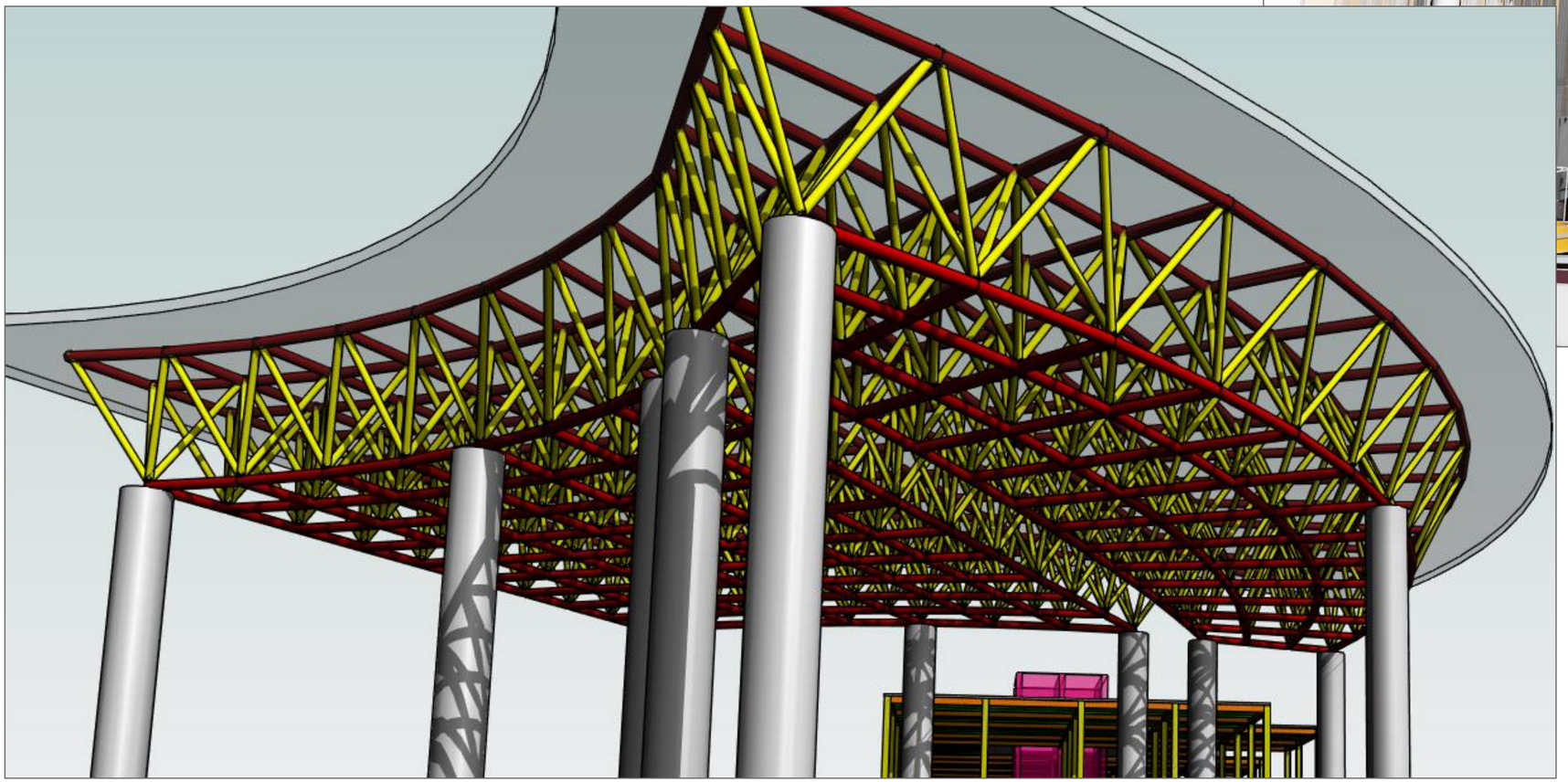


Truss Design

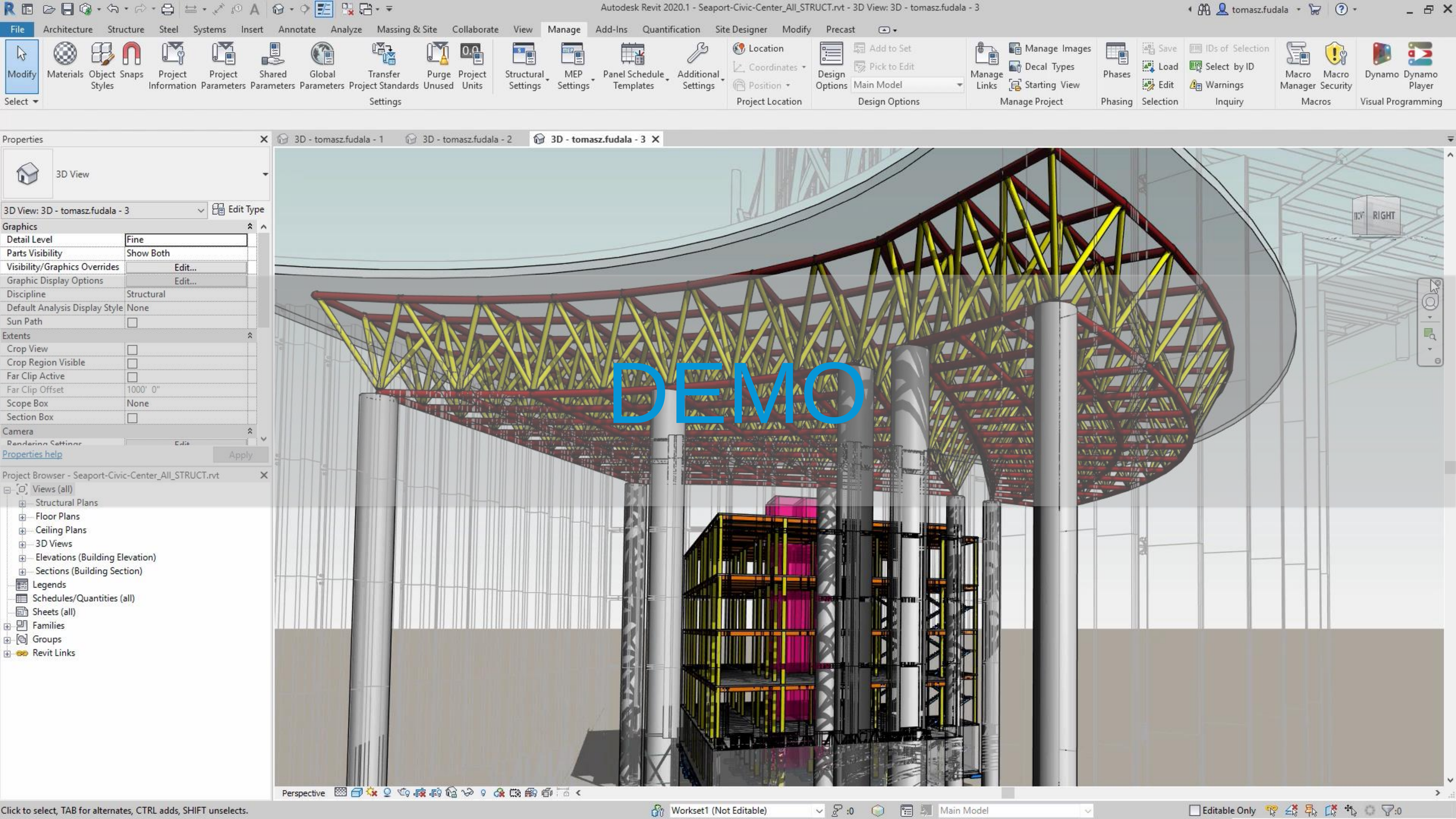
Structural Design Dynamo Package

- Examples





@TomekF


Autodesk Revit 2020.1 - Seaport-Civic-Center_All_STRUCT.rvt - 3D View: 3D - tomasz.fudala - 3
tomasz.fudala
File
Architecture
Structure
Steel
Systems
Insert
Annotate
Analyze
Massing & Site
Collaborate
View
Manage
Add-Ins
Quantification
Site Designer
Modify
Precast
Modify
Select
Materials
Object Styles
Snaps
Project Information
Project Parameters
Shared Parameters
Global Parameters
Transfer Project Standards
Purge Unused
Project Units
Settings
Structural Settings
MEP Settings
Panel Schedule Templates
Additional Settings
Location
Coordinates
Position
Project Location
Design Options
Add to Set
Pick to Edit
Main Model
Design Options
Manage Links
Manage Images
Decal Types
Starting View
Manage Project
Phases
Phasing
Save
Load
Edit
Selection
IDs of Selection
Select by ID
Warnings
Inquiry
Macro Manager
Macro Security
Macros
Dynamo
Dynamo Player
Visual Programming
Properties
3D View
3D View: 3D - tomasz.fudala - 3
Edit Type
Graphics
Detail Level
Fine
Parts Visibility
Show Both
Visibility/Graphics Overrides
Edit...
Graphic Display Options
Edit...
Discipline
Structural
Default Analysis Display Style
None
Sun Path
Extents
Crop View
Crop Region Visible
Far Clip Active
Far Clip Offset
1000' 0"
Scope Box
None
Section Box
Camera
Properties help
Apply
Project Browser - Seaport-Civic-Center_All_STRUCT.rvt
Views (all)
Structural Plans
Floor Plans
Ceiling Plans
3D Views
Elevations (Building Elevation)
Sections (Building Section)
Legends
Schedules/Quantities (all)
Sheets (all)
Families
Groups
Revit Links
3D - tomasz.fudala - 1
3D - tomasz.fudala - 2
3D - tomasz.fudala - 3
DEMO
RIGHT
Perspective
Click to select, TAB for alternates, CTRL adds, SHIFT unselects.
Workset1 (Not Editable)
Main Model
Editable Only

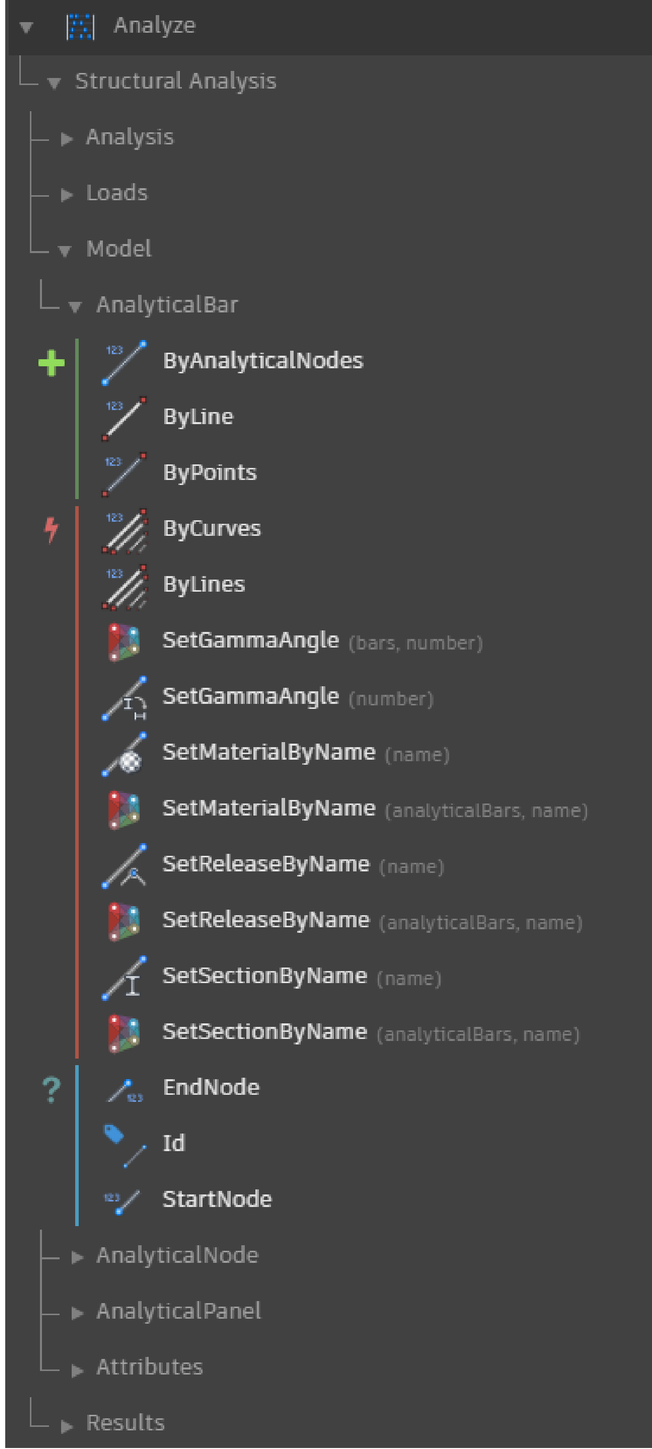
Structural Analysis for Dynamo Package

@TomekF

Automate structural analysis

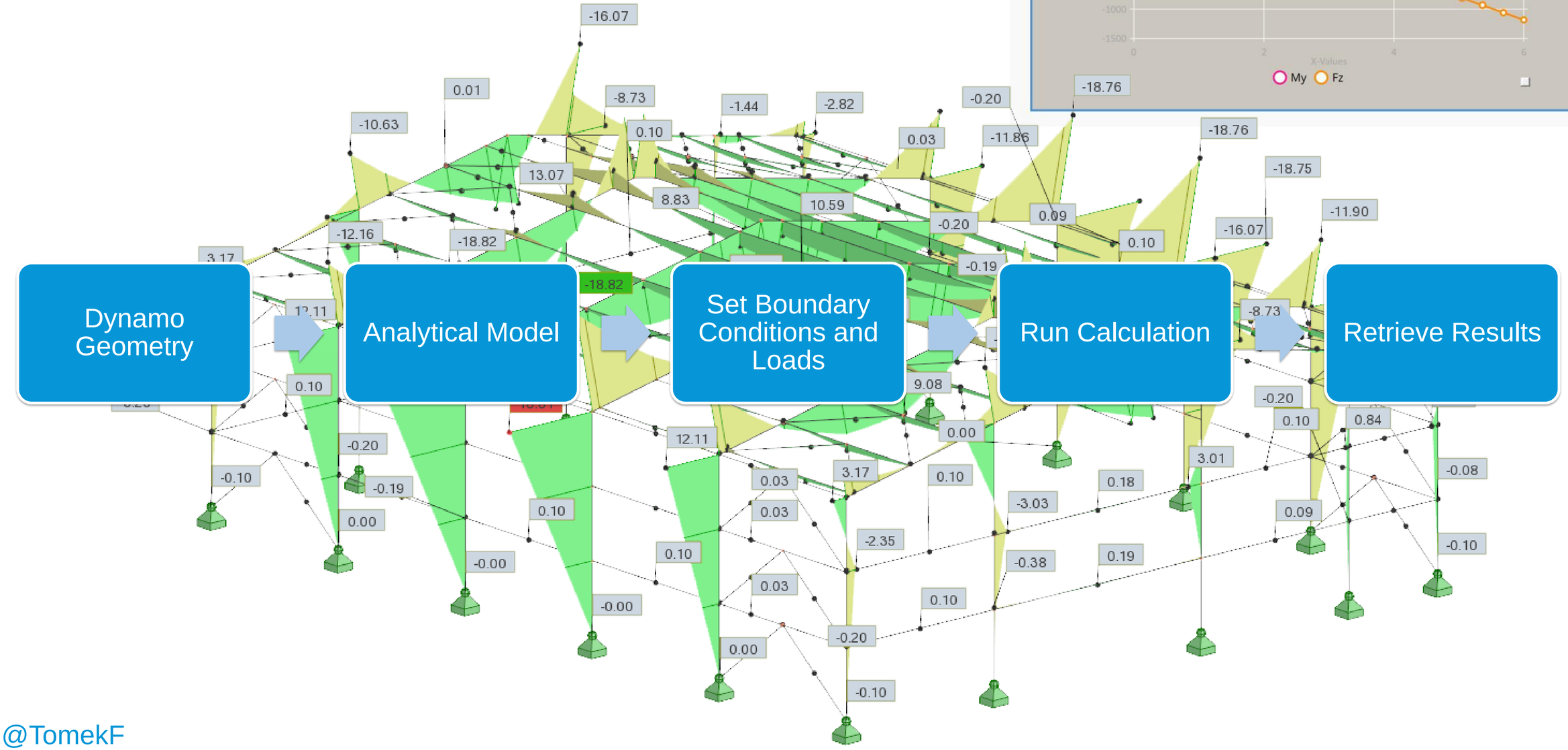
Structural Analysis for Dynamo Package, Robot Structural Analysis

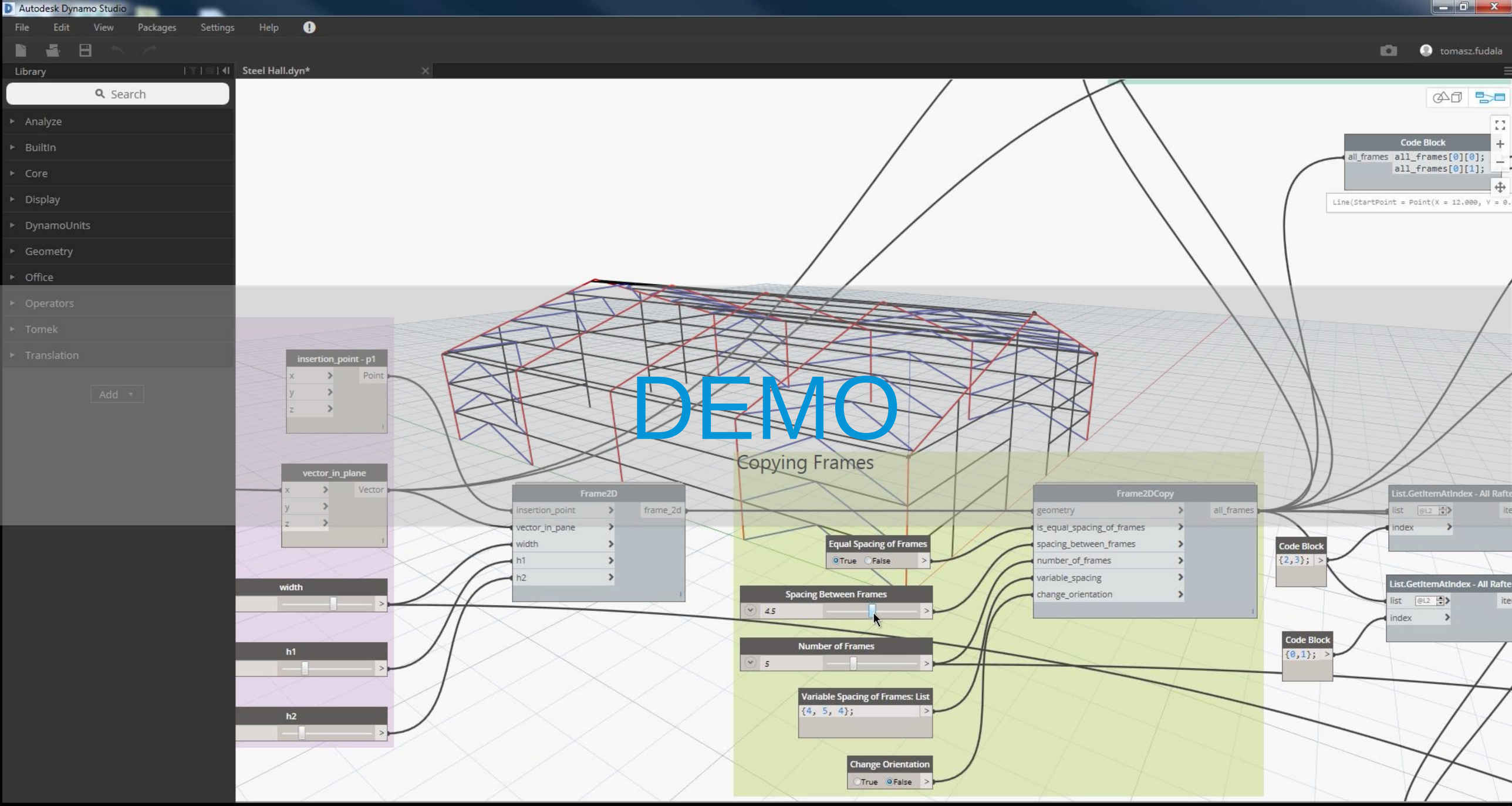
- Create Analytical Model in Robot
  - Analytical Nodes, Lines, Surfaces
- Set Attributes: Section Shapes, Gamma Angles, Materials
- Definition of Boundary Conditions
  - Supports, Releases
- Definition of Loads
  - Load cases
  - Applying: nodal, linear and surface loads
- Running Calculation from Dynamo
- Getting results of the analysis from RSA in Dynamo



Automate structural analysis

Structural Analysis for Dynamo Package, Robot Structural Analysis

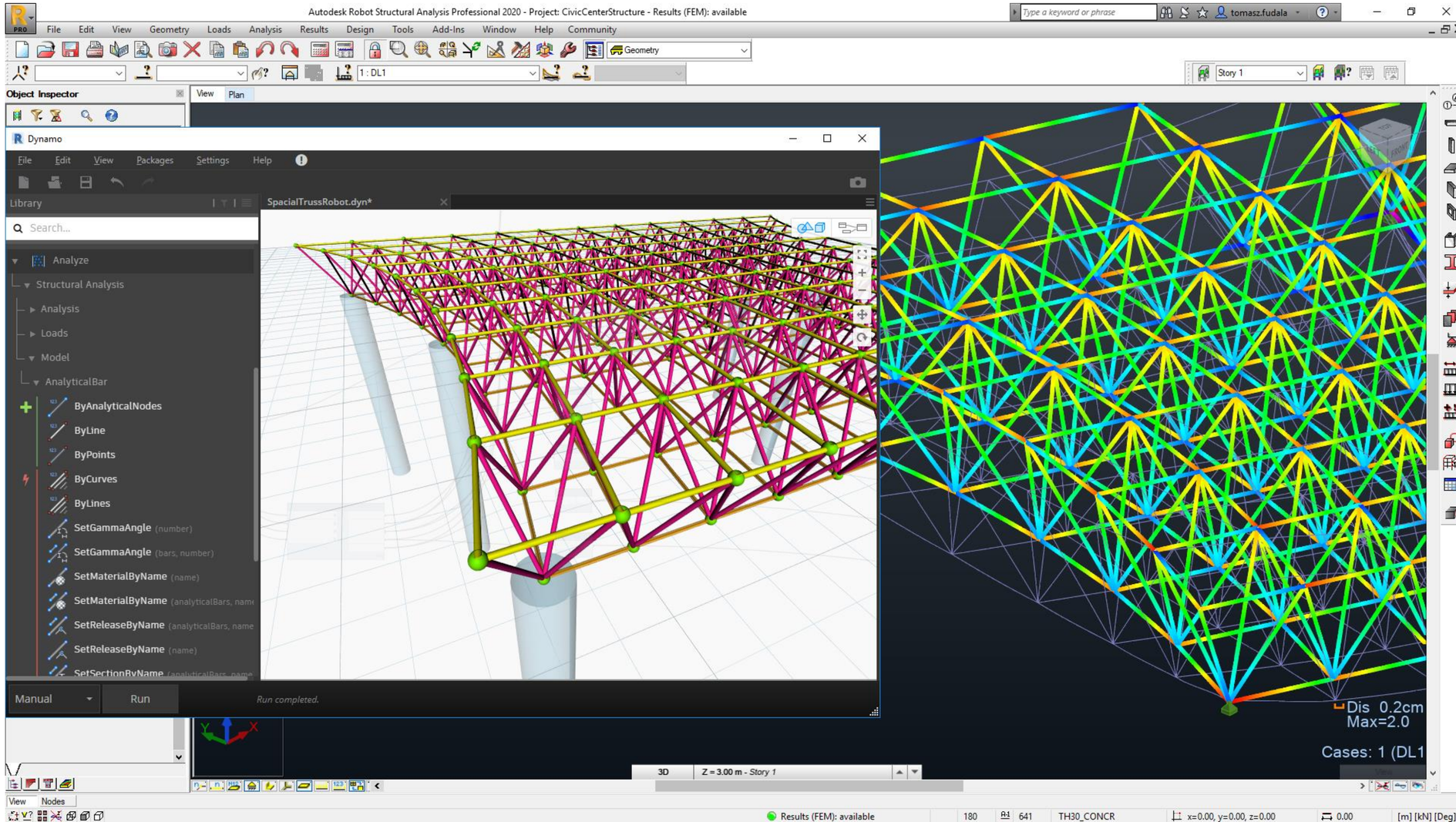



Autodesk Dynamo Studio
File
Edit
View
Packages
Settings
Help
tomasz.fudala
Library
Steel Hall.dyn*
Search
Analyze
BuiltIn
Core
Display
DynamoUnits
Geometry
Office
Operators
Tomek
Translation
Add
DEMO
Copying Frames
insertion_point - p1
x
y
z
Point
vector_in_plane
Vector
width
h1
h2
Frame2D
insertion_point
vector_in_pane
width
h1
h2
frame_2d
Equal Spacing of Frames
True
False
Spacing Between Frames
4.5
Number of Frames
5
Variable Spacing of Frames: List
{4, 5, 4};
Change Orientation
Frame2DCopy
geometry
is_equal_spacing_of_frames
spacing_between_frames
number_of_frames
variable_spacing
change_orientation
all_frames
Code Block
all_frames[0][0];
all_frames[0][1];
Line(StartPoint = Point(X = 12.000, Y = 0.
{2,3};
{0,1};
List.GetItemAtIndex - All Rafte
list
index
Automatic
Run completed.

Automate structural analysis

Structural Analysis for Dynamo Package, Robot Structural Analysis

- Dynamo in Robot



@TomekF

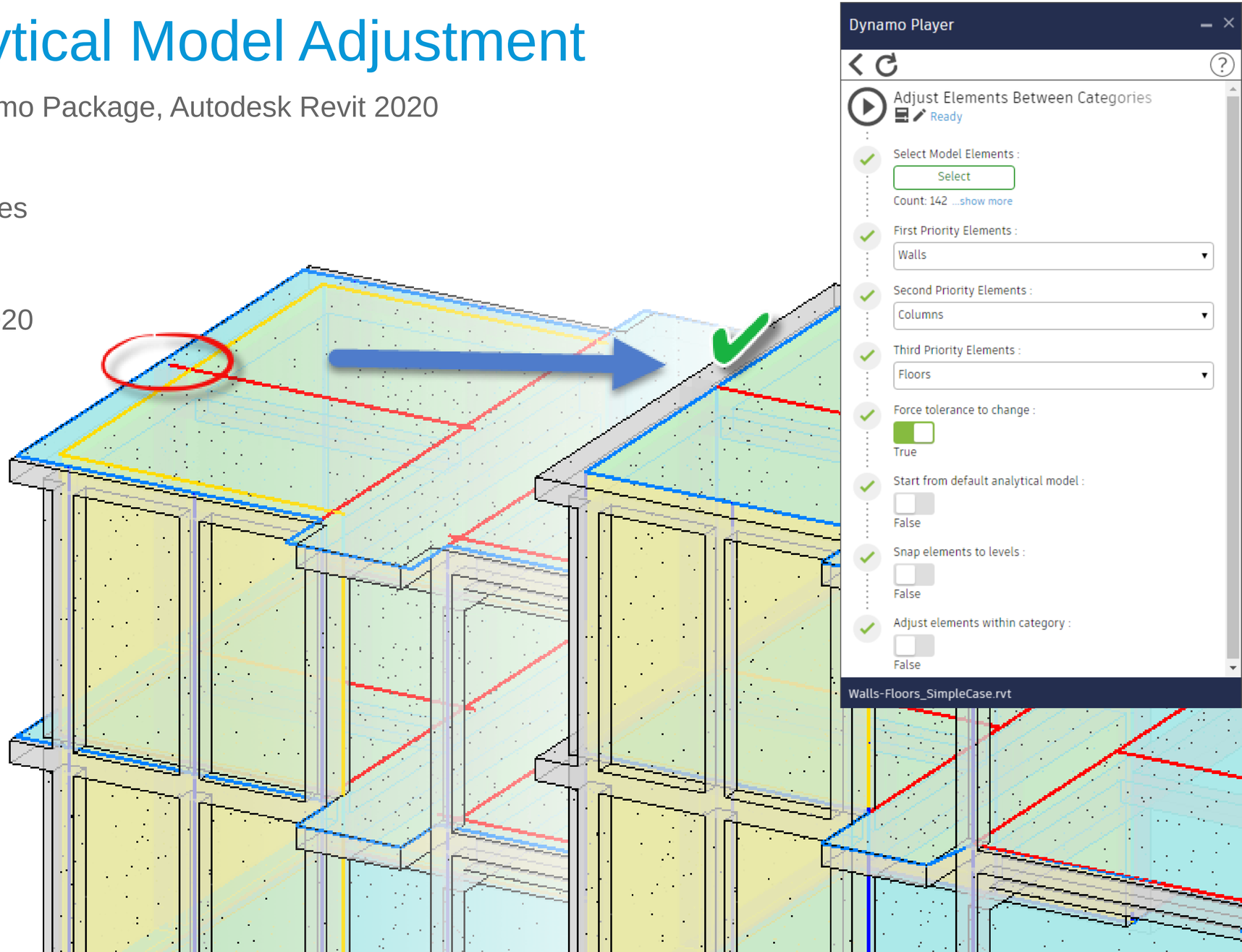
Autodesk Analytical Model Dynamo Package

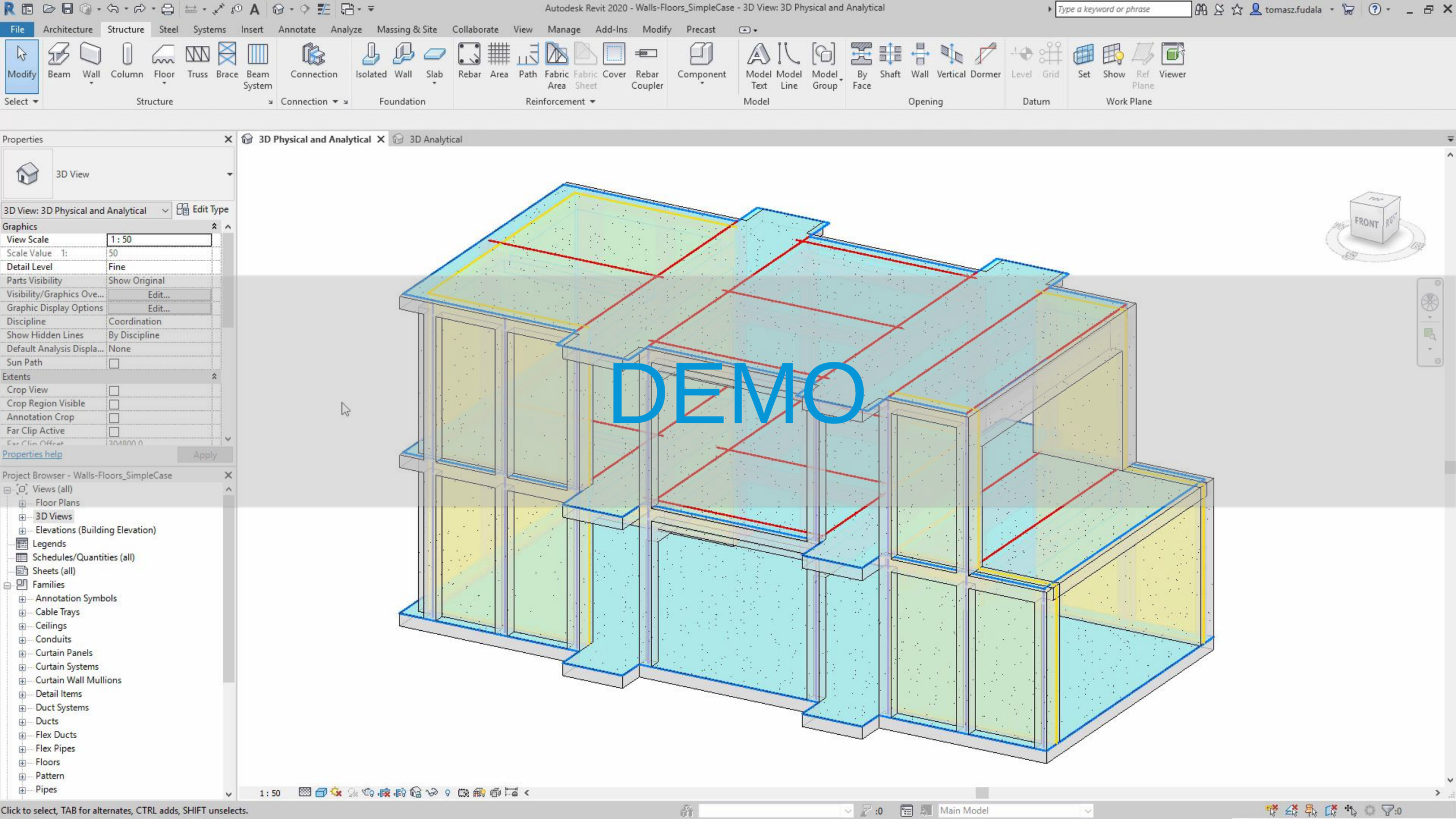
@TomekF

Automation of Analytical Model Adjustment

Autodesk Analytical Model 2020 Dynamo Package, Autodesk Revit 2020

- Adjust Elements Between Categories
- Adjust Elements Within Categories
- Works with Dynamo 2 and Revit 2020




Autodesk Revit 2020 - Walls-Floors_SimpleCase - 3D View: 3D Physical and Analytical
Type a keyword or phrase
tomasz.fudala
File
Architecture
Structure
Steel
Systems
Insert
Annotate
Analyze
Massing & Site
Collaborate
View
Manage
Add-Ins
Modify
Precast
Modify
Beam
Wall
Column
Floor
Truss
Brace
Beam System
Connection
Isolated
Wall
Slab
Rebar
Area
Path
Fabric Area
Fabric Sheet
Cover
Rebar Coupler
Component
Model Text
Model Line
Model Group
By Face
Shaft
Wall
Vertical
Dormer
Level
Grid
Set
Show
Ref Plane
Viewer
Select
Structure
Connection
Foundation
Reinforcement
Model
Opening
Datum
Work Plane
Properties
3D View
3D View: 3D Physical and Analytical
Edit Type
Graphics
View Scale
1 : 50
Scale Value 1:
50
Detail Level
Fine
Parts Visibility
Show Original
Visibility/Graphics Ove...
Edit...
Graphic Display Options
Edit...
Discipline
Coordination
Show Hidden Lines
By Discipline
Default Analysis Displa...
None
Sun Path
Extents
Crop View
Crop Region Visible
Annotation Crop
Far Clip Active
Properties help
Apply
Project Browser - Walls-Floors_SimpleCase
Views (all)
Floor Plans
3D Views
Elevations (Building Elevation)
Legends
Schedules/Quantities (all)
Sheets (all)
Families
Annotation Symbols
Cable Trays
Ceilings
Conduits
Curtain Panels
Curtain Systems
Curtain Wall Mullions
Detail Items
Duct Systems
Ducts
Flex Ducts
Flex Pipes
Floors
Pattern
Pipes
3D Physical and Analytical
3D Analytical
DEMO
FRONT
1 : 50
Click to select, TAB for alternates, CTRL adds, SHIFT unselects.
Main Model

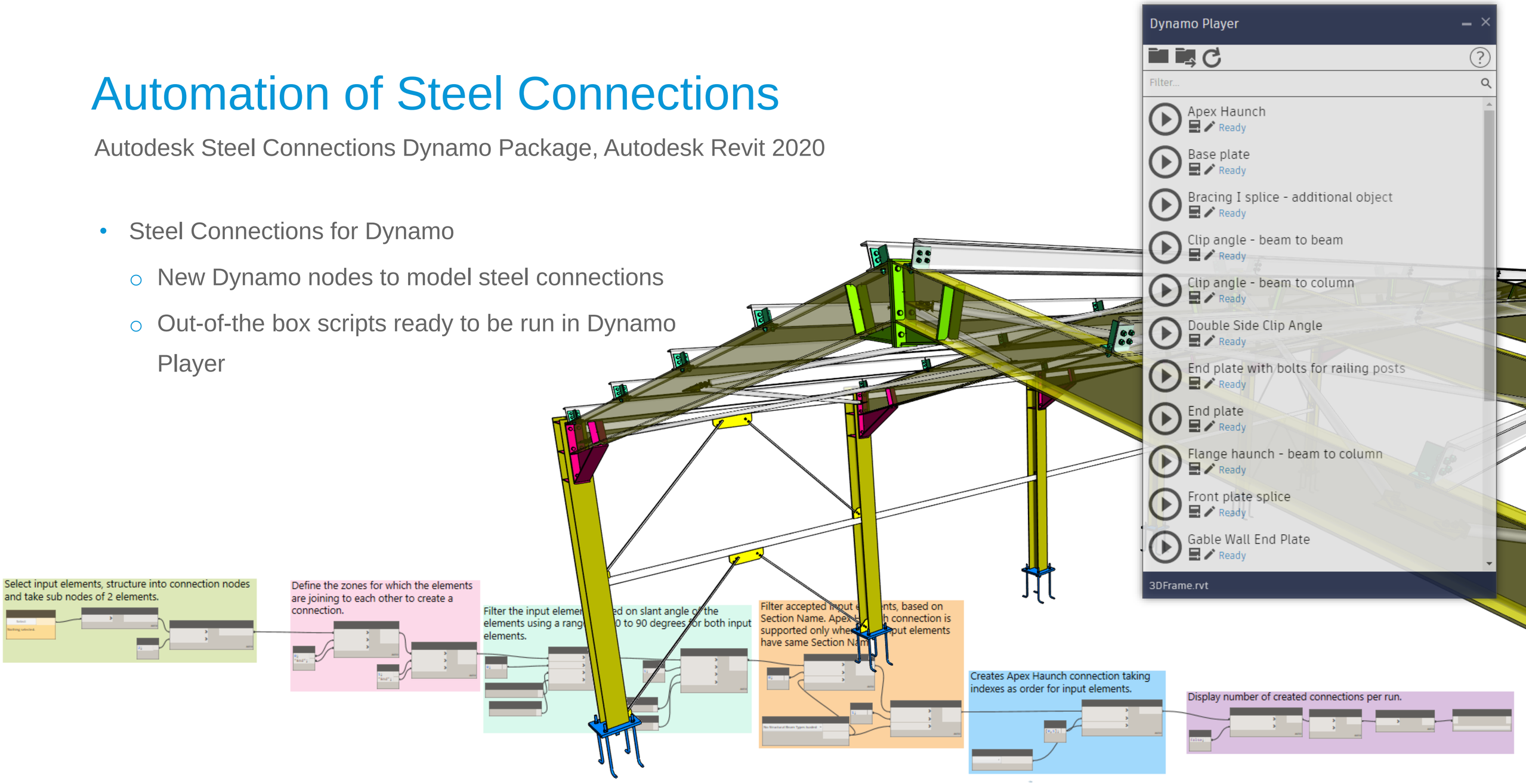
Autodesk Steel Connections Dynamo Package

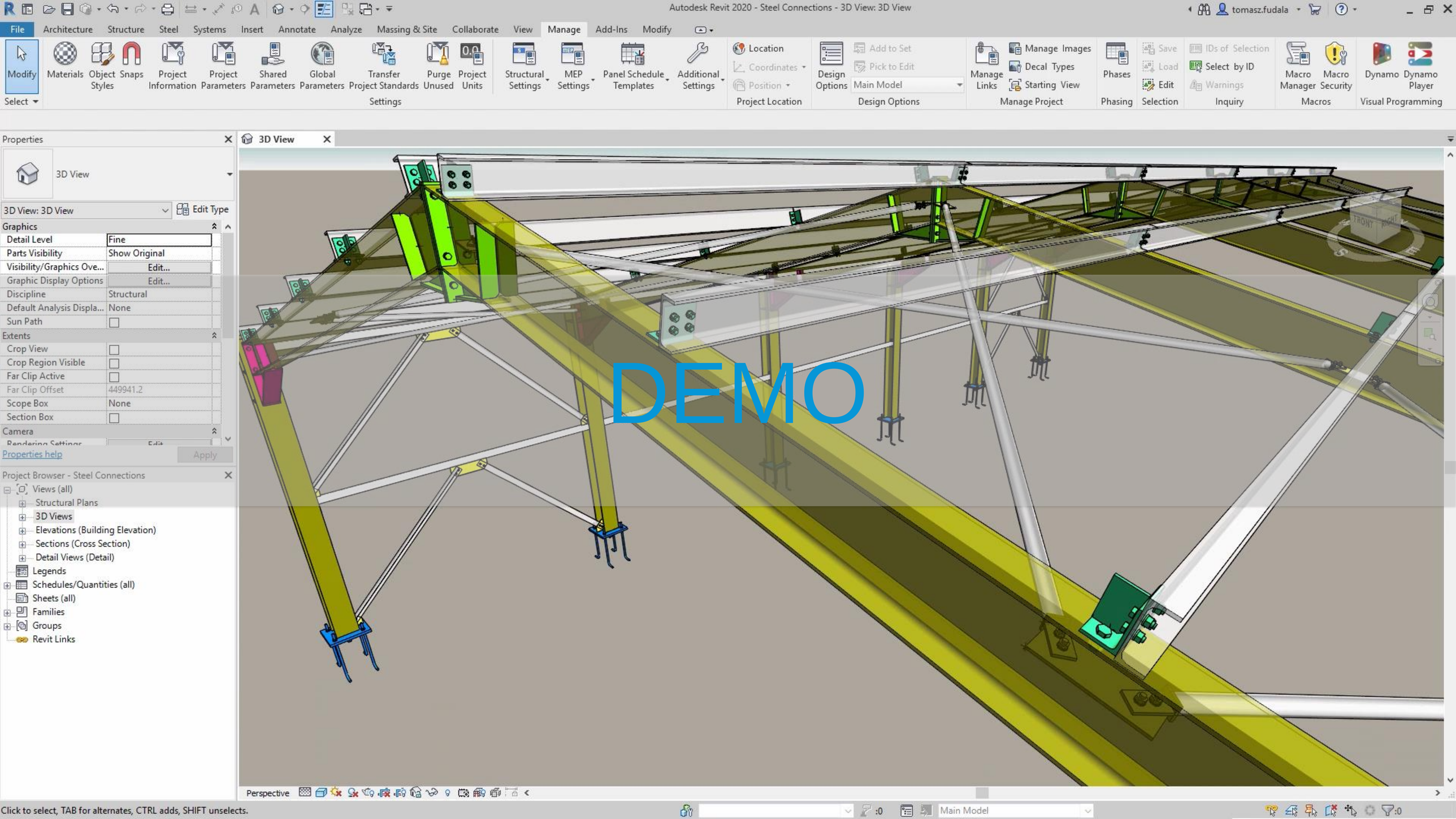
@TomekF

Automation of Steel Connections

Autodesk Steel Connections Dynamo Package, Autodesk Revit 2020

- Steel Connections for Dynamo
  - New Dynamo nodes to model steel connections
  - Out-of-the box scripts ready to be run in Dynamo Player

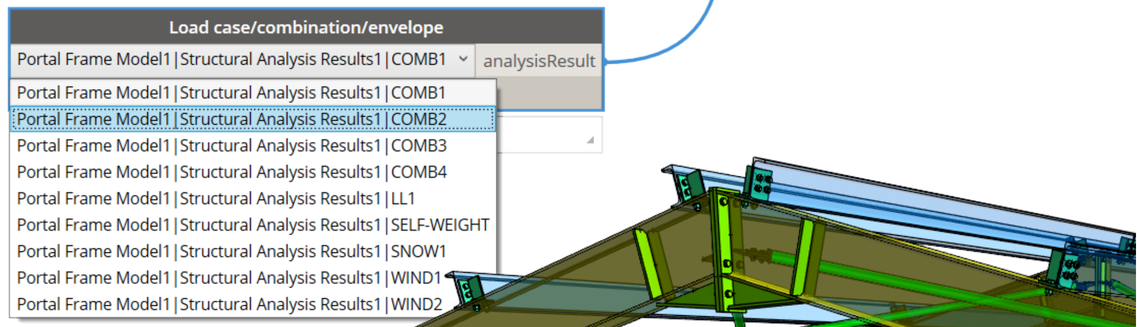


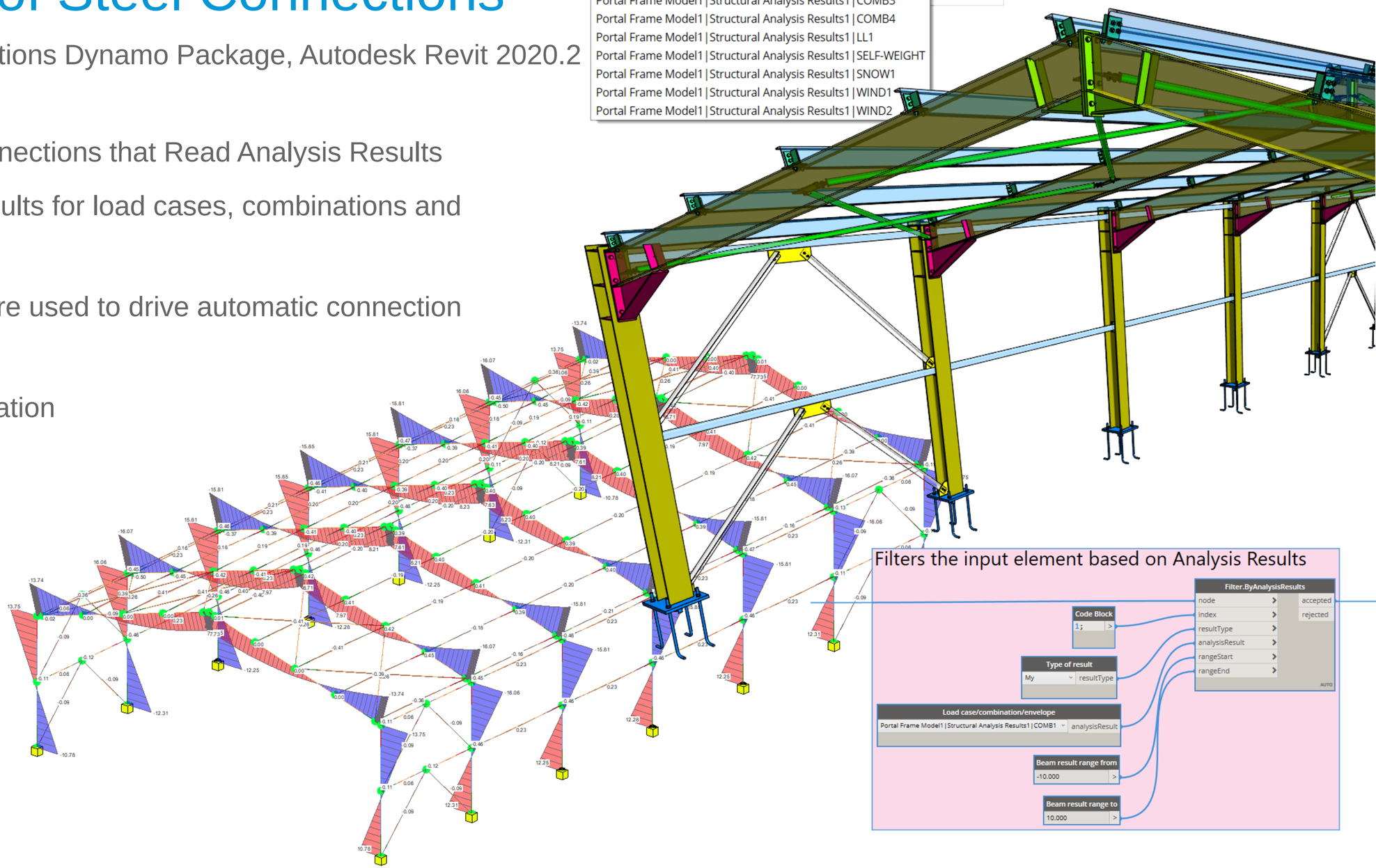

Autodesk Revit 2020 - Steel Connections - 3D View: 3D View
tomasz.fudala
File
Architecture
Structure
Steel
Systems
Insert
Annotate
Analyze
Massing & Site
Collaborate
View
Manage
Add-Ins
Modify
Modify
Select
Materials
Object Styles
Snaps
Project Information
Project Parameters
Shared Parameters
Global Parameters
Transfer Project Standards
Purge Unused
Project Units
Settings
Structural Settings
MEP Settings
Panel Schedule Templates
Additional Settings
Location
Coordinates
Position
Project Location
Add to Set
Pick to Edit
Design Options
Main Model
Design Options
Manage Links
Manage Images
Decal Types
Starting View
Manage Project
Phases
Phasing
Save
Load
Edit
Selection
IDs of Selection
Select by ID
Warnings
Inquiry
Macro Manager
Macro Security
Macros
Dynamo
Dynamo Player
Visual Programming
Properties
3D View
3D View: 3D View
Edit Type
Graphics
Detail Level
Fine
Parts Visibility
Show Original
Visibility/Graphics Ove...
Edit...
Graphic Display Options
Edit...
Discipline
Structural
Default Analysis Displa...
None
Sun Path
Extents
Crop View
Crop Region Visible
Far Clip Active
Far Clip Offset
449941.2
Scope Box
None
Section Box
Camera
Properties help
Apply
Project Browser - Steel Connections
Views (all)
Structural Plans
3D Views
Elevations (Building Elevation)
Sections (Cross Section)
Detail Views (Detail)
Legends
Schedules/Quantities (all)
Sheets (all)
Families
Groups
Revit Links
3D View
DEMO
Perspective
Click to select, TAB for alternates, CTRL adds, SHIFT unselects.
Main Model

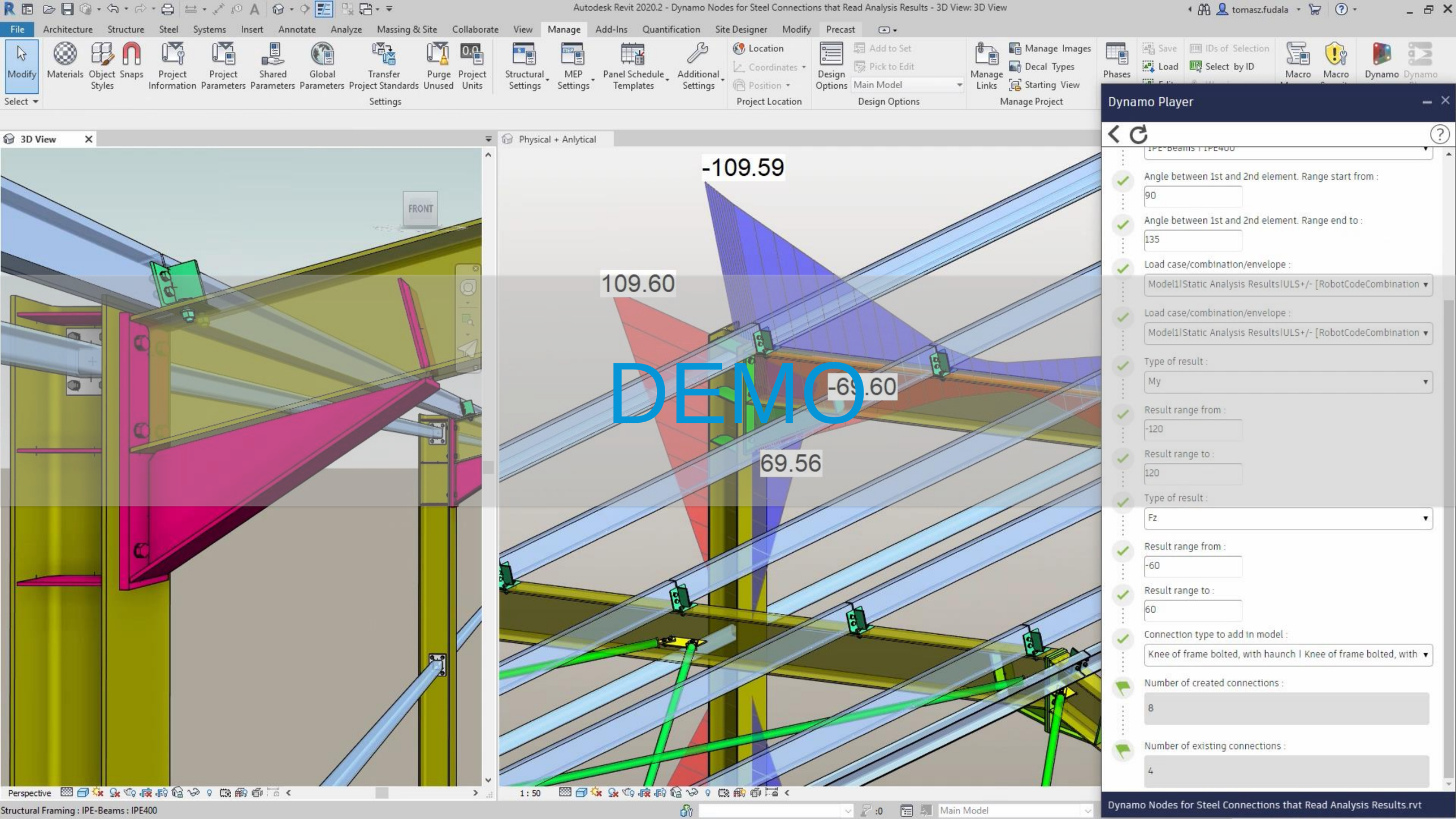
Automation of Steel Connections

Autodesk Steel Connections Dynamo Package, Autodesk Revit 2020.2

- Nodes for Steel Connections that Read Analysis Results
  - Read analysis results for load cases, combinations and envelopes
  - Analysis results are used to drive automatic connection placement
  - Faster design iteration



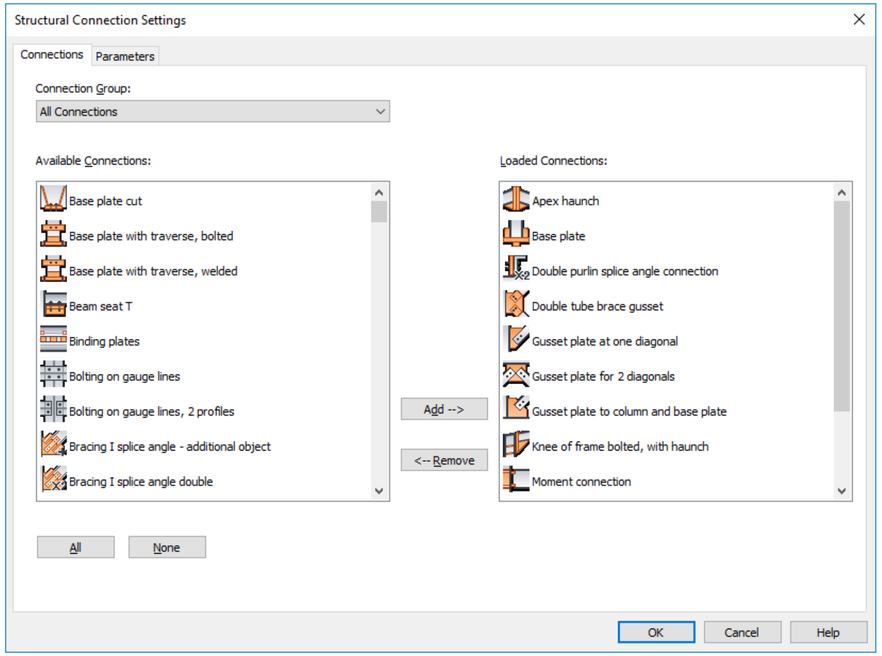


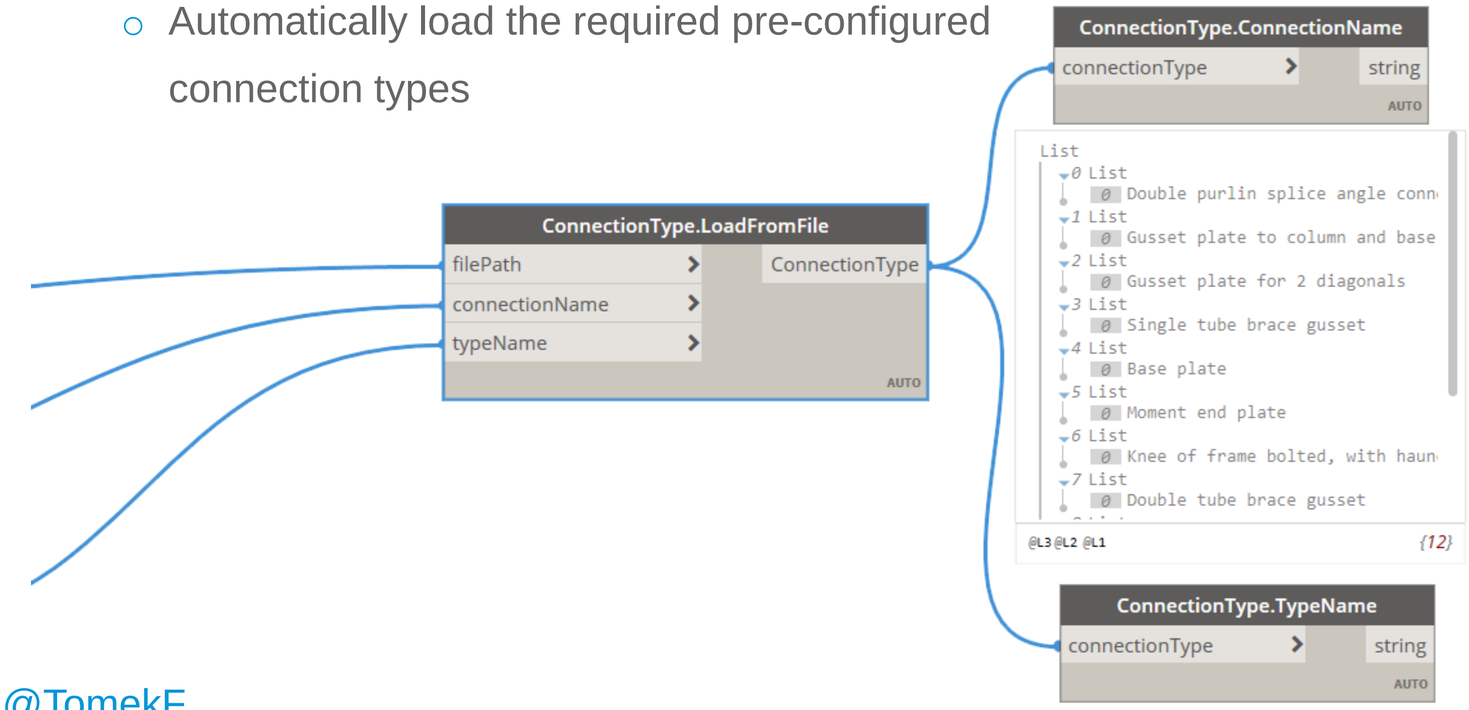

Autodesk Revit 2020.2 - Dynamo Nodes for Steel Connections that Read Analysis Results - 3D View: 3D View
tomasz.fudala
File
Architecture
Structure
Steel
Systems
Insert
Annotate
Analyze
Massing & Site
Collaborate
View
Manage
Add-Ins
Quantification
Site Designer
Modify
Precast
Modify
Select
Materials
Object Styles
Snaps
Project Information
Project Parameters
Shared Parameters
Global Parameters
Transfer Project Standards
Purge Unused
Project Units
Settings
Structural Settings
MEP Settings
Panel Schedule Templates
Additional Settings
Location
Coordinates
Position
Project Location
Add to Set
Pick to Edit
Design Options
Main Model
Design Options
Manage Links
Manage Images
Decal Types
Starting View
Manage Project
Phases
Save
Load
IDs of Selection
Select by ID
Macro
Macro
Dynamo
Dynamo
3D View
Physical + Anlytical
FRONT
-109.59
109.60
DEMO
-69.60
69.56
Perspective
1 : 50
Main Model
Structural Framing : IPE-Beams : IPE400
Dynamo Player
Angle between 1st and 2nd element. Range start from :
90
Angle between 1st and 2nd element. Range end to :
135
Load case/combination/envelope :
Model1|Static Analysis Results|ULS+/- [RobotCodeCombination
Load case/combination/envelope :
Model1|Static Analysis Results|ULS+/- [RobotCodeCombination
Type of result :
My
Result range from :
-120
Result range to :
120
Type of result :
Fz
Result range from :
-60
Result range to :
60
Connection type to add in model :
Knee of frame bolted, with haunch | Knee of frame bolted, with
Number of created connections :
8
Number of existing connections :
4
Dynamo Nodes for Steel Connections that Read Analysis Results.rvt

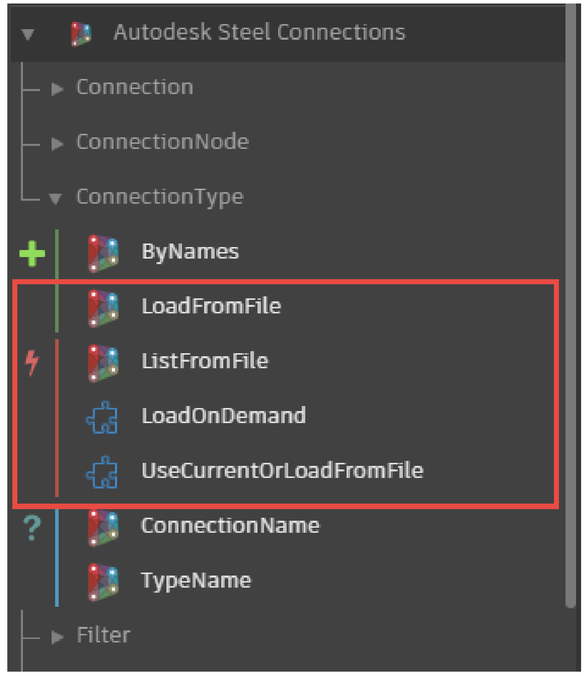
Automation of Steel Connections

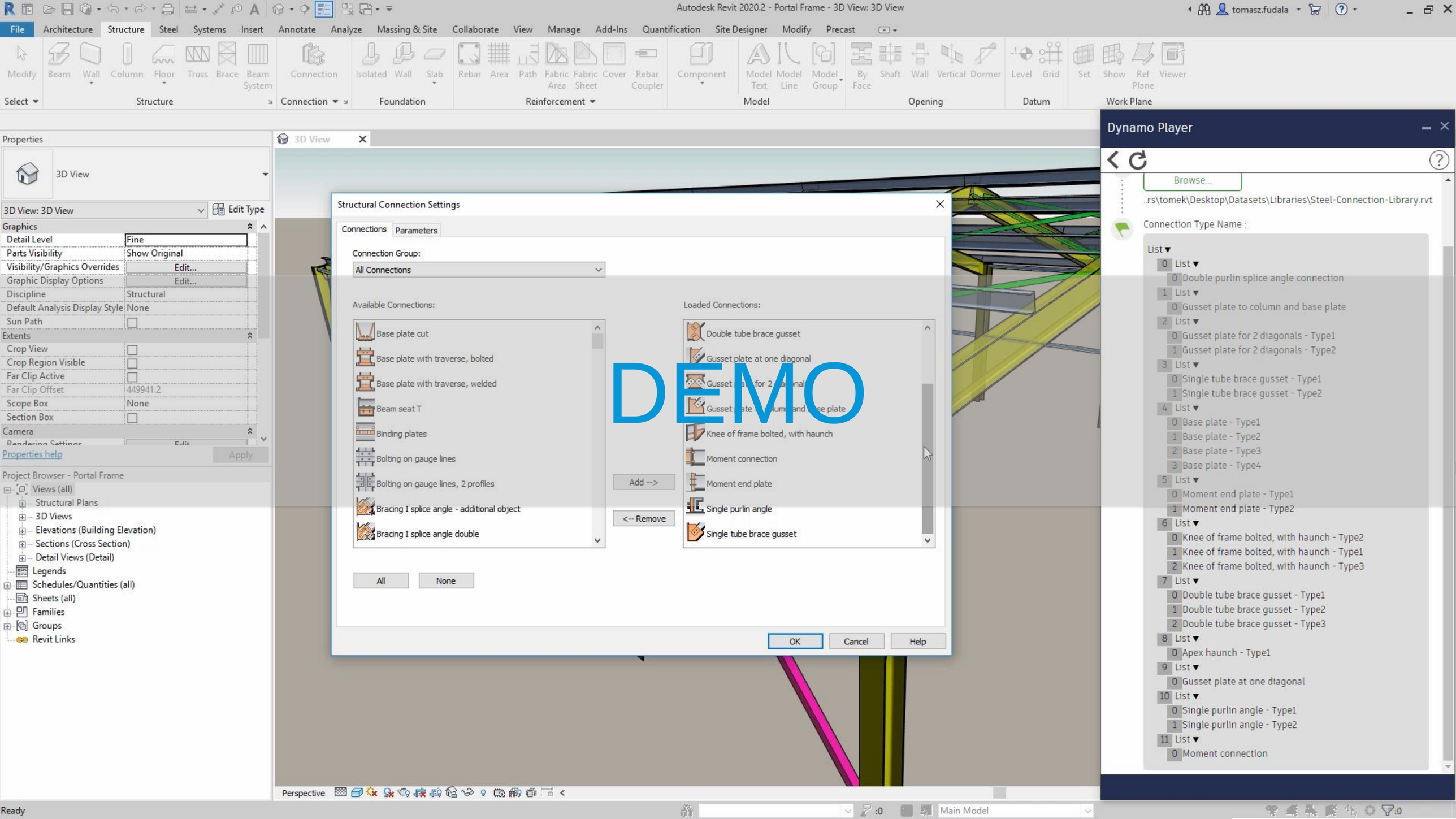
Autodesk Steel Connections Dynamo Package, Autodesk Revit 2020.2

- Nodes that Load Steel Connections from Libraries
  - Save libraries of connections as Revit project files
  - New nodes for rule-based loading of connections from libraries
  - Automatically load the required pre-configured connection types





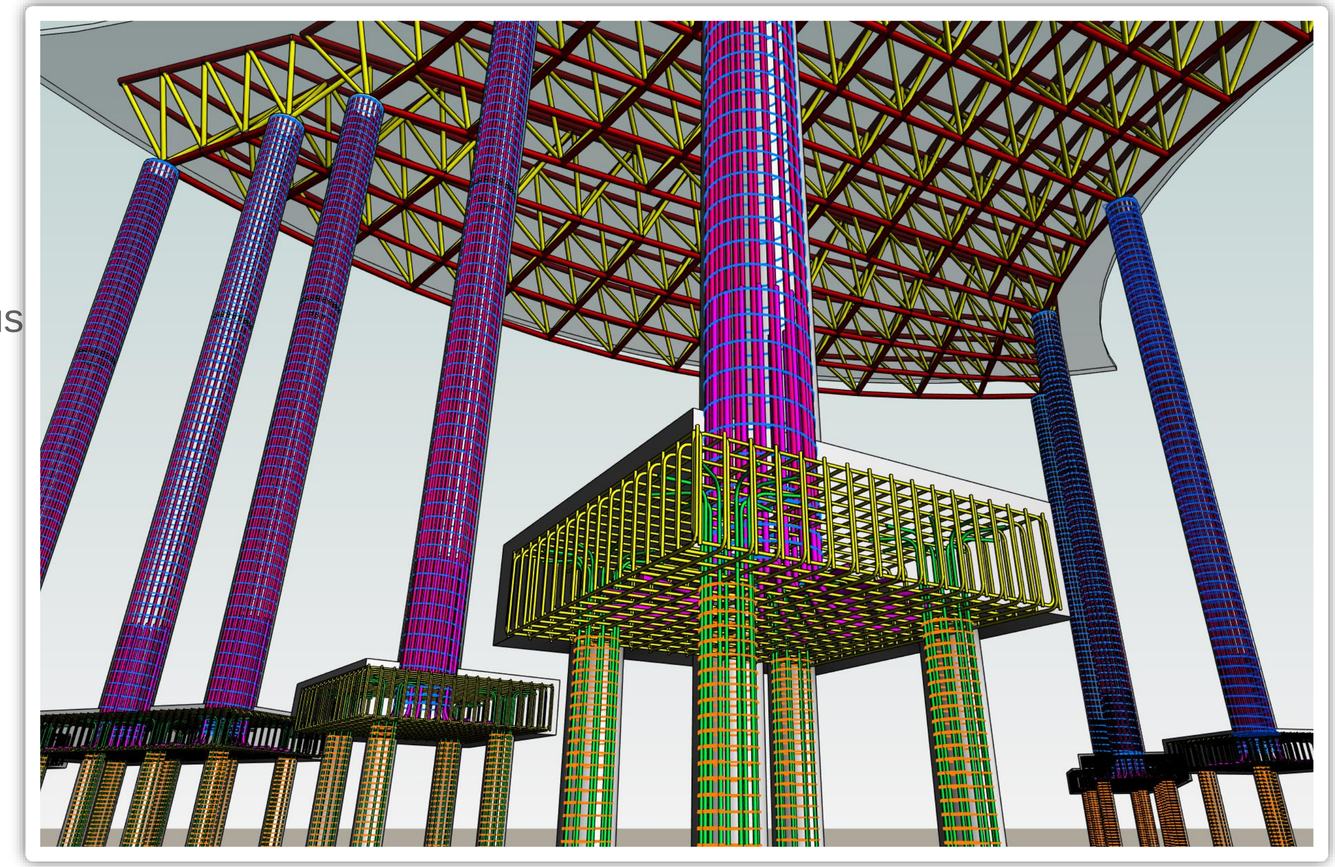


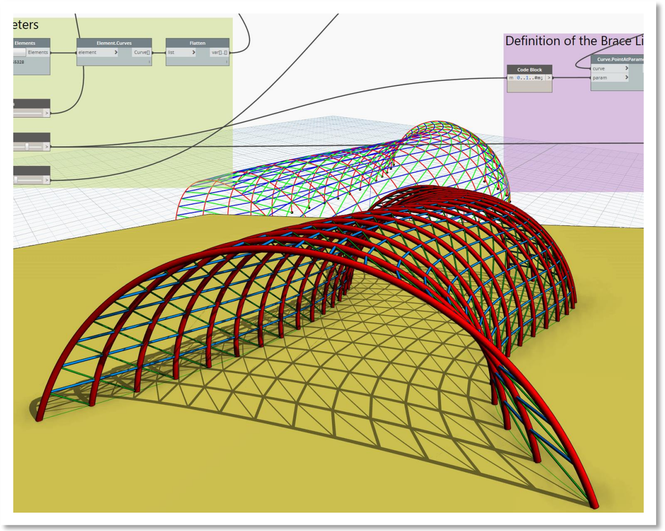

Autodesk Revit 2020.2 - Portal Frame - 3D View: 3D View
tomasz.fudala
File
Architecture
Structure
Steel
Systems
Insert
Annotate
Analyze
Massing & Site
Collaborate
View
Manage
Add-Ins
Quantification
Site Designer
Modify
Precast
Modify
Beam
Wall
Column
Floor
Truss
Brace
Beam System
Connection
Isolated
Wall
Slab
Rebar
Area
Path
Fabric Area
Fabric Sheet
Cover
Rebar Coupler
Component
Model Text
Model Line
Model Group
By Face
Shaft
Wall
Vertical
Dormer
Level
Grid
Set
Show
Ref Plane
Viewer
Select
Structure
Connection
Foundation
Reinforcement
Model
Opening
Datum
Work Plane
Properties
3D View
3D View: 3D View
Edit Type
Graphics
Detail Level
Fine
Parts Visibility
Show Original
Visibility/Graphics Overrides
Edit...
Graphic Display Options
Edit...
Discipline
Structural
Default Analysis Display Style
None
Sun Path
Extents
Crop View
Crop Region Visible
Far Clip Active
Far Clip Offset
449941.2
Scope Box
None
Section Box
Camera
Properties help
Apply
Project Browser - Portal Frame
Views (all)
Structural Plans
3D Views
Elevations (Building Elevation)
Sections (Cross Section)
Detail Views (Detail)
Legends
Schedules/Quantities (all)
Sheets (all)
Families
Groups
Revit Links
3D View
Structural Connection Settings
Connections
Parameters
Connection Group:
All Connections
Available Connections:
Base plate cut
Base plate with traverse, bolted
Base plate with traverse, welded
Beam seat T
Binding plates
Bolting on gauge lines
Bolting on gauge lines, 2 profiles
Bracing I splice angle - additional object
Bracing I splice angle double
Add -->
<-- Remove
Loaded Connections:
Double tube brace gusset
Gusset plate at one diagonal
Knee of frame bolted, with haunch
Moment connection
Moment end plate
Single purlin angle
Single tube brace gusset
All
None
OK
Cancel
Help
DEMO
Perspective
Dynamo Player
Browse...
..rs\tomek\Desktop\Datasets\Libraries\Steel-Connection-Library.rvt
Connection Type Name :
List
0 List
0 Double purlin splice angle connection
1 List
0 Gusset plate to column and base plate
2 List
0 Gusset plate for 2 diagonals - Type1
1 Gusset plate for 2 diagonals - Type2
3 List
0 Single tube brace gusset - Type1
1 Single tube brace gusset - Type2
4 List
0 Base plate - Type1
1 Base plate - Type2
2 Base plate - Type3
3 Base plate - Type4
5 List
0 Moment end plate - Type1
1 Moment end plate - Type2
6 List
0 Knee of frame bolted, with haunch - Type2
1 Knee of frame bolted, with haunch - Type1
2 Knee of frame bolted, with haunch - Type3
7 List
0 Double tube brace gusset - Type1
1 Double tube brace gusset - Type2
2 Double tube brace gusset - Type3
8 List
0 Apex haunch - Type1
9 List
0 Gusset plate at one diagonal
10 List
0 Single purlin angle - Type1
1 Single purlin angle - Type2
11 List
0 Moment connection
Ready
Main Model

Conclusions

Automation of Structural Design with Dynamo

- Making your own design tools is easy
- Build optimized structures with minimal energy
- Work faster with complex structures
- Automated processes save tones of manual and tedious work, save a lot of time
- Dynamo opens a world of possibilities for all structural personas






Q&A

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Make anything™

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