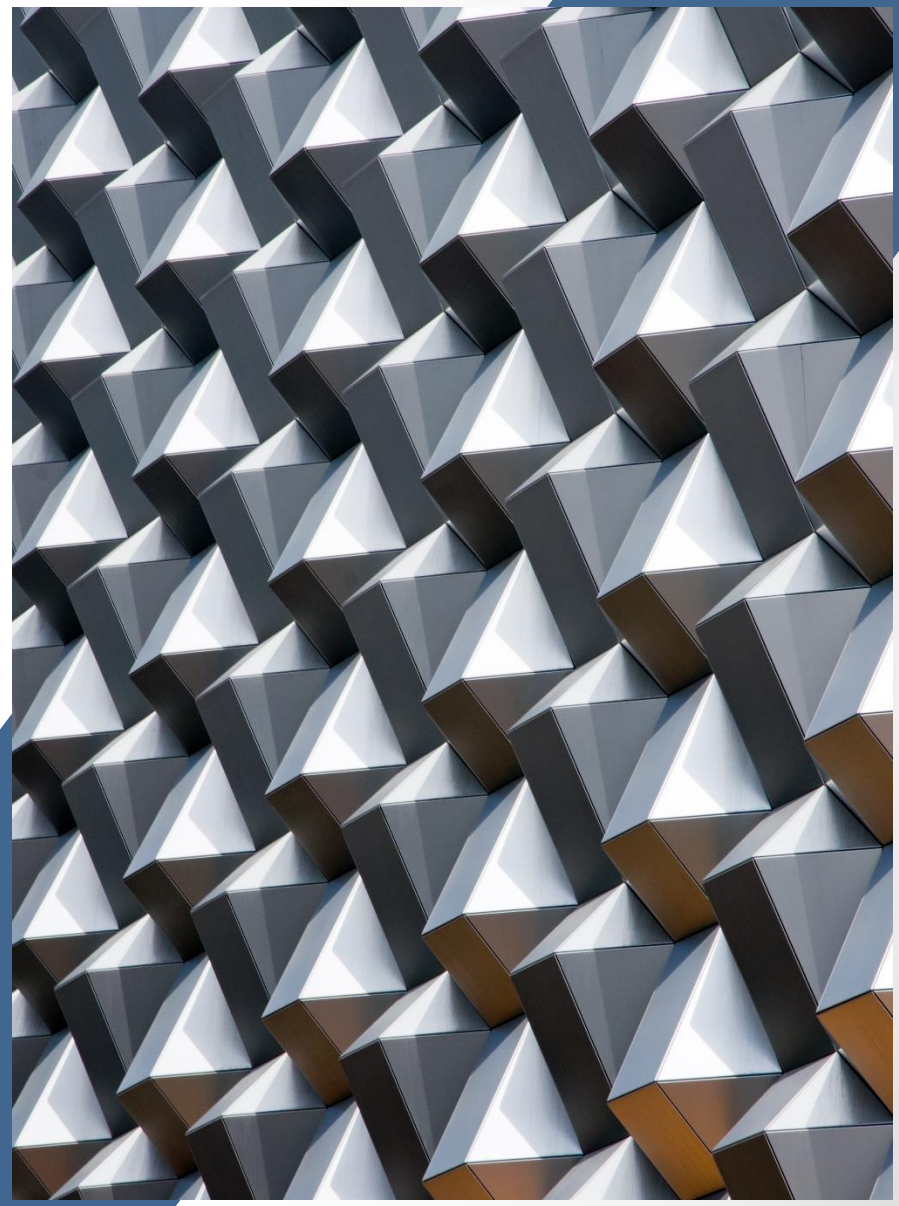
>> September 21 -23, Moscow

AlumForum 2021

International Forum «Aluminum in Architecture and Construction»

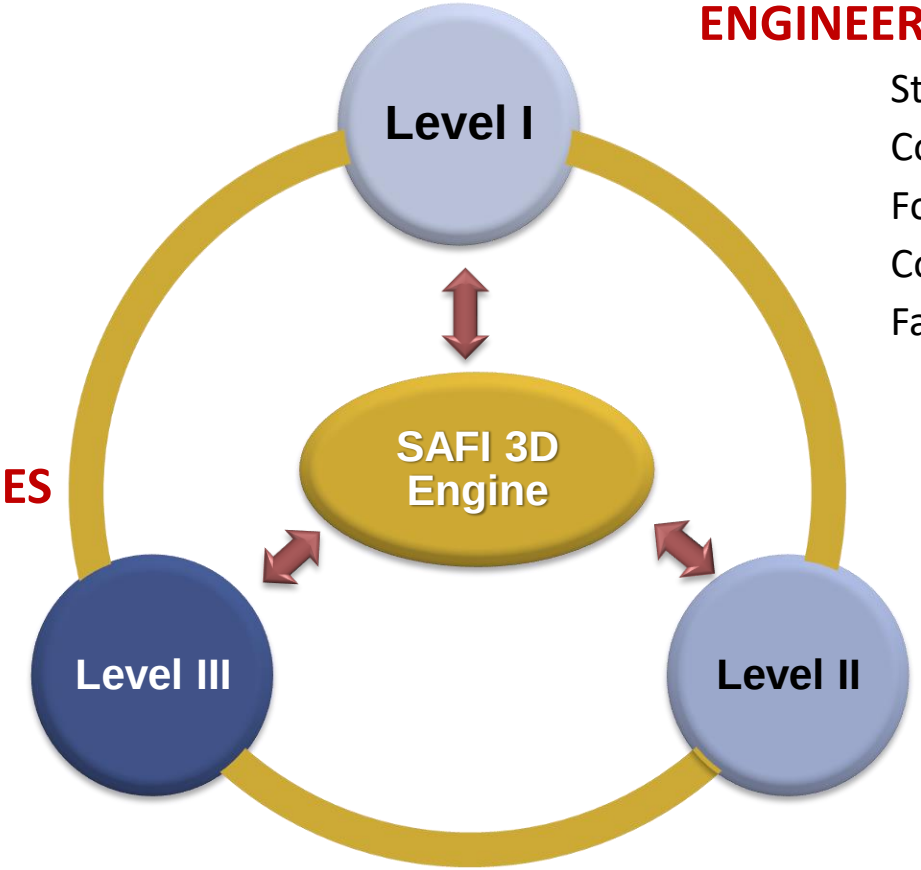


Rachik Elmaraghy, Ph.D., M.A.Sc. P.Eng.,FCSCE
Founder & CEO
SAFI Canada – Est. 1986

SAFI Products Philosophy – Seamless Fully Integrated

ENGINEERING CALCULATORS

- Steel Calculator™
- Concrete Calculator™
- Footing Calculator
- Connection Calculator
- Fatigue Calculator



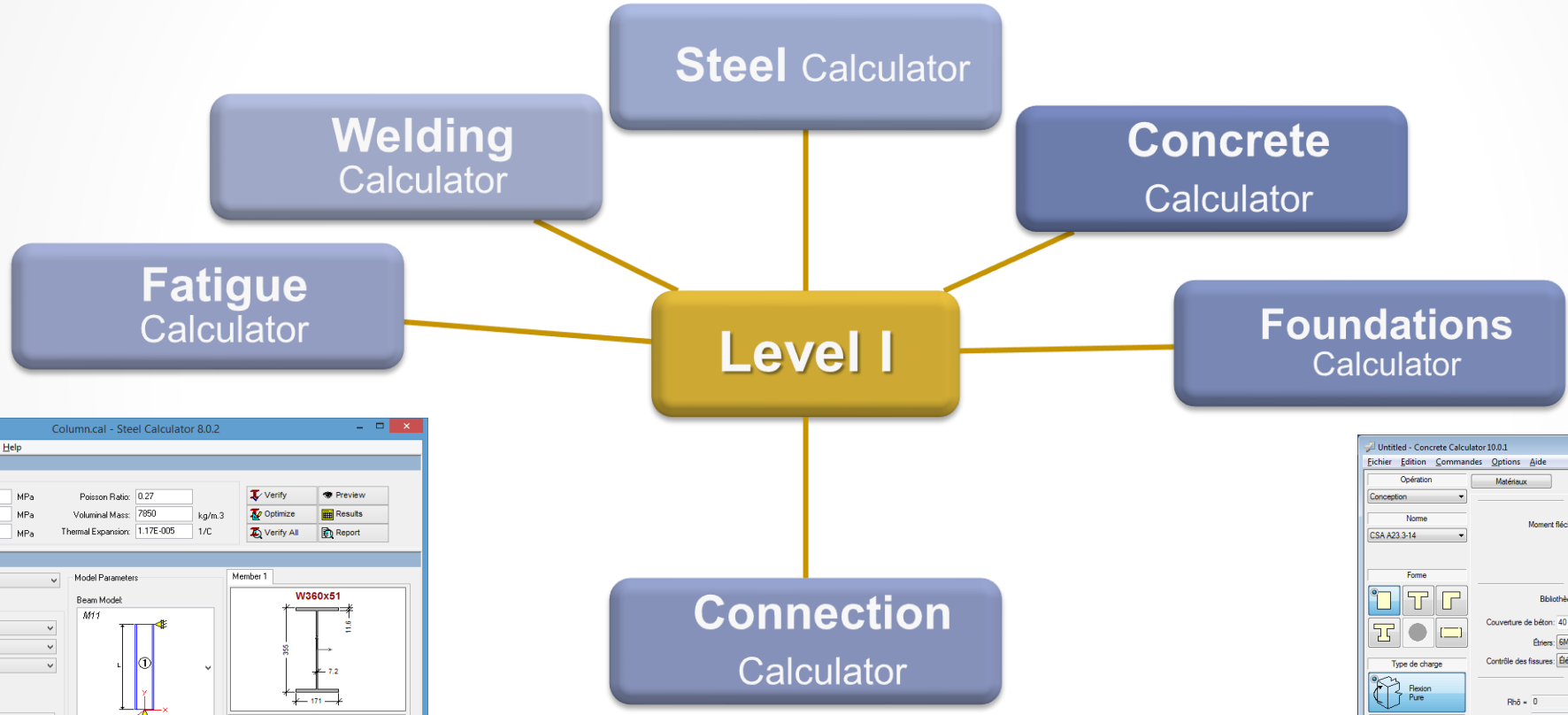
VIRTUAL A.E.C. TECHNOLOGIES

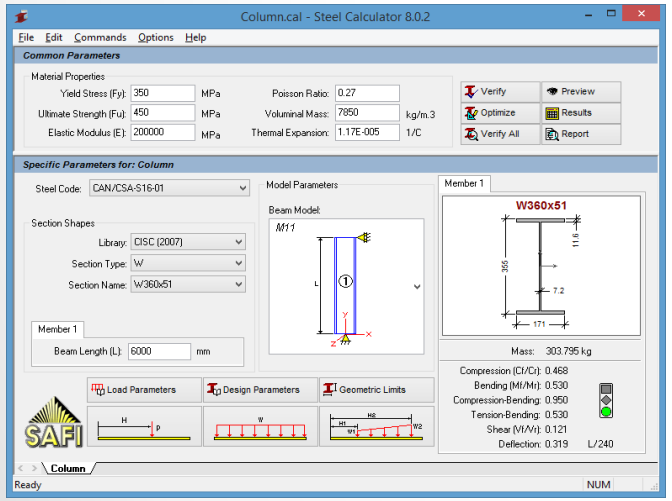
- Engineering
- Manufacturing
- Fabrication
- Construction

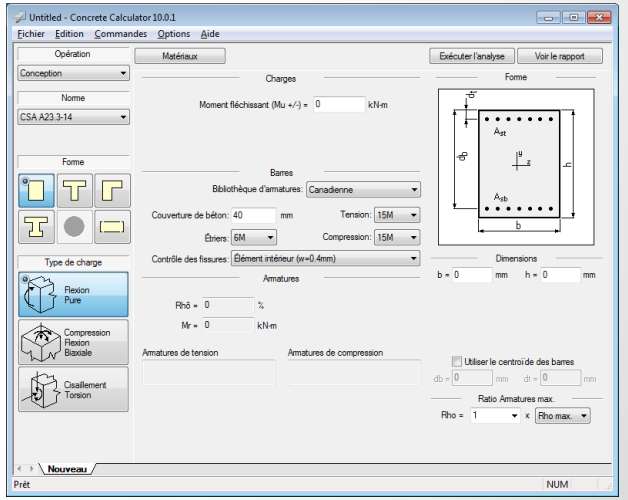
ENGINEERING APPLICATIONS

- Intuitive Modeling
- Advanced Analysis
- International Design Codes

Engineering Calculators – **Level I**



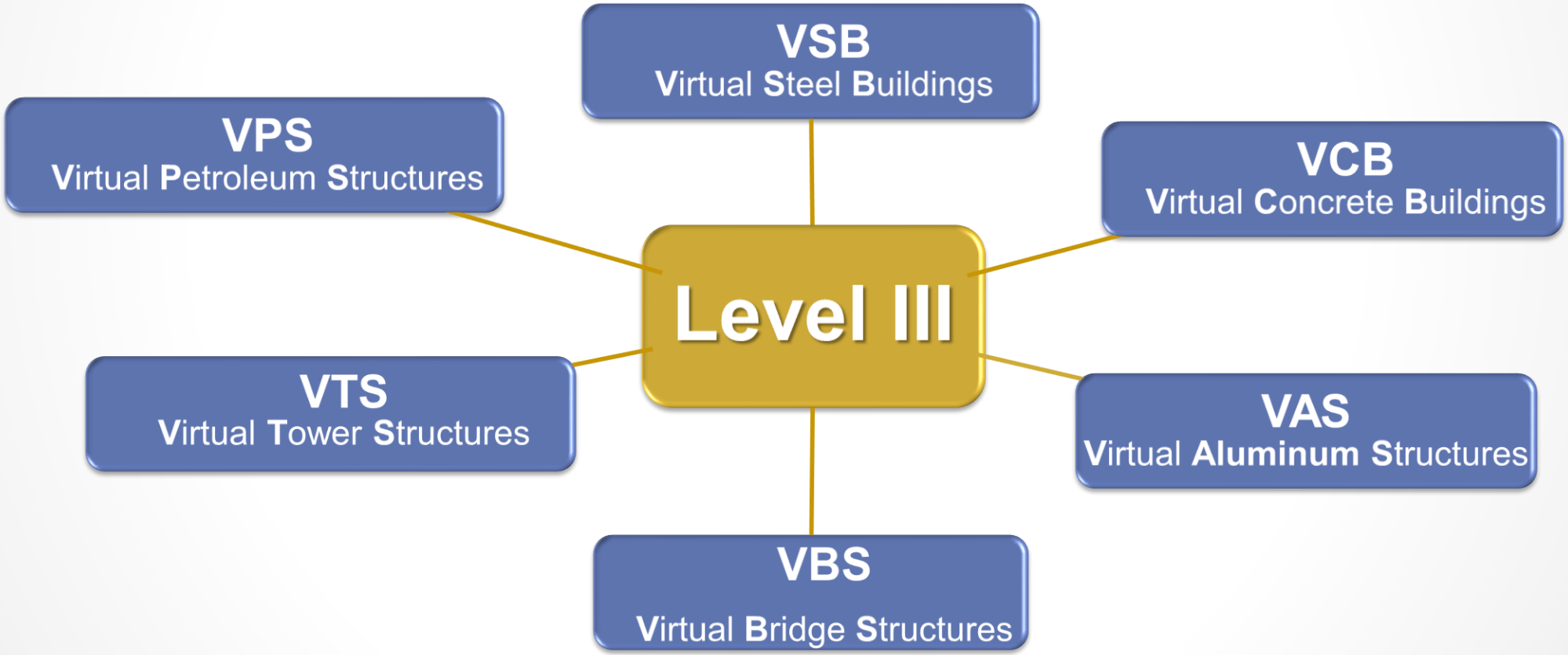




Integrated Structural Design Applications – **Level II**

A.E.C. Virtual Technologies – **Level III**

Seamless Integration / Engineering / Connections / Detailing / Manufacturing & Fabrication



SAFI Structural Engineering Solutions – **Aluminum** capabilities

GSE Software

GENERAL STRUCTURAL ENGINEERING

Steel, Concrete, Wood and **Aluminum** structures of all types.

BSE Software

BRIDGE STRUCTURAL ENGINEERING

Steel, Concrete, Composite and **Aluminum** bridges.

TSE Software

TOWER STRUCTURAL ENGINEERING

Electrical substations, transmission towers and telecom towers.

PSE Software

PETROLEUM STRUCTURAL ENGINEERING®

Offshore and Onshore drilling structures for oil, gas and water drilling.

SAFI Structural Engineering Solutions – **Aluminum** capabilities

Aluminum in Transport and Road Infrastructure

HSE Software

HIGHWAY SIGN STRUCTURAL ENGINEERING

Overhead structural sign support, traffic signal supports and high-mast lighting towers.

HSE SOFTWARE - Steel & Aluminum Standards

The program supports the required specifications of the:

- **AASHTO LTS-13 ASD (6th edition)**
- **AASHTO LTS-15 LRFD (1st edition)**
- **Canadian CSA S6**

HSE SOFTWARE - Applications

The HSE software is a versatile program allowing users to design various structures for overhead signage for highway, roadway or traffic applications.

Overhead sign structures

The HSE software allows users to design highway overhead structural sign supports with various road sign panels such as simple panel, reinforced panel, variable message sign (VMS), walkway or secondary panel.

Traffic lights

The HSE software allows users to design various types of traffic light supports and signal mast arm structures.

High-mast lighting towers (HMLT)

The HSE software allows users to design various types of lighting solutions such as street lighting poles, high-mast lighting towers and lamp posts.

- Overhead sign structures
- Cantilever sign structures
- Gantry structures
- Traffic lights
- Traffic signal mast arms
- Street lighting poles
- Luminaire support structures
- High-mast lighting towers

HSE SOFTWARE – Highlighted technical features

- The HSE Software is a technology built on powerful user-friendly interface
- Allows to generate Standard and Non-Standard structures related to the bridge sign industry.
- HSE covers the Analysis, Design and Fatigue of overhead structural sign support, traffic signal supports and high-mast lighting towers.
- Linear, non-Linear, seismic and dynamic analysis are available.
- Non-Linear Catenary cable may be included in general HSE models.
- Automatically determines the wind and ice loads acting on the elements of the model.
- Generate the equivalent fatigue loads such as galloping, natural wind gust and truck-induced gust to compute the fatigue limit states.
- The highway sign wizard also calculates the various design parameters required such as buckling parameters, aluminum weld parameters and fatigue parameters.

HSE SOFTWARE - Overhead sign structures

Highway and roadway sign structures

- The software allows users to design highway overhead structural sign supports with various road sign panels such as:

  Simple panel, reinforced panel, variable message sign (VMS), walkway or secondary panel.
- Wind, ice, and gravity loads are automatically calculated by the program.
- The fatigue limit states are also computed by the software.

HSE SOFTWARE – Traffic lights

Traffic signal support structures

- The software allows users to design various types of traffic light supports and signal mast arm structures.

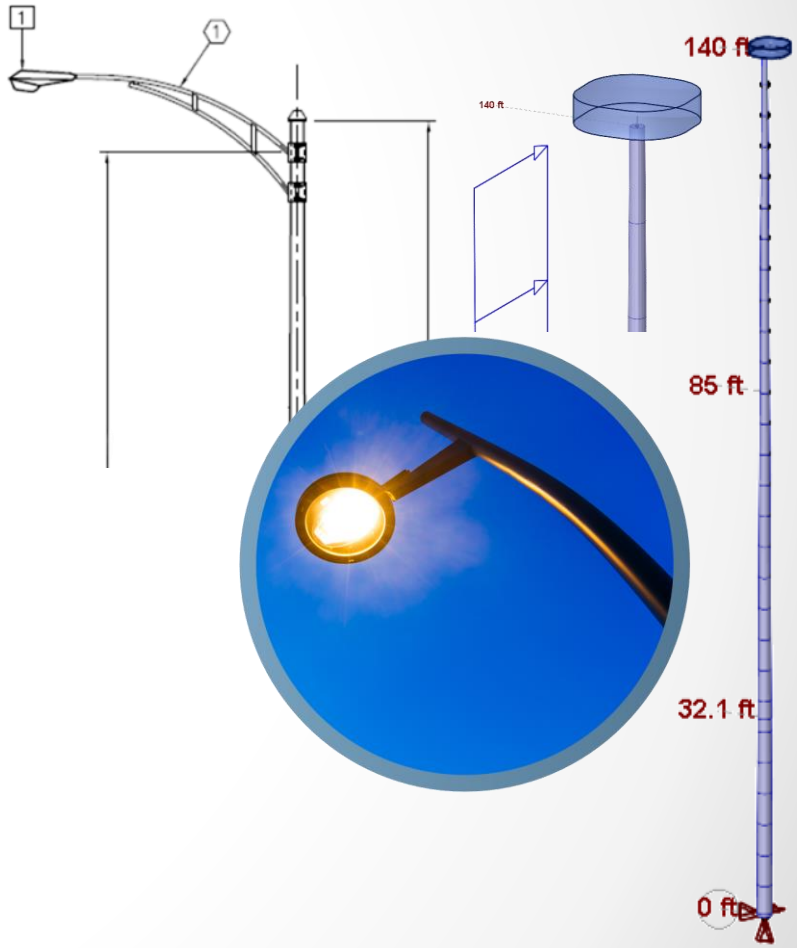
- The program takes into consideration truck-induced gust loads caused by the passage of trucks under traffic structures as well as the galloping force based on the frontal projected area of each traffic signal including all other devices attached to the arm masts.

HSE SOFTWARE – Street lighting

Street lighting poles and High-mast lighting towers (HMLT)

- The software allows users to design various types of lighting solutions such as street lighting poles, high-mast lighting towers and lamp posts.

- The program takes into consideration natural wind gusts that may induce cyclic loads in lighting structures.

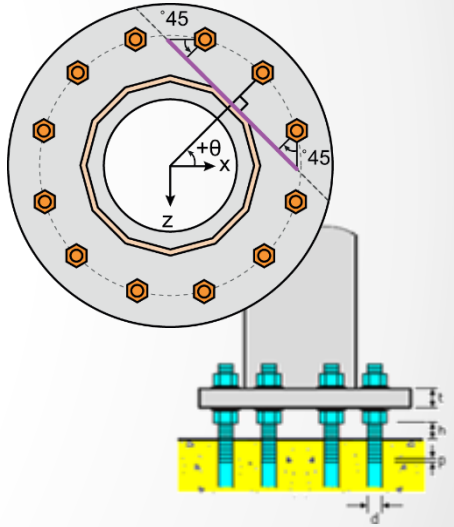


HSE SOFTWARE – Design Specifications

- Structure design for compression, tension, bending, shear, torsion and warping, slenderness, deflection and fatigue
- Anchor rods verification
- Base plate design and verification

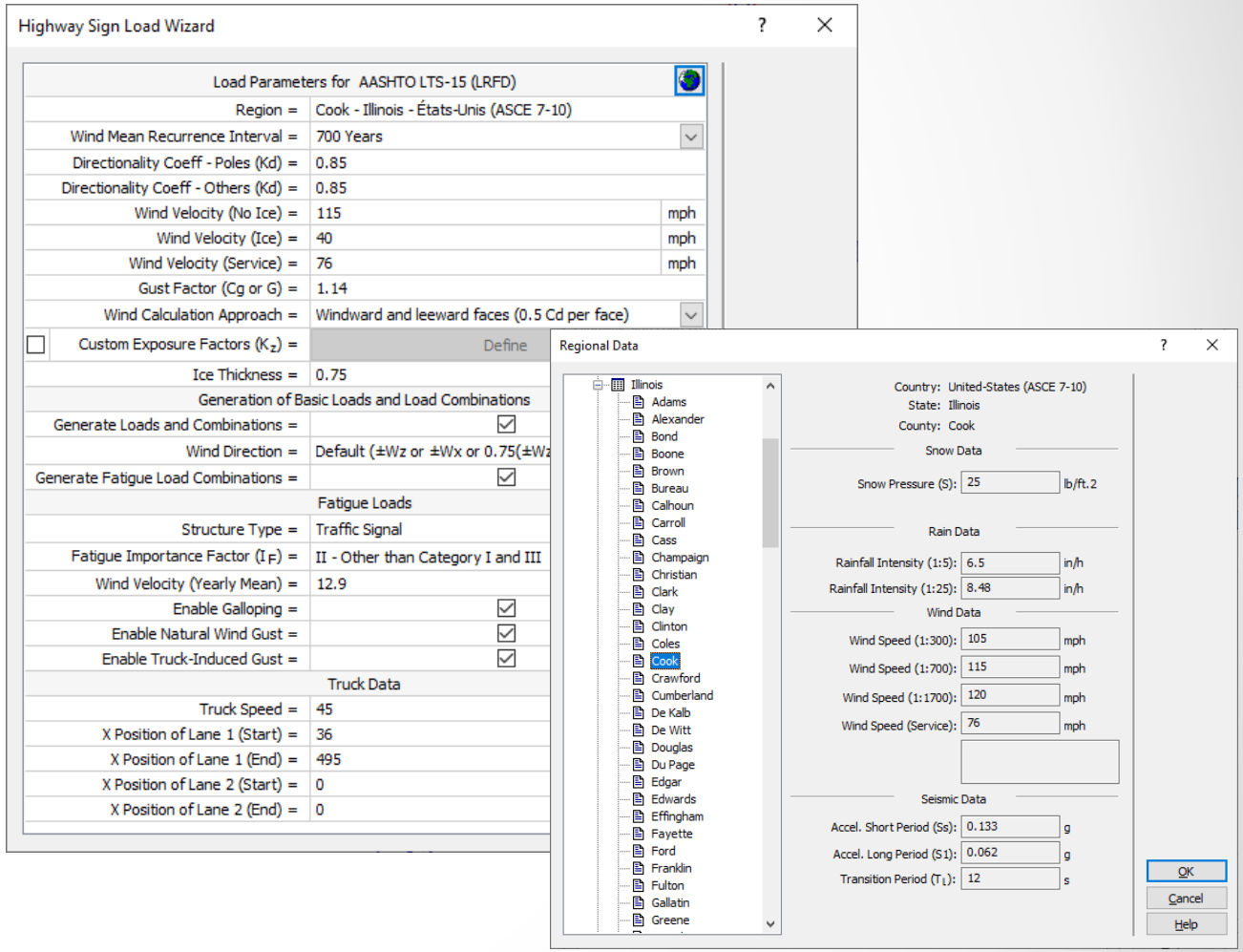
Computation of base plates

The HSE software allows users to compute the resistance and the thickness of base plates with levelling nuts.



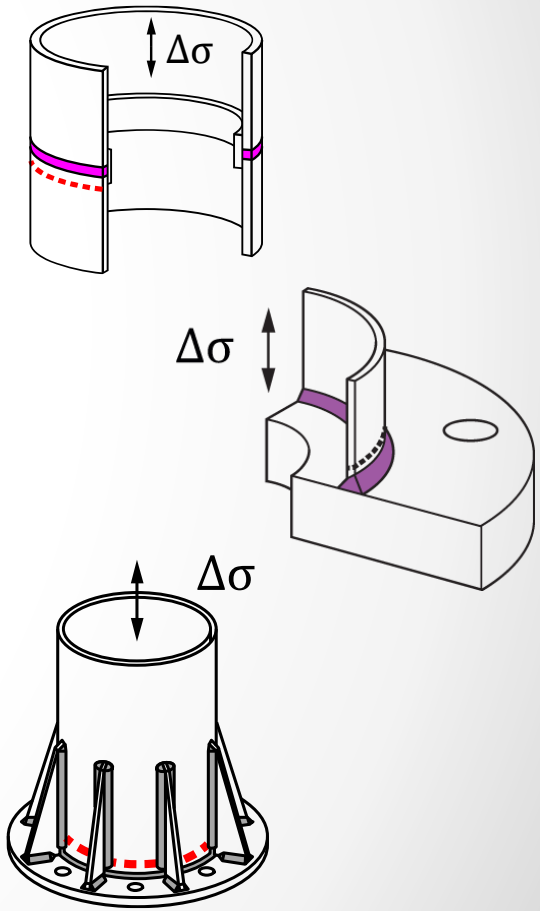
HSE SOFTWARE - Loading features

- Automated self-weight
- Automated wind and ice loads
- Concentrated and distributed loads
- Automated fatigue (Galloping, Natural Wind Gust, Truck-Induced Gust)
- Thermal gradient loads
- Seismic analysis capabilities
- Automated load combinations



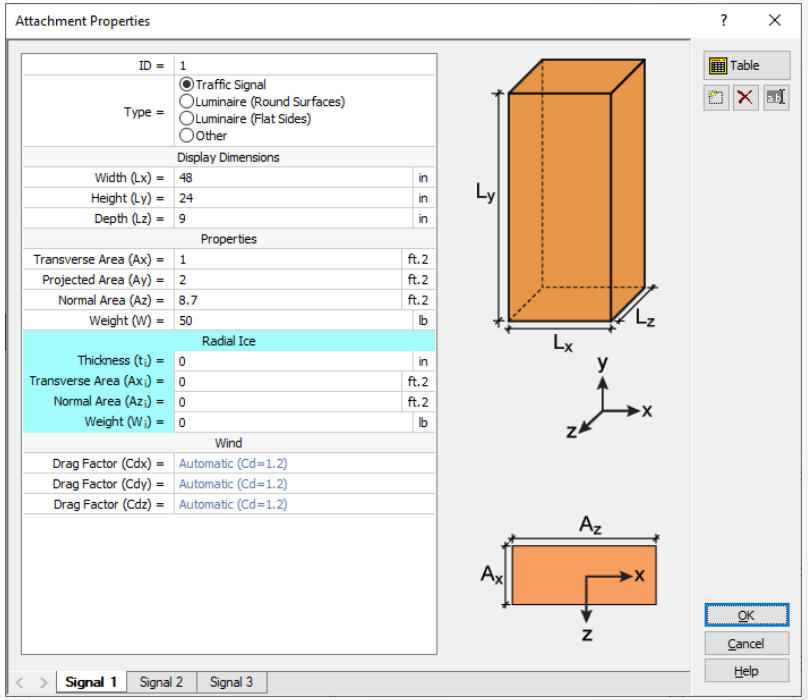
HSE SOFTWARE - Fatigue

- Fatigue verification according to chapter 11 of AASHTO LTS-13 (ASD) and AASHTO LTS-15 (LRFD).
- Verification of stresses according to the Constant Amplitude Fatigue Threshold (CAFT).
- The AASHTO LTS standards provides fatigue calculation for the three following types of structures: signs, traffic lights and luminaires.
- This choice has an influence on the displayed fatigue options.
- The HSE software also allows to run the fatigue calculations for the HMLT (High-Mast Lighting Towers) by using the approach defined in the AASHTO LTS.

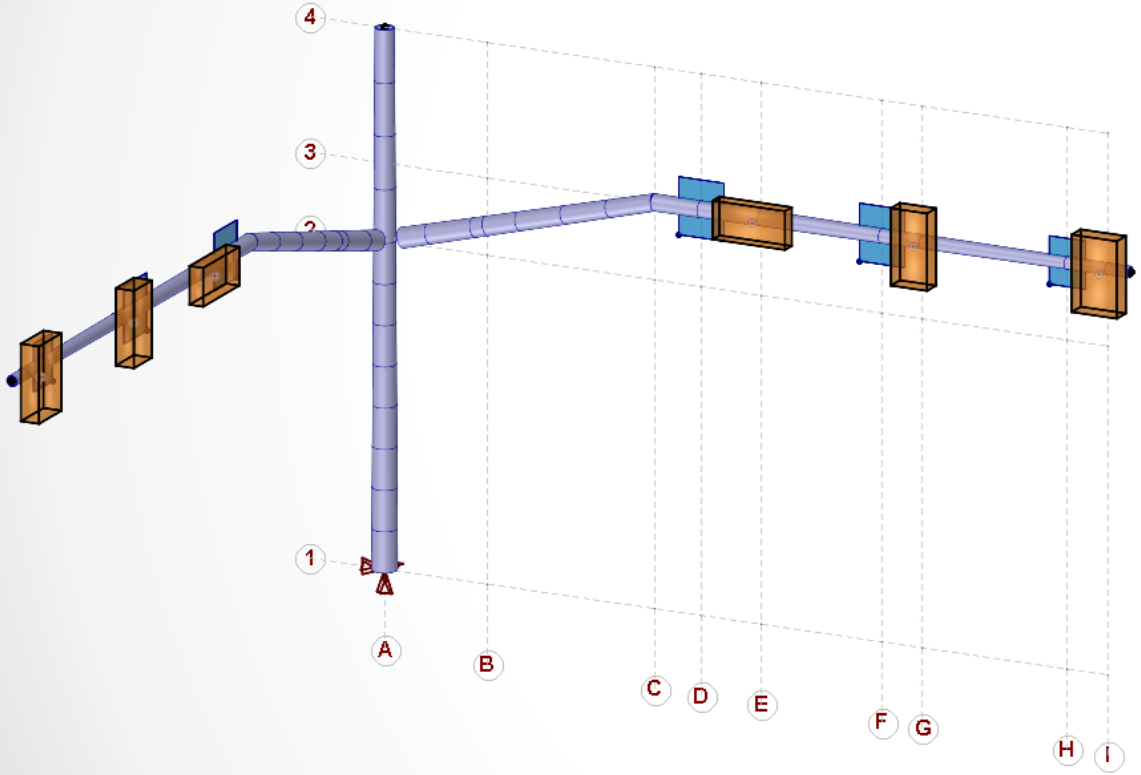


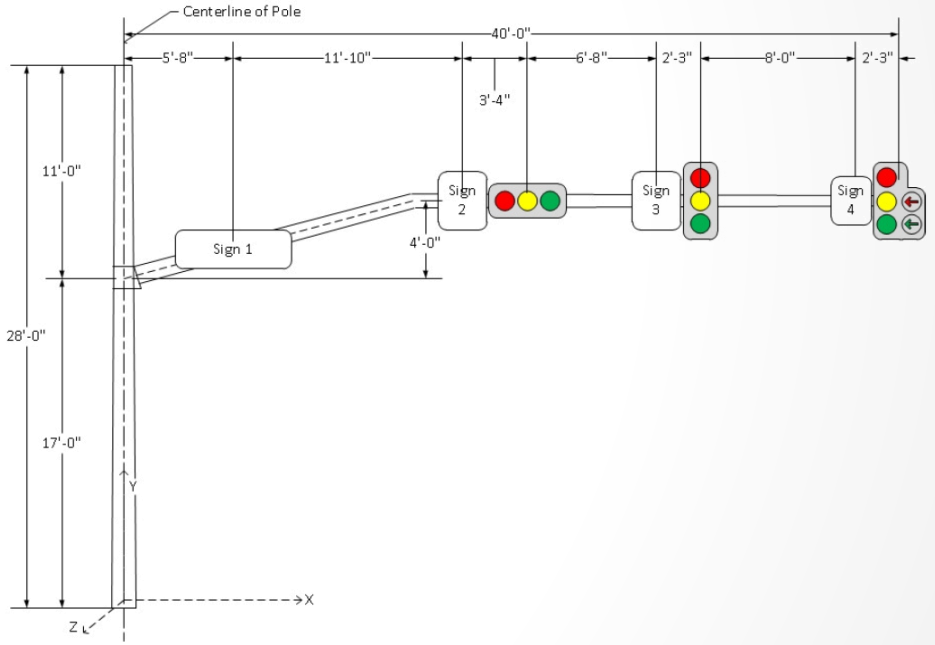
HSE SOFTWARE - LUMINAIRES, TRAFFIC LIGHTS AND OTHER ATTACHMENTS

- The HSE Software Attachments command allows to create a list of traffic signals, luminaires and other accessories attached to the structure.
- These accessories can later be attached to the structure with the Add Luminaire/Traffic Signal command.
- It is also possible to validate the wind and ice loads automatically generated on the attachments.



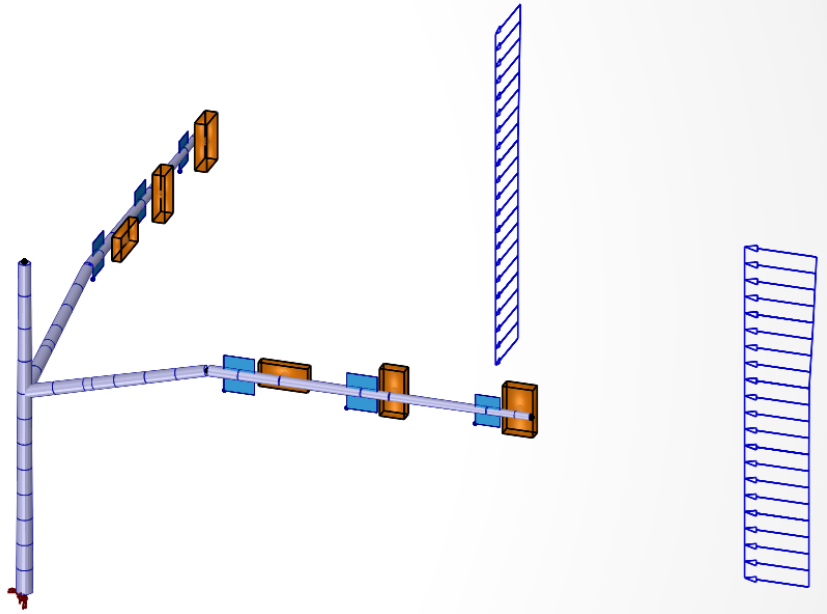
HSE SOFTWARE - LUMINAIRES, TRAFFIC LIGHTS AND OTHER ATTACHMENTS





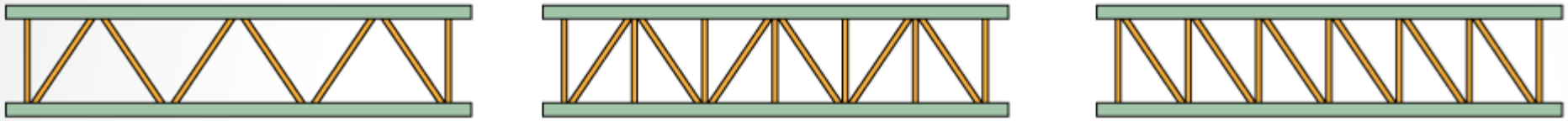
HSE SOFTWARE - PANELS IN XY AND YZ PLANES

- The HSE software allows to create structures like a traffic signal pole with two arms at 90 degrees with attach panels and attachments in XY and YZ planes.
- For the AASHTO LTS-13 (ASD) and S6, the Wind Direction option in the Highway sign load wizard allows to compute the wind for these structures.
- The wind is applied on all possible directions according to the selected option available.

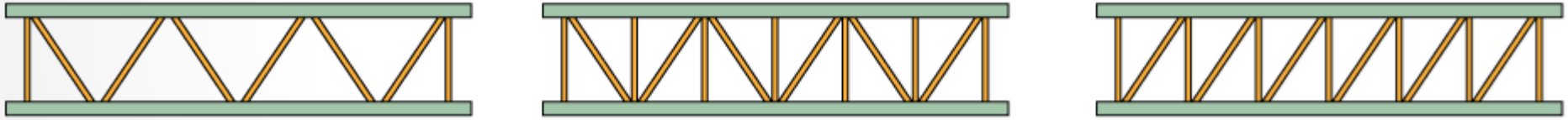


HSE SOFTWARE - POWERFUL BEAM GENERATION

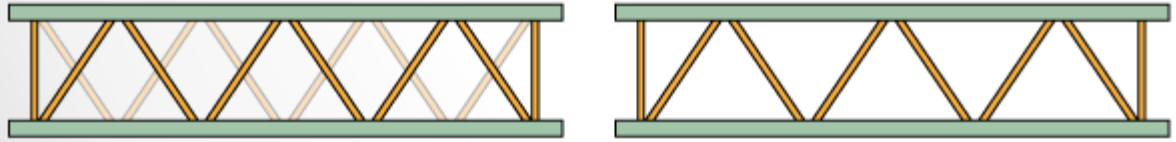
- Many features for the generation of beams are available to HSE users. For example, it is possible to select different panel models (Warren, Pony Warren or Pratt) for the beam diagonals.



- These panel models can be reverted with the Discontinuous diagonals option.



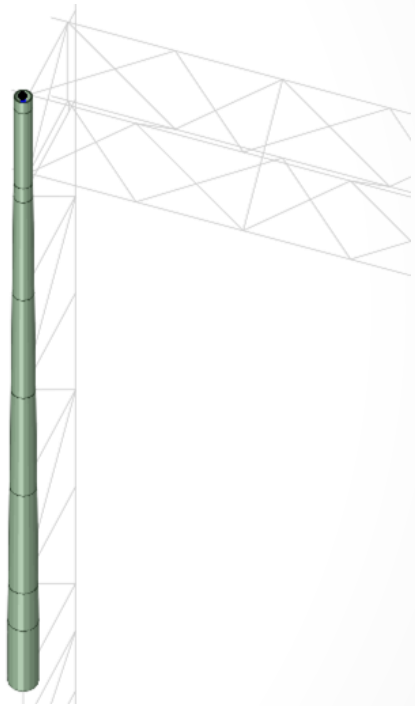
- When the invert opposite face option is unchecked, it is possible to align the arrangement of the diagonals on the opposite face of the beam.

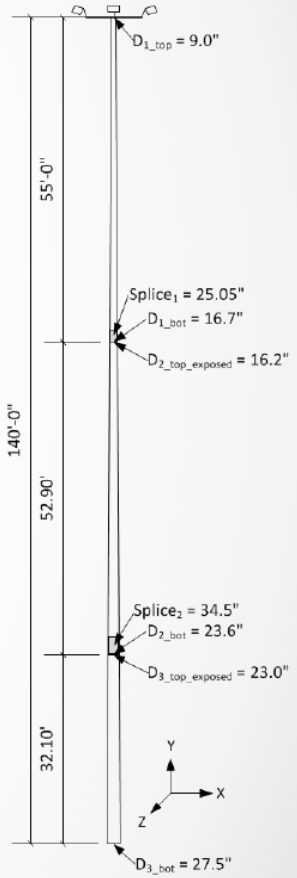


HSE SOFTWARE - POWERFUL COLUMN GENERATION

BY SAFI™

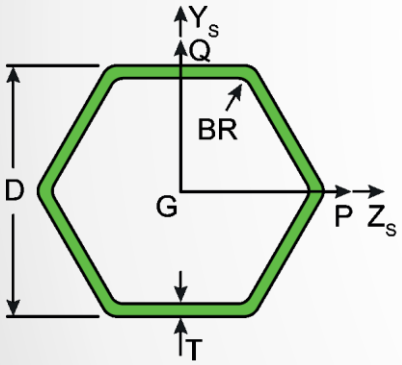
- The HSE software allows to seamlessly edit variable inertia columns after the model generation.
- Regular or Variable inertia sections.
- For example, a column can be divided at any position and the variable inertia section properties will automatically be adjusted.



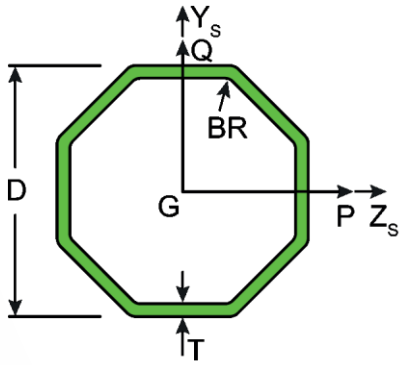


HSE SOFTWARE – Polygonal sections

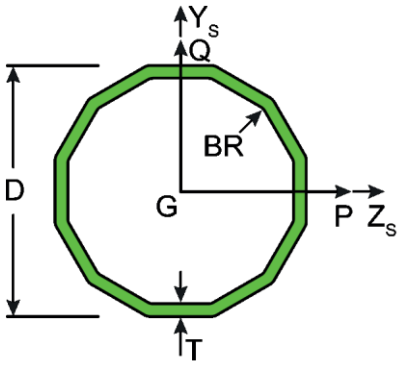
In addition to all existing section shapes (circular, rectangular, I, L, 2L, T, and more), the HSE Highway Sign Structural Engineering software allows the use of tubular polygonal sections.



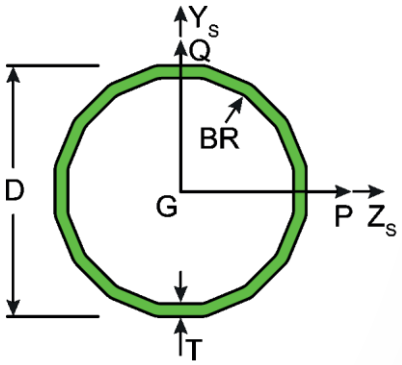
6-sided tube



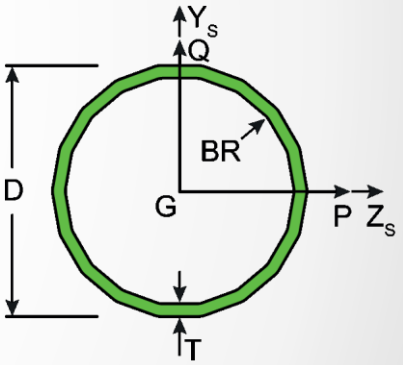
8-sided tube



12-sided tube



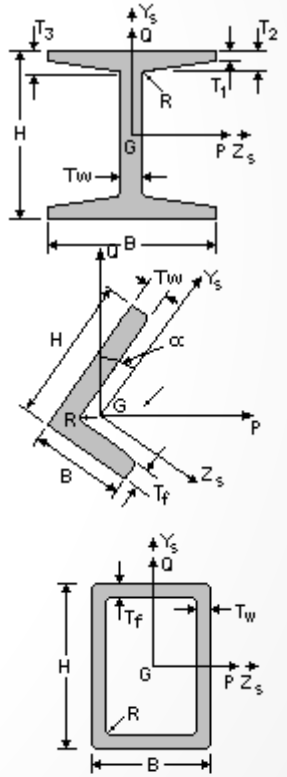
16-sided tube



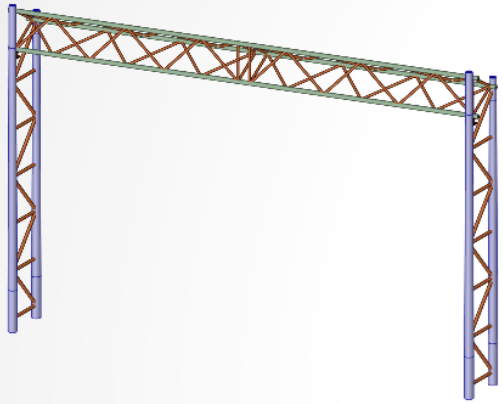
18-sided tube

HSE SOFTWARE – Sections properties

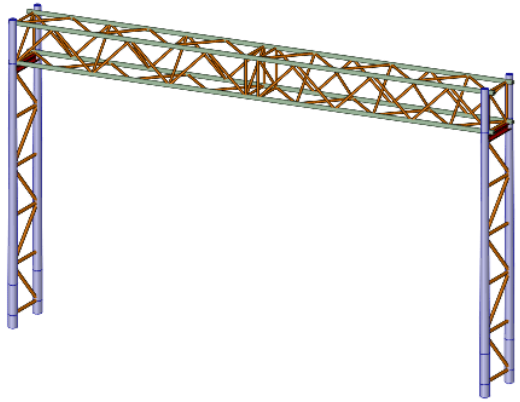
- In Library of standard Sections (CISC, AISC, European and Indian)
- Non-standard
- Tapered sections (variable inertia)
- Library of cable sections
- Built-up sections
- Plate and Shells (finite elements)
- Custom sections



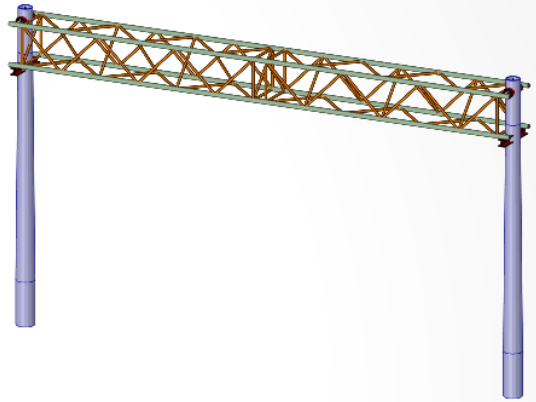
HSE Software - Automated models



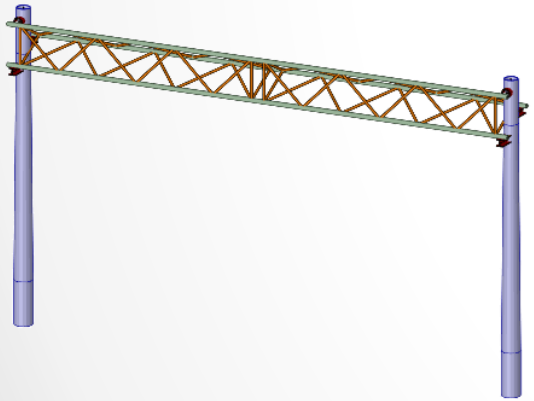
Latticed column with 4-sided latticed beam



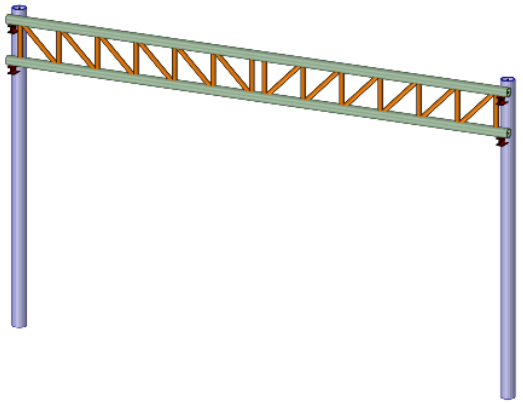
Latticed column with 3-sided latticed beam



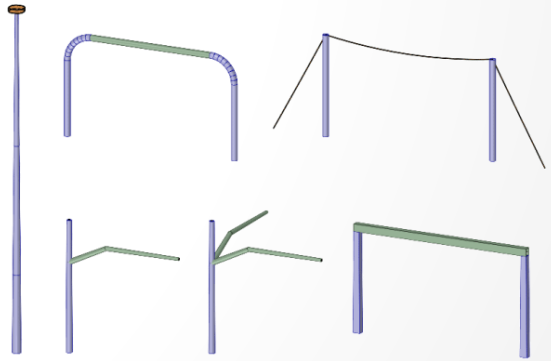
Pole column with 4-sided latticed beam



Pole column with 3-sided latticed beam

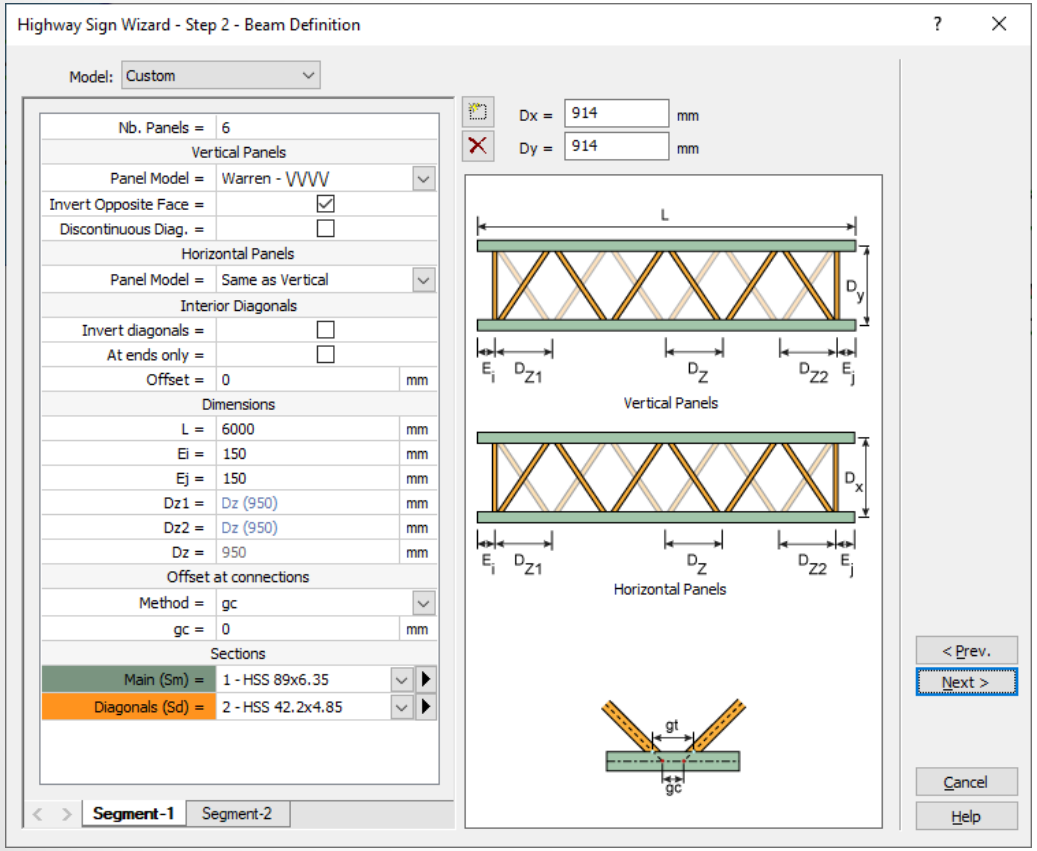


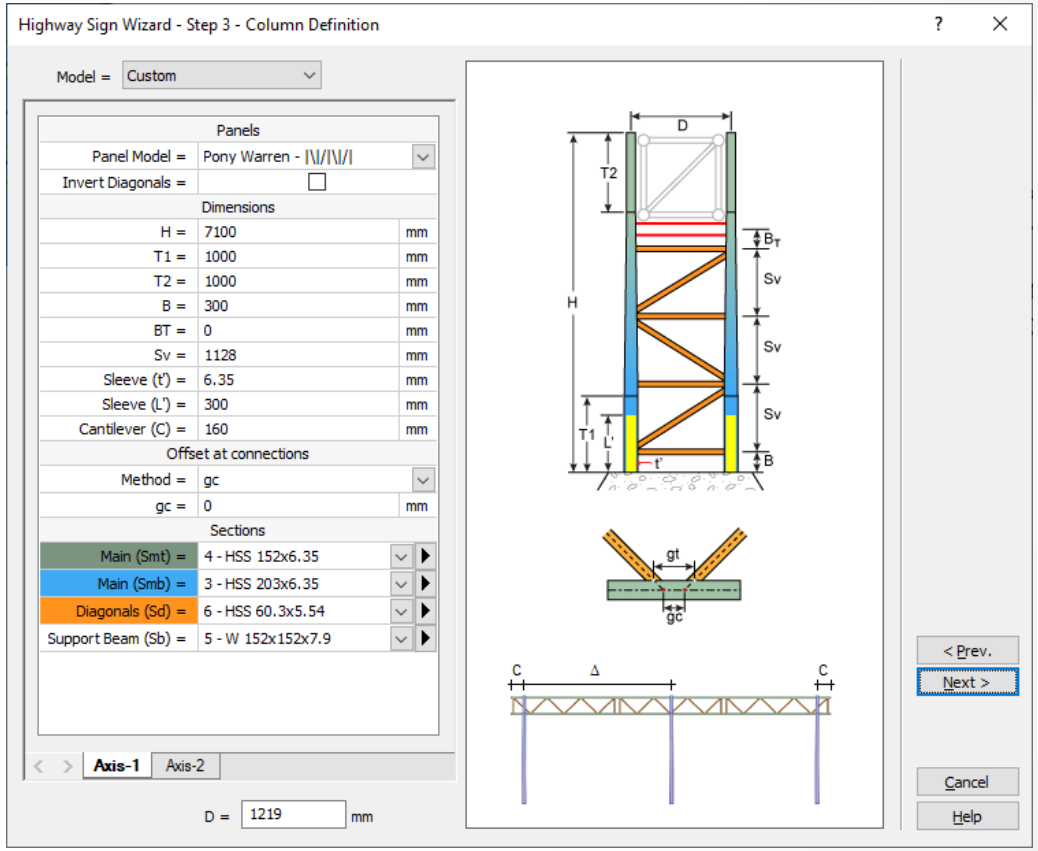
Pole column with flat latticed beam



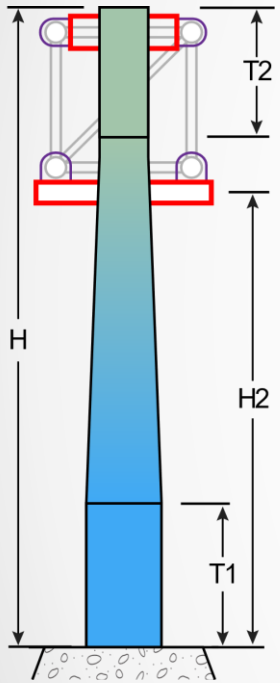
Manually made models

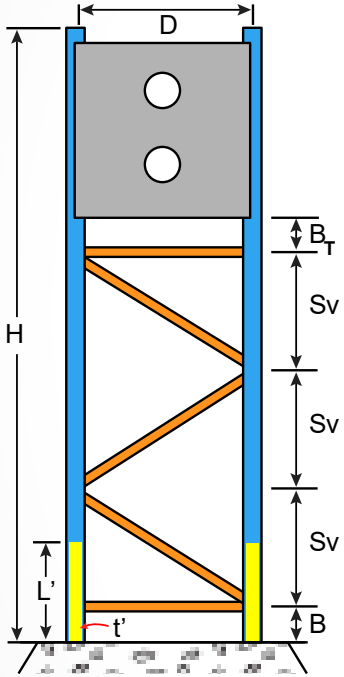
HSE Software - Highway Sign Wizard Input Data

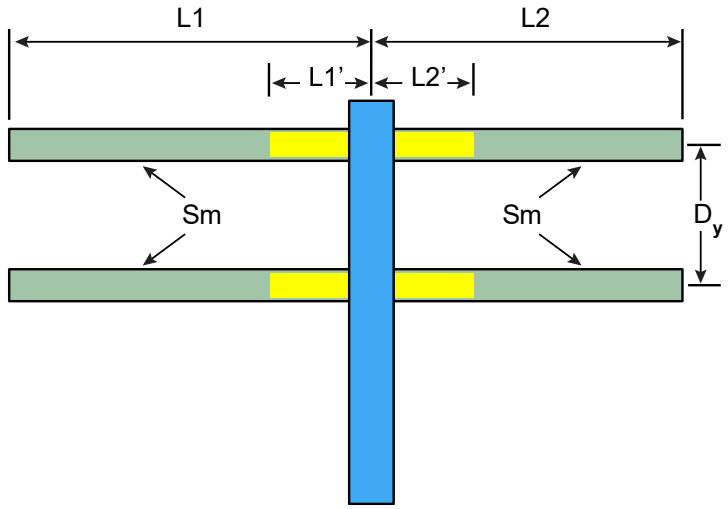


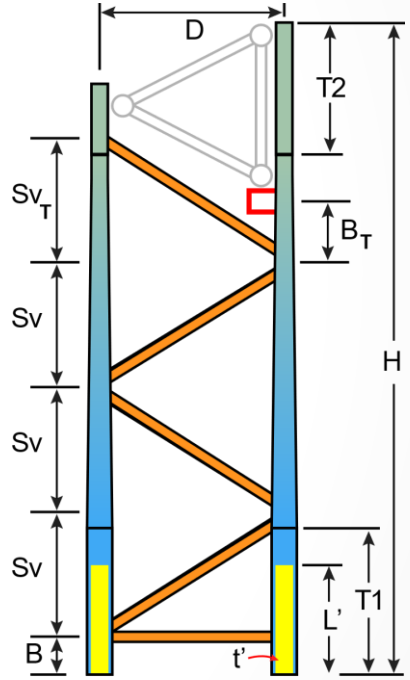


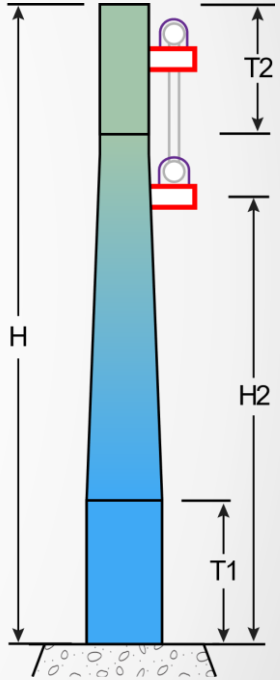
HSE Software - Highway Sign Wizard Input Data



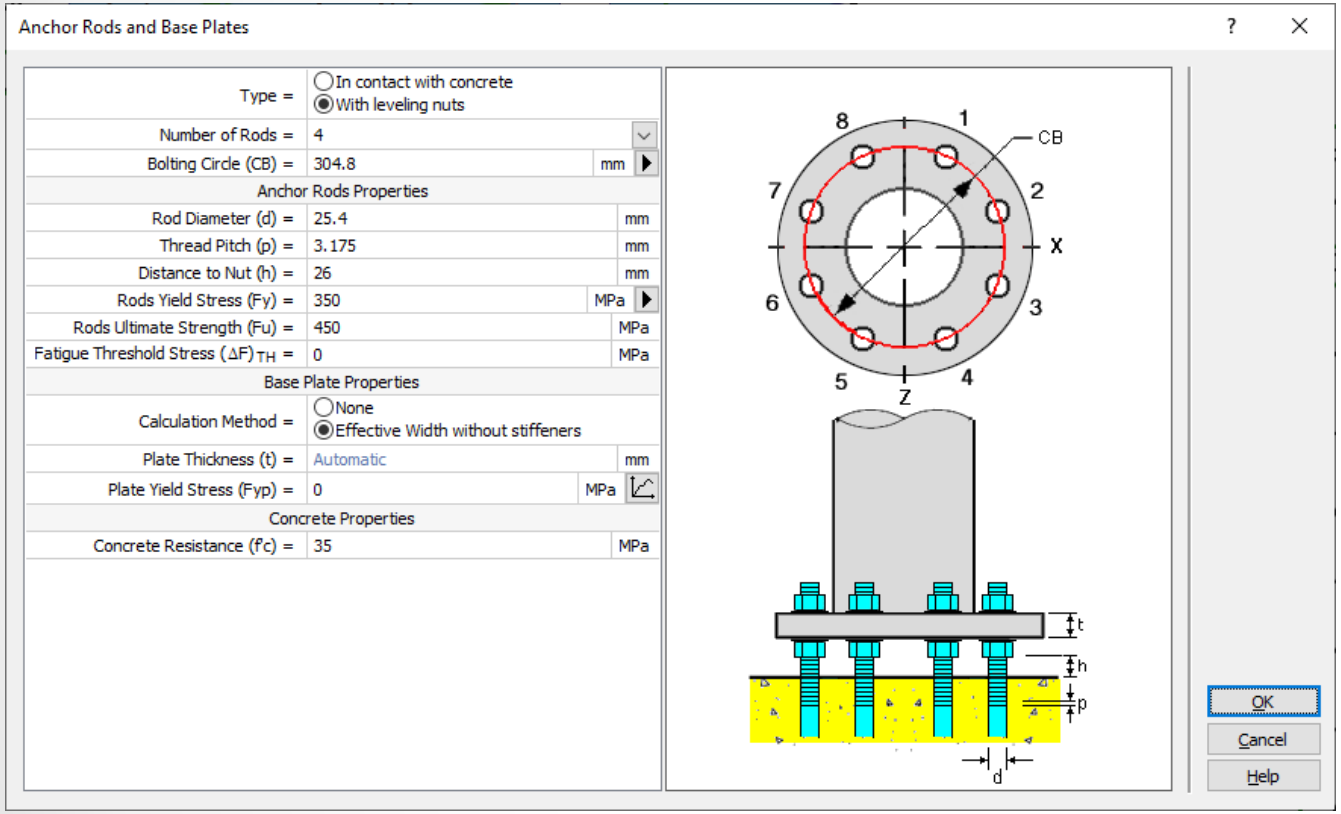


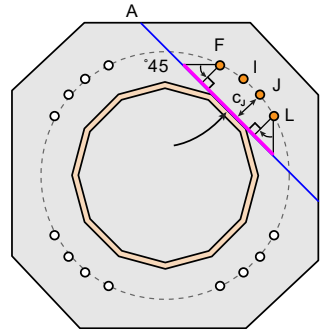


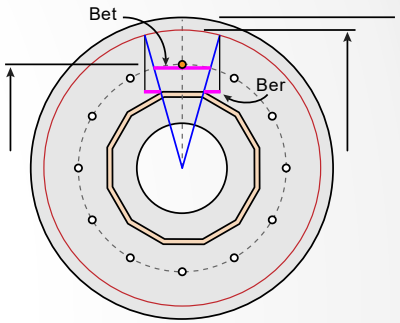


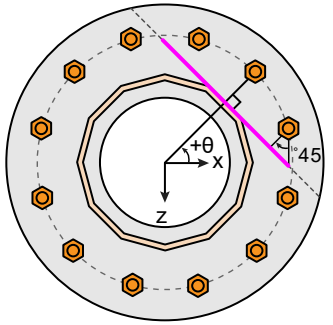


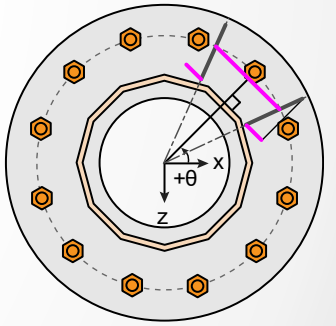
HSE Software - Anchor Rods and Base Plate Input



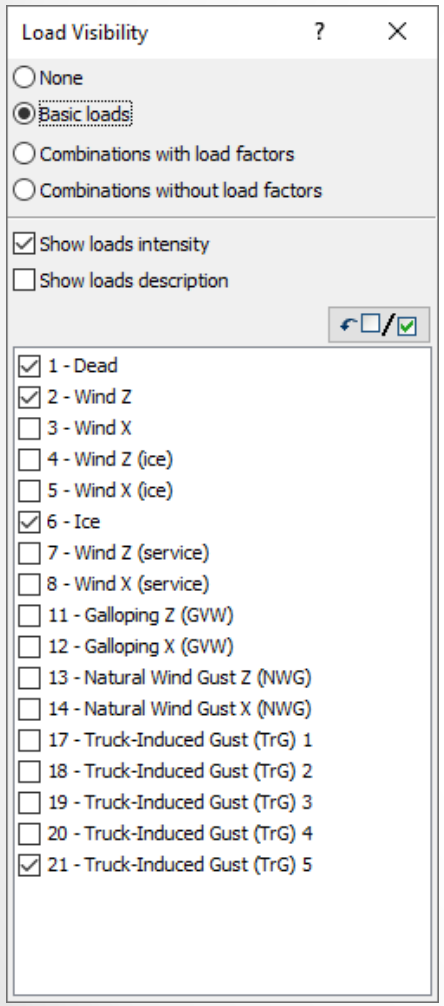


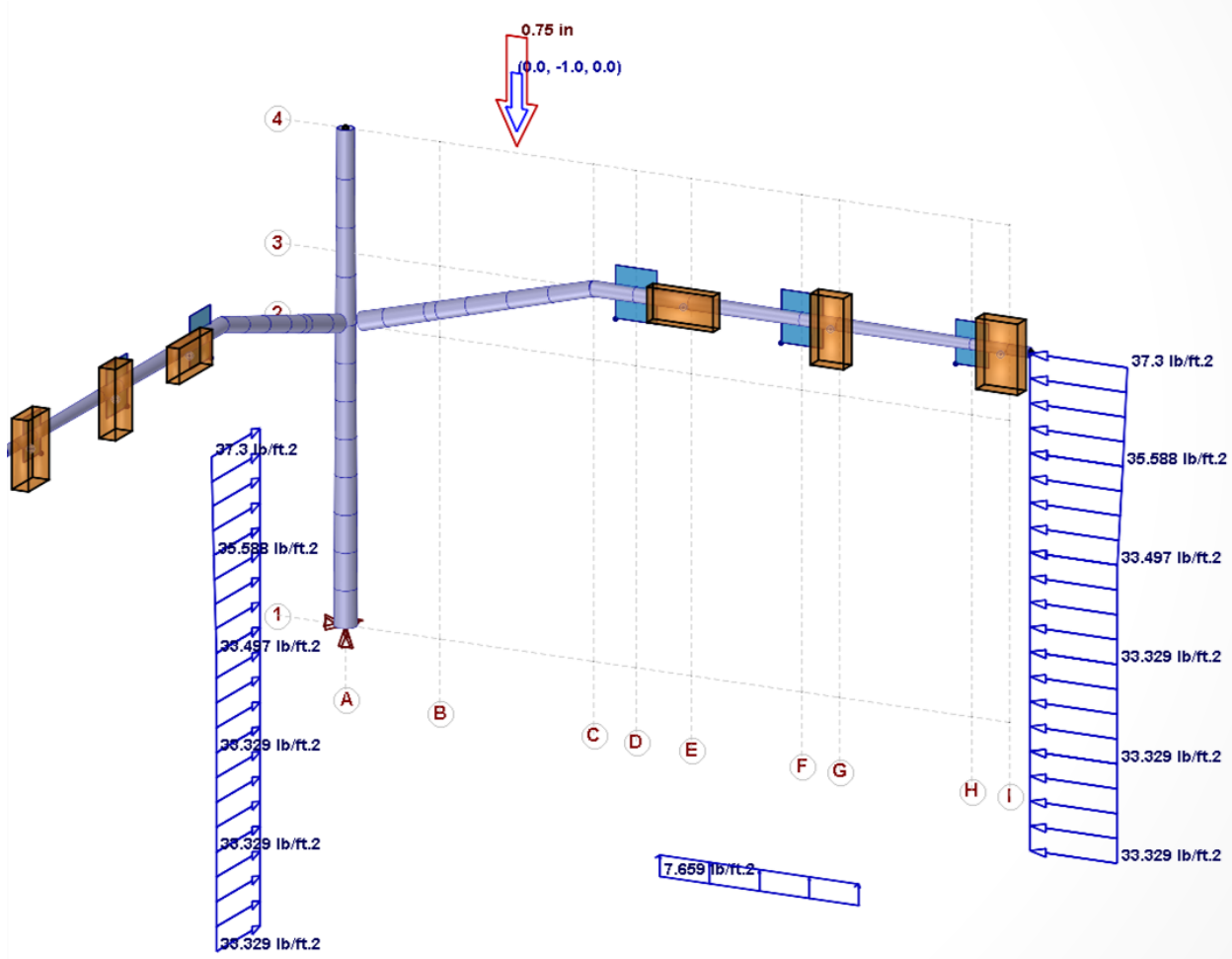






HSE Software - Generated Wind, Ice and Fatigue Loads





HSE Software - Generated Basic Loads and Combinations

BY SAFI™

Basic Loads

	Basic Load Name	Load Type
1	Dead	(D) Dead Load
2	Wind Z	(W) Wind Load
3	Wind X	(W) Wind Load
4	Wind Z (ice)	(W) Wind Load
5	Wind X (ice)	(W) Wind Load
6	Ice	(I) Ice Load
7	Wind Z (service)	(W) Wind Load
8	Wind X (service)	(W) Wind Load
9		
10		
11	Galloping Z (GVW)	(W) Wind Load
12	Galloping X (GVW)	(W) Wind Load
13	Natural Wind Gust Z (NWG)	(W) Wind Load
14	Natural Wind Gust X (NWG)	(W) Wind Load
15		
16		
17	Truck-Induced Gust (TrG) 1	(W) Wind Load
18	Truck-Induced Gust (TrG) 2	(W) Wind Load
19	Truck-Induced Gust (TrG) 3	(W) Wind Load
20	Truck-Induced Gust (TrG) 4	(W) Wind Load
21	Truck-Induced Gust (TrG) 5	(W) Wind Load

Load Combinations

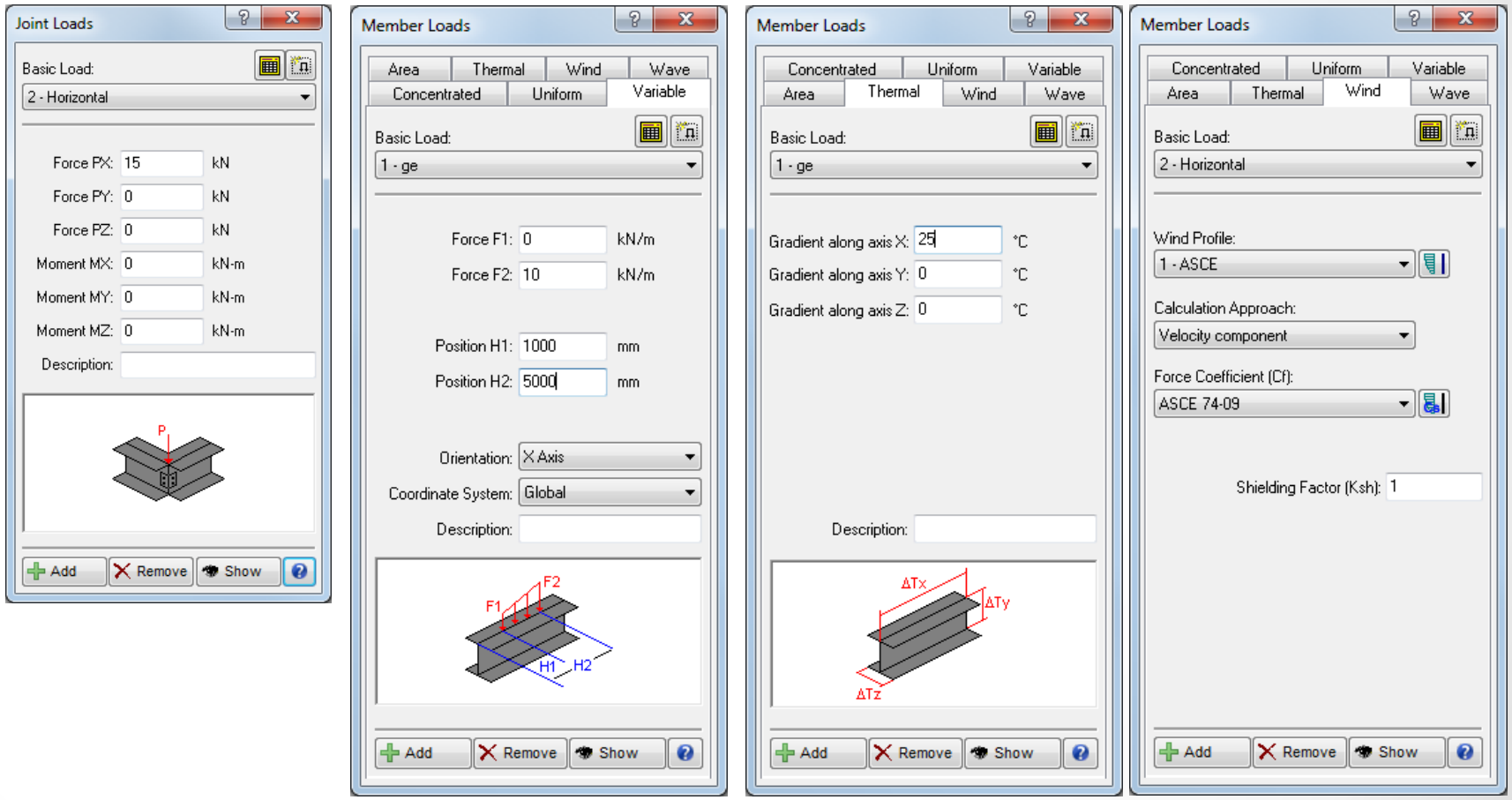
Table Commands View

	Combination ID	Combination Name	Enabled	Combination Type	Deflection Criterion	Notional Lateral Loads	1 - Dead	2 - Wind Z	3 - Wind X	4 - Wind Z (ice)	5 - Wind X (ice)	6 - Ice
	1	Strength I, DLmax	☑	ULS		Disabled	1.250					
	2	Extreme I, DLmin+Wz	☑	ULS		Disabled	0.900	1.000				
	3	Extreme I, DLmax+Wz	☑	ULS		Disabled	1.100	1.000				
	4	Extreme I, DLmin-Wz	☑	ULS		Disabled	0.900	-1.000				
	5	Extreme I, DLmax-Wz	☑	ULS		Disabled	1.100	-1.000				
	6	Extreme I, DLmin+Wx	☑	ULS		Disabled	0.900		1.000			
	7	Extreme I, DLmax+Wx	☑	ULS		Disabled	1.100		1.000			
	8	Extreme I, DLmin-Wx	☑	ULS		Disabled	0.900		-1.000			
	9	Extreme I, DLmax-Wx	☑	ULS		Disabled	1.100		-1.000			
	10	Extreme I, DLmin+0.75(Wz+Wx)	☑	ULS		Disabled	0.900	0.750	0.750			
	11	Extreme I, DLmax+0.75(Wz+Wx)	☑	ULS		Disabled	1.100	0.750	0.750			
	12	Extreme I, DLmin+0.75(Wz-Wx)	☑	ULS		Disabled	0.900	0.750	-0.750			
	13	Extreme I, DLmax+0.75(Wz-Wx)	☑	ULS		Disabled	1.100	0.750	-0.750			
	14	Extreme I, DLmin+0.75(-Wz+Wx)	☑	ULS		Disabled	0.900	-0.750	0.750			
	15	Extreme I, DLmax+0.75(-Wz+Wx)	☑	ULS		Disabled	1.100	-0.750	0.750			
	16	Extreme I, DLmin+0.75(-Wx-Wz)	☑	ULS		Disabled	0.900	-0.750	-0.750			
	17	Extreme I, DLmax+0.75(-Wx-Wz)	☑	ULS		Disabled	1.100	-0.750	-0.750			
	22	Extreme I, DLmax+Ice+Wz	☑	ULS		Disabled	1.100			1.000		1.000
	23	Extreme I, DLmax+Ice-Wz	☑	ULS		Disabled	1.100			-1.000		1.000
	24	Extreme I, DLmax+Ice+Wx	☑	ULS		Disabled	1.100				1.000	1.000
	25	Extreme I, DLmax+Ice-Wx	☑	ULS		Disabled	1.100				-1.000	1.000

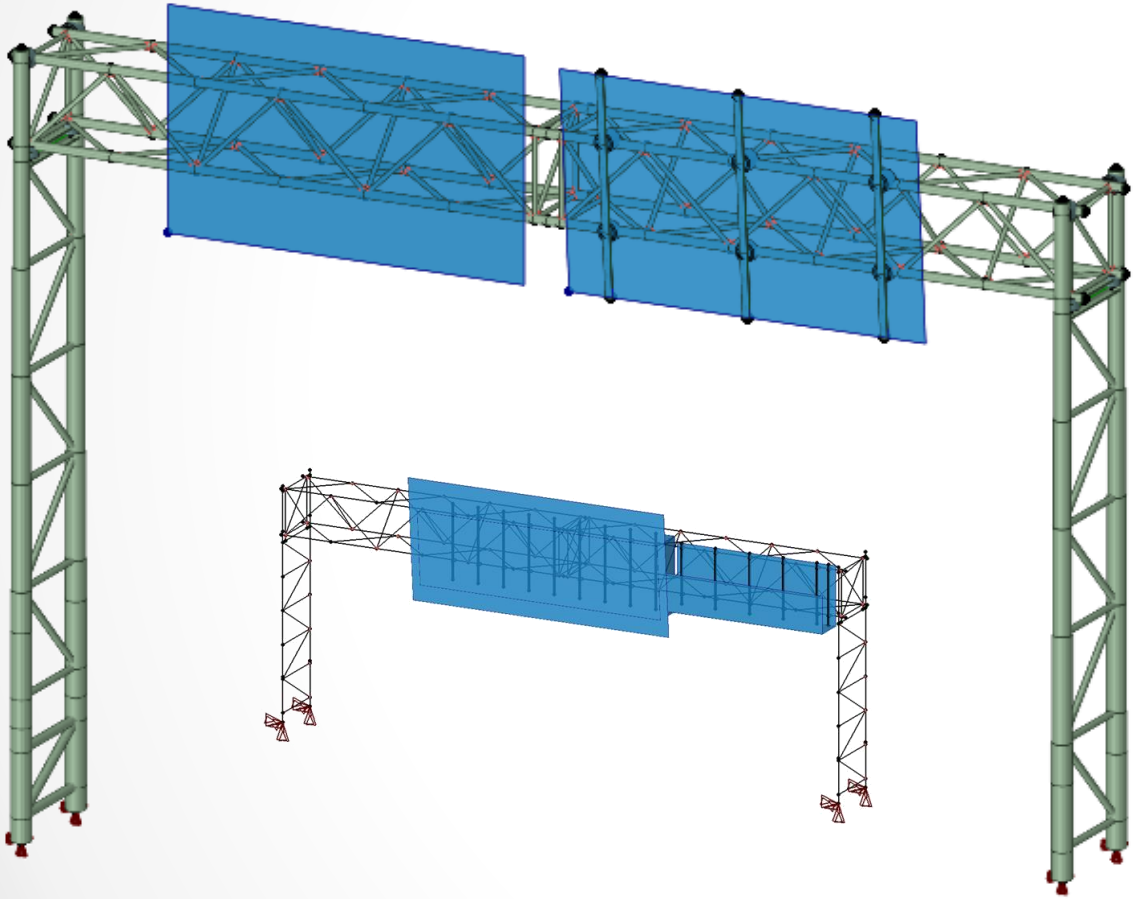
OK
Cancel
Help

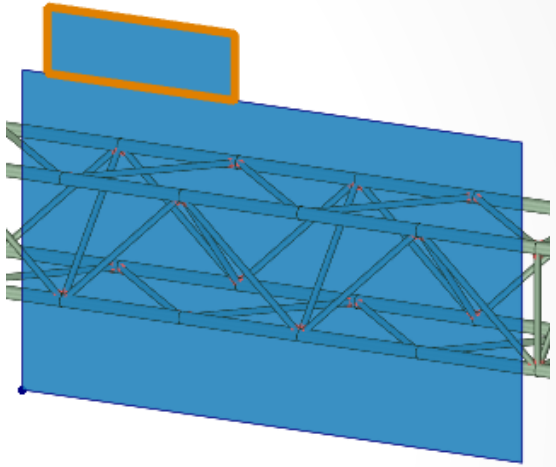
HSE Software – Other possible load types

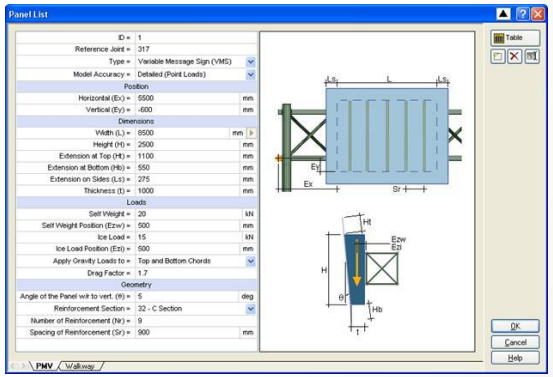
- **Joints loads**
  - Concentrated
- **Members loads**
  - Concentrated
  - Uniform
  - Variable
  - Thermal
  - Wind



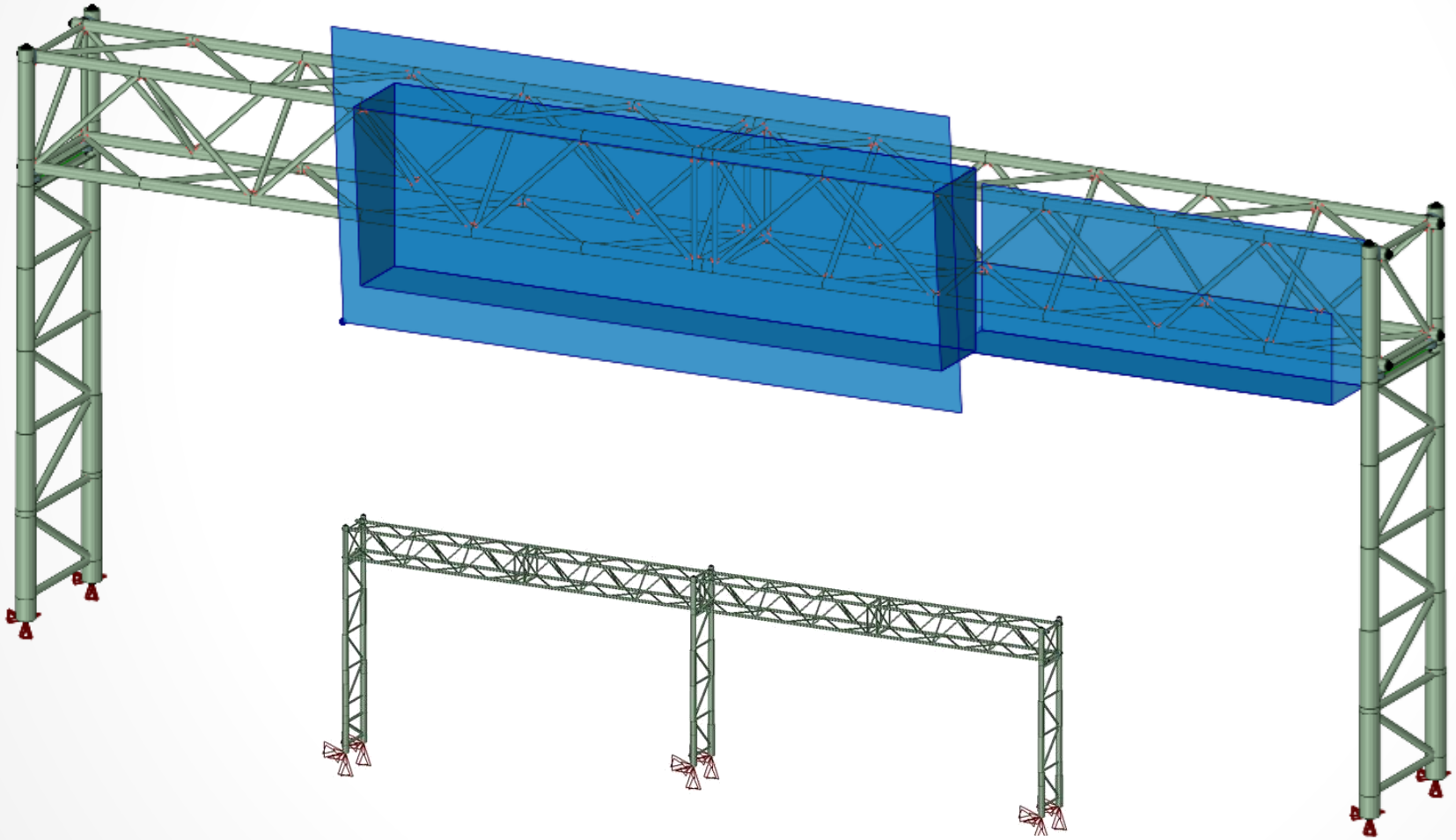
HSE Software - Simple and Secondary Panels



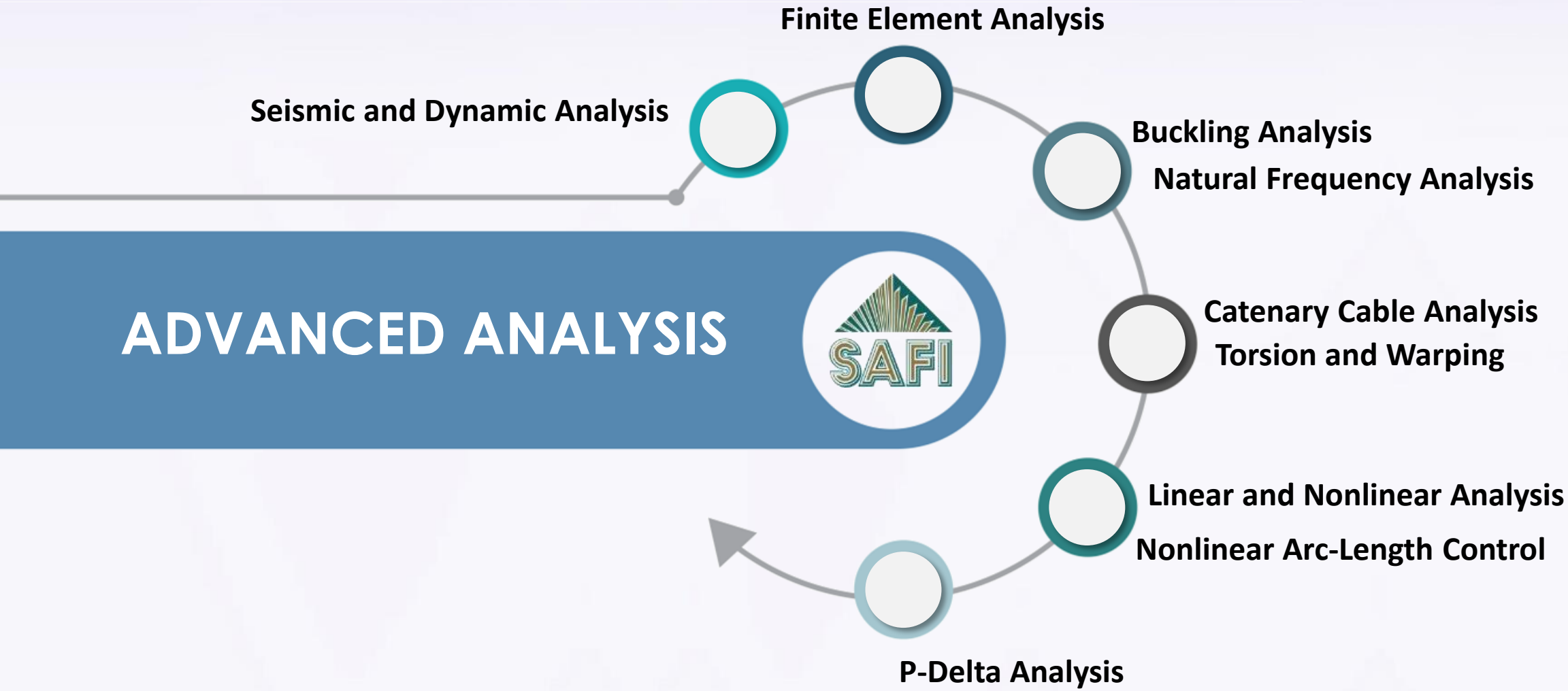




HSE Software - Variable Message Sign (VMS) and Walkway

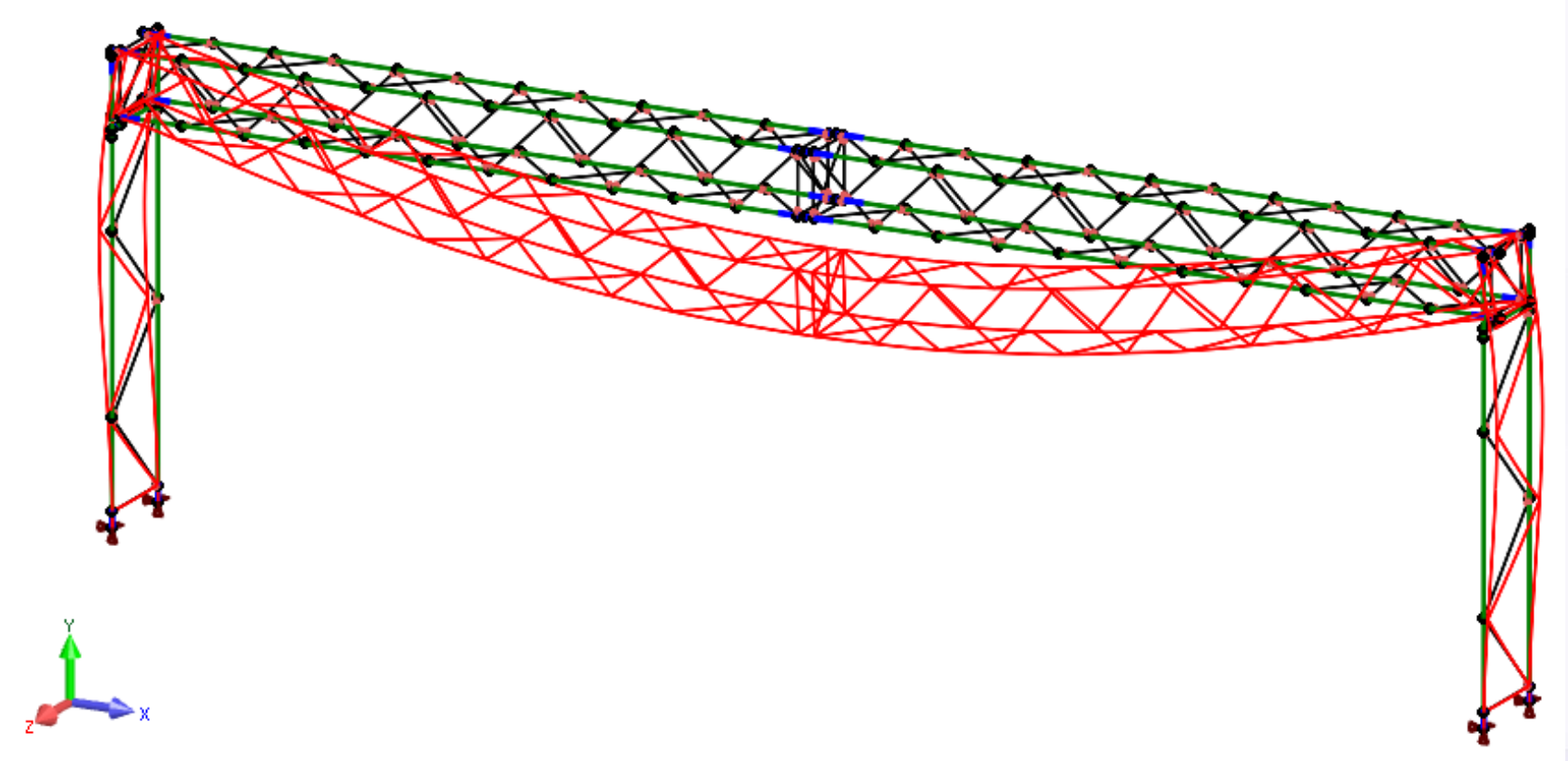


Advanced Structural Analysis



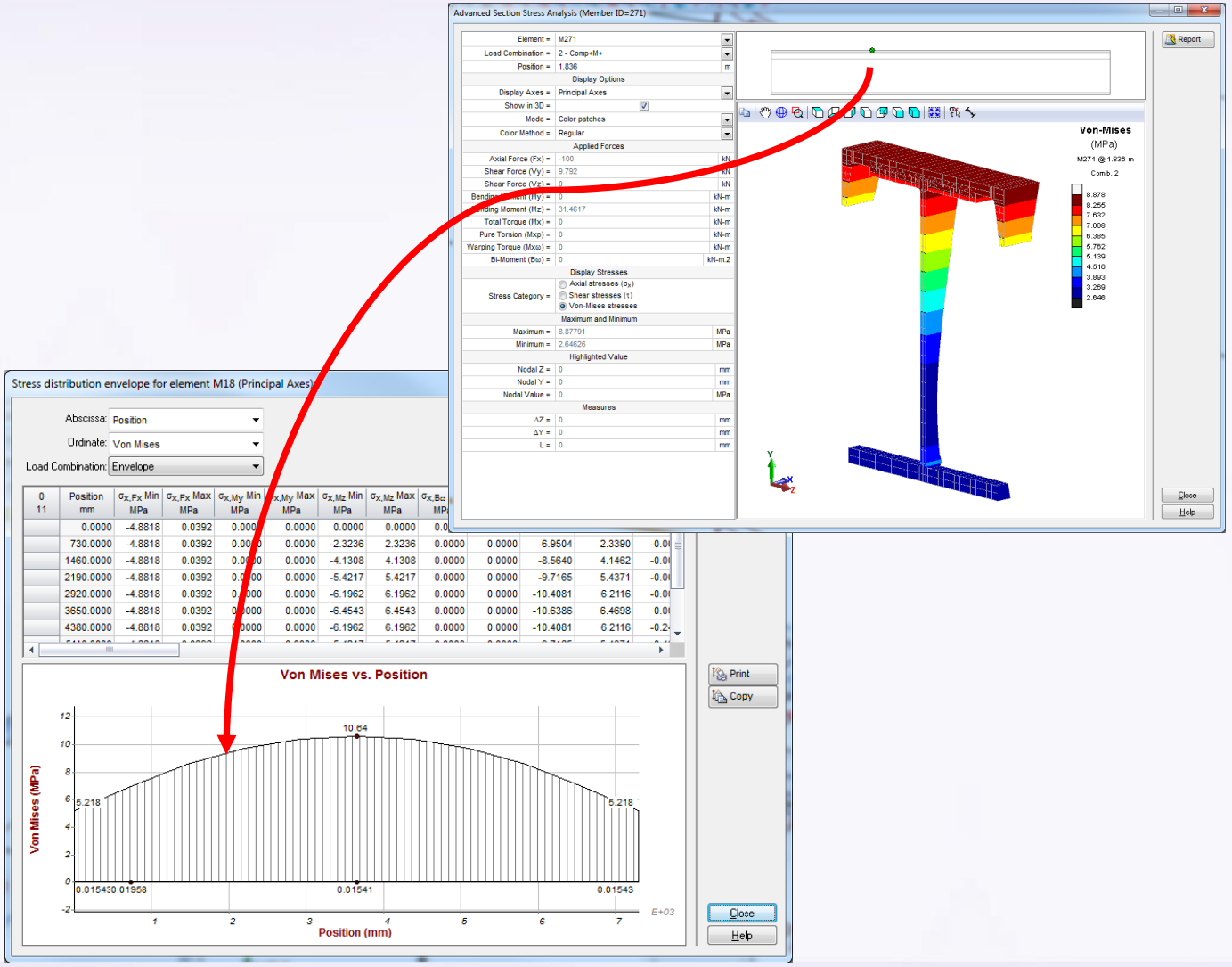
SAFI 3D: Analysis Results

- Displacements
- Reactions
- Forces and Moments
- Stresses

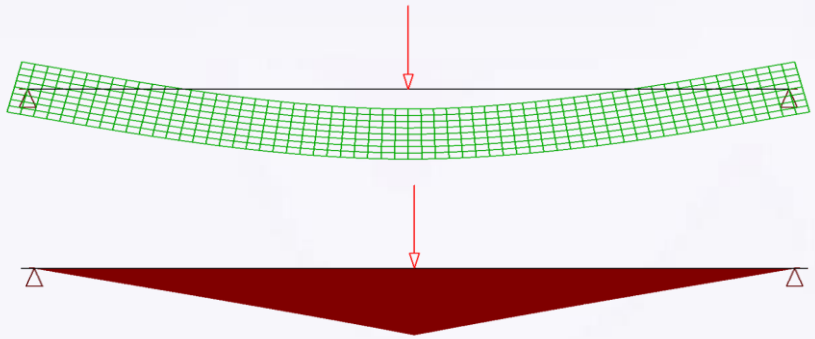


SAFI 3D: Advanced Section Stress Analysis

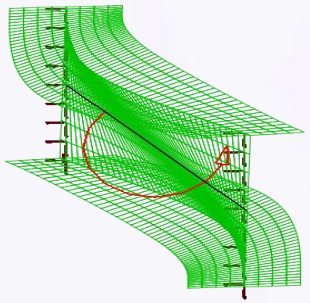
- Calculated stresses
- Axial stresses
- Bending stresses
- Shear stresses
- Torsion stresses
- Warping stresses
- Von-Mises stresses
- Stress distribution at point
- Stress envelope



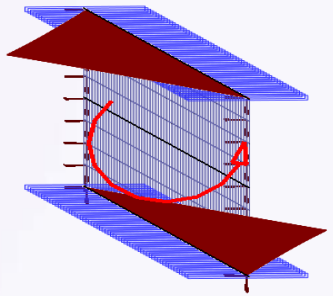
SAFI 3D: Torsion and Warping



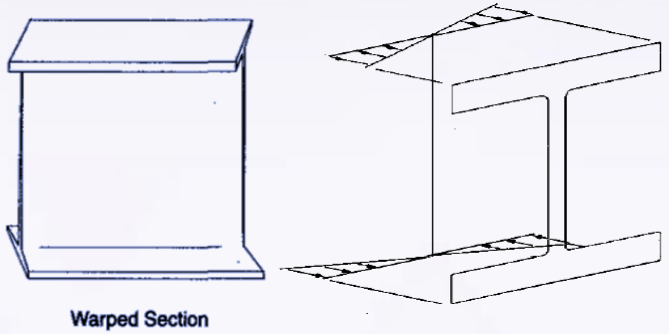
Equivalent view of the top flange

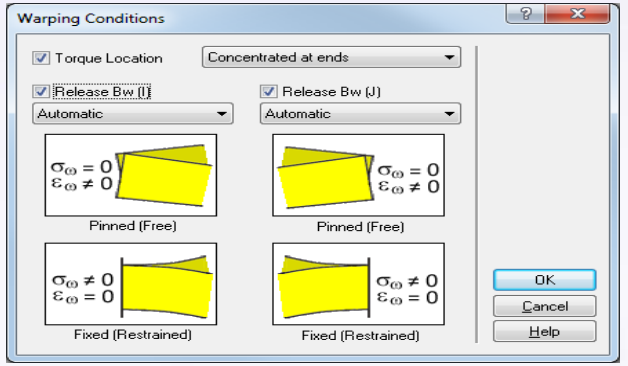


Deformation

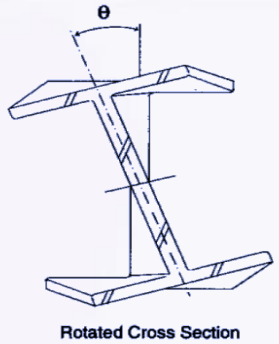


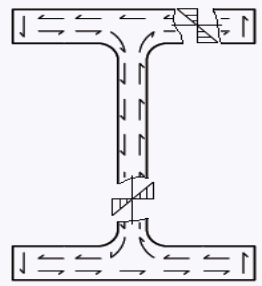
Bending in flanges

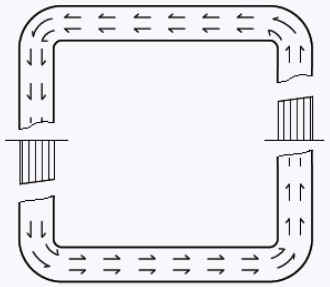


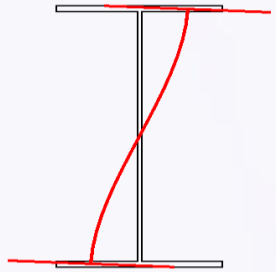


Axial stress (σ_x) due to warping







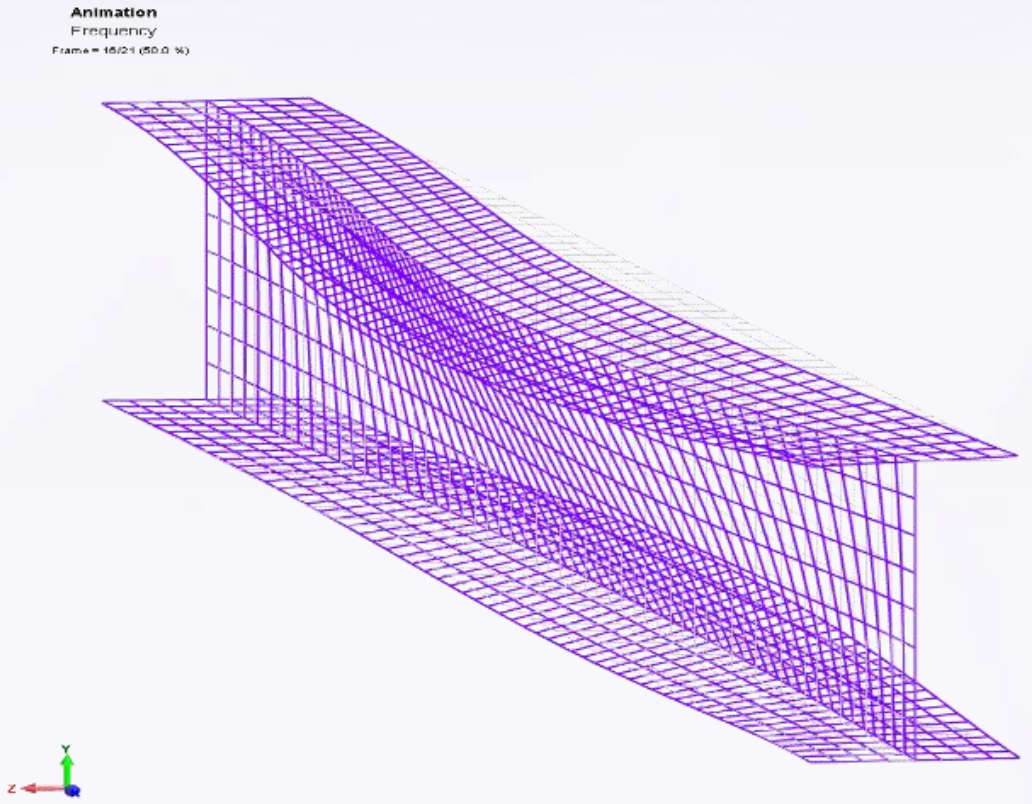


Shear stress (τ_t) due to pure torsion

SAFI 3D: Buckling Analysis

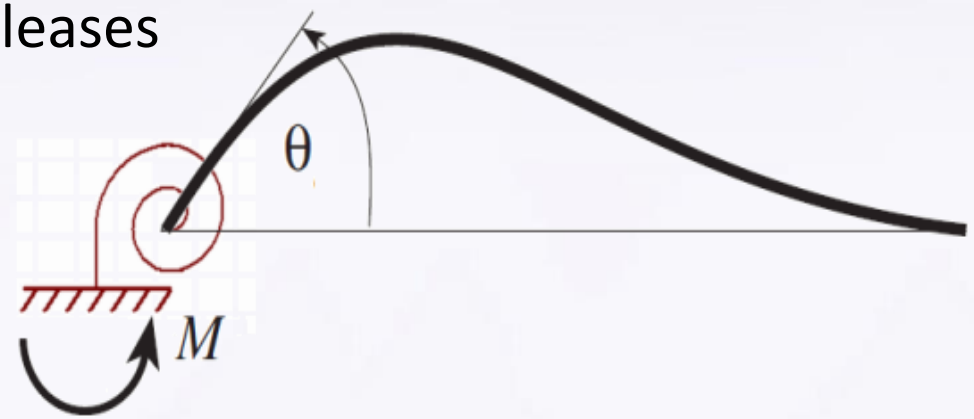
The buckling analysis can be used to get elastic buckling load associated with the following instabilities:

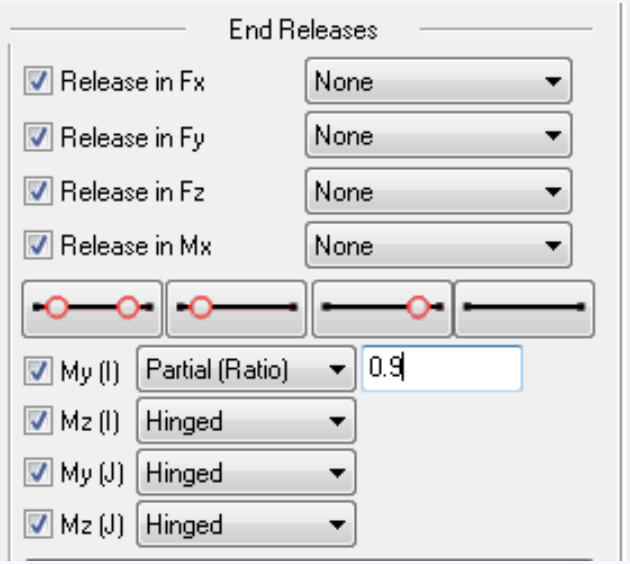
- **Beam elements**
  - Column compression buckling
  - Overall buckling of structure
  - Get the effective length “kL”
- **Finite elements**
  - Flange or web local buckling (FLB, WLB)
  - Beam Lateral Torsional Buckling (LTB)
  - Flexural-Torsional Buckling (FTB)



SAFI 3D: Partial Releases

Partial bending releases





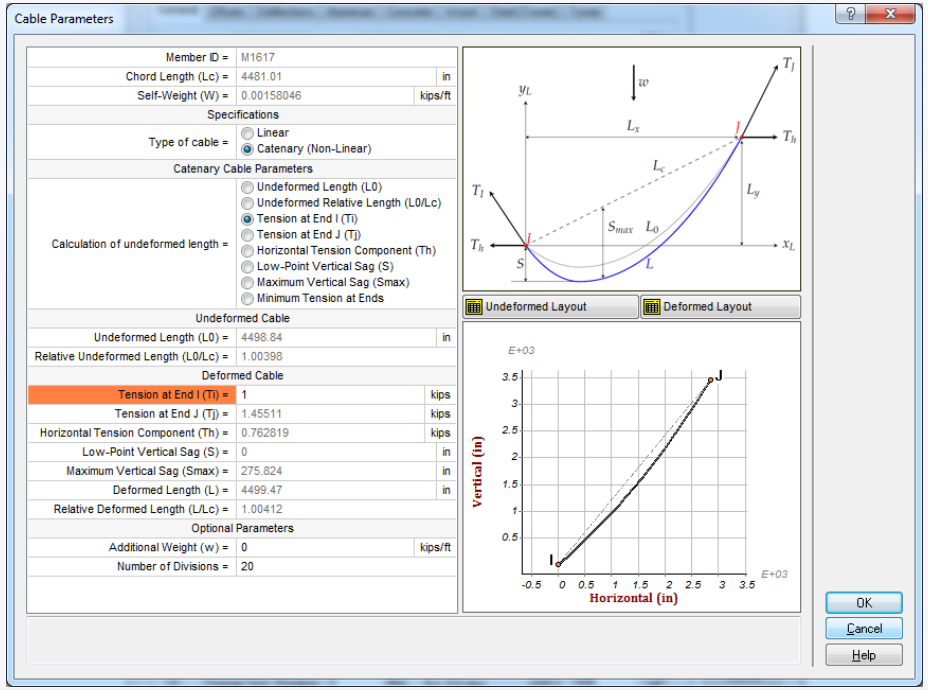
There is a direct relation between rotational rigidity (k) and the ratio of transferred moment (γ).

$$k = \frac{3 \cdot EI}{L} \frac{\gamma}{1-\gamma}$$

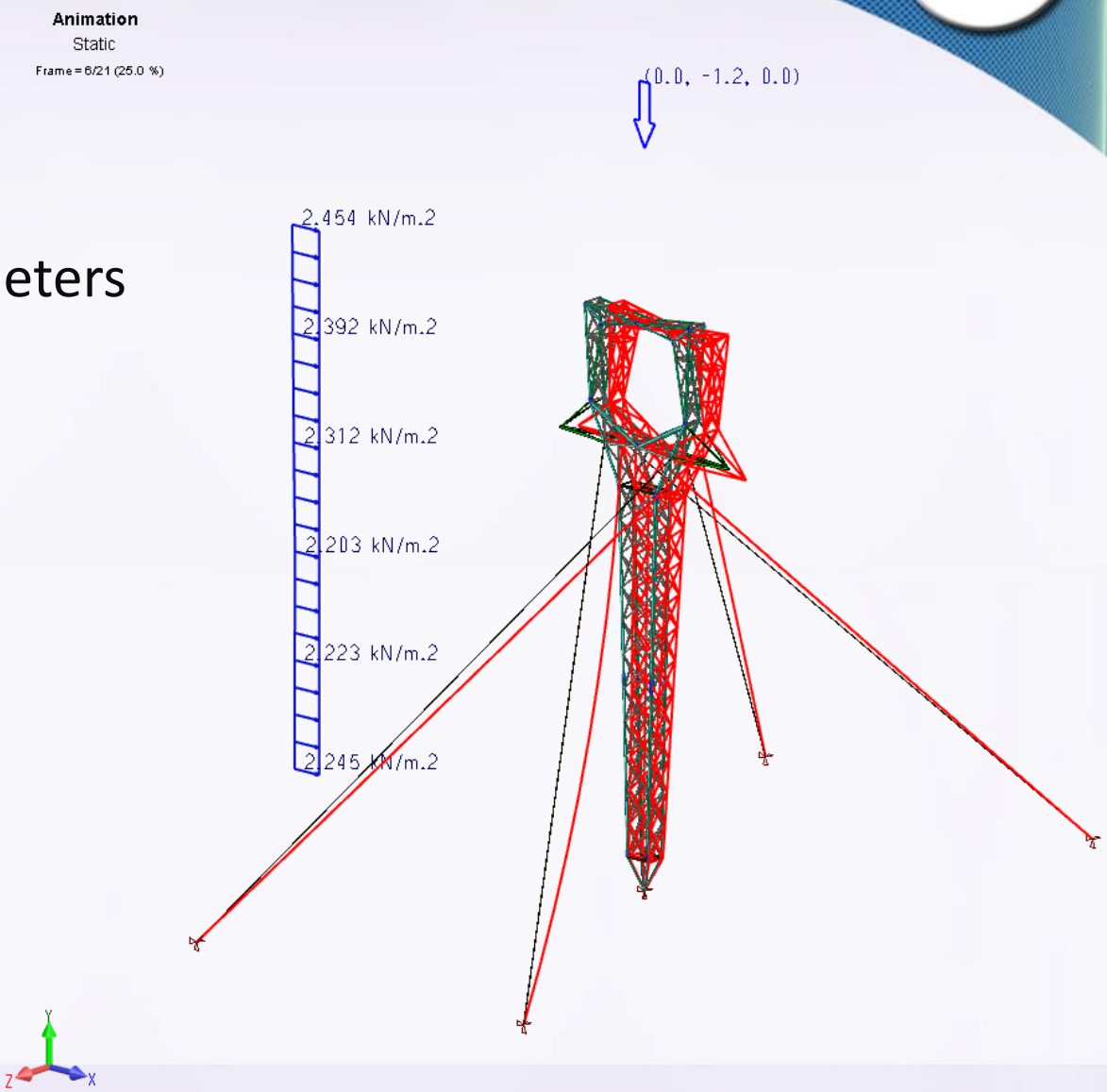
where	EI	Elastic modulus times the inertia of the member.
	L	Length of the member.
	γ	Ratio of transferred moments between 0 and 1
	k	Rotational rigidity (in units of moment per radian)

SAFI 3D: Catenary Cables

- Cable sections library (ASTM, CSA)
- Custom sections
- Define the catenary cable using different parameters
- Nonlinear analysis

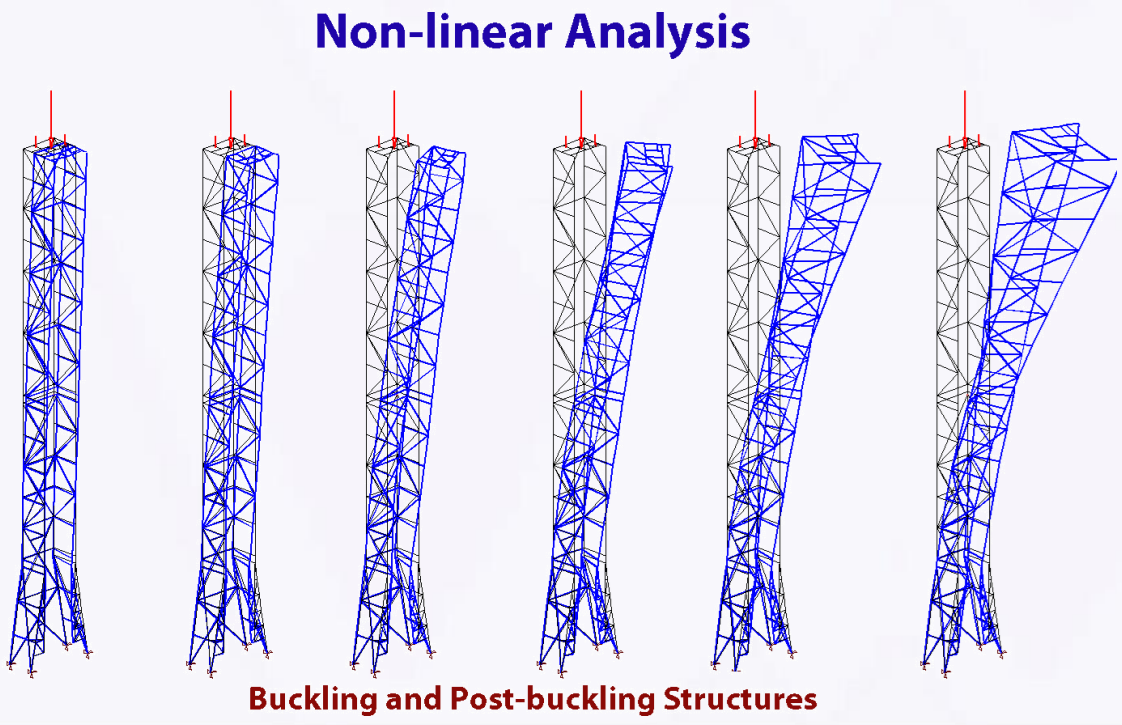


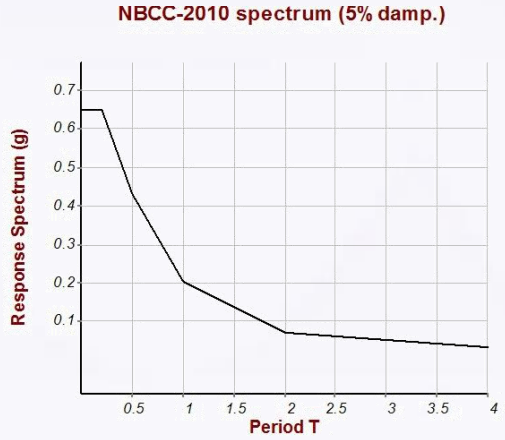
Cable parameters

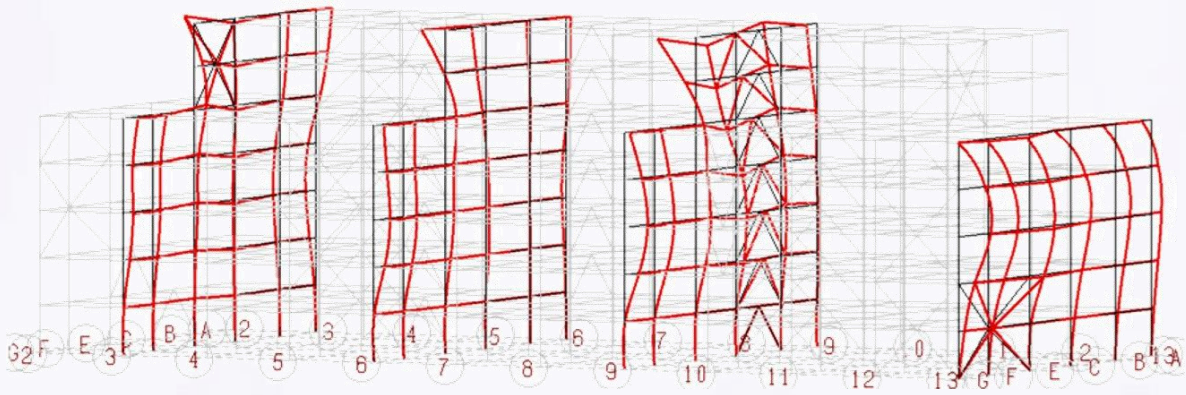


SAFI 3D: Non-Linear Analysis Buckling Structures

- P-delta
- Non-Linear Geometric analysis: 1-Load Control 2-Displacement Control 3-Arc-Length Method



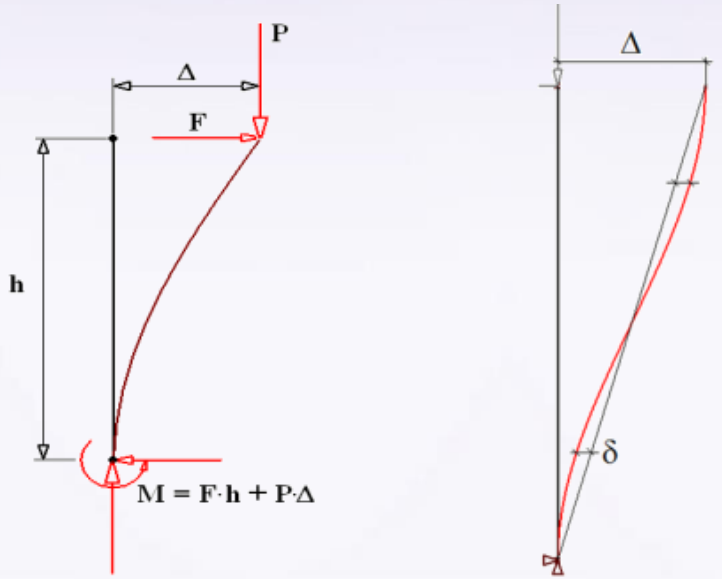




SAFI 3D: P-Delta Analysis

Second-Order Effects: (AISC 360-16)

A-The second order effects can be separated in two components: P-Δ (P-"big"-Delta) and P-δ (P-"little"-delta).



The first-order analysis results should be amplified with equation:

$M_r = B_1 M_{nd} + B_2 M_{lt}$; AISC 360-16 eq. A-8-1

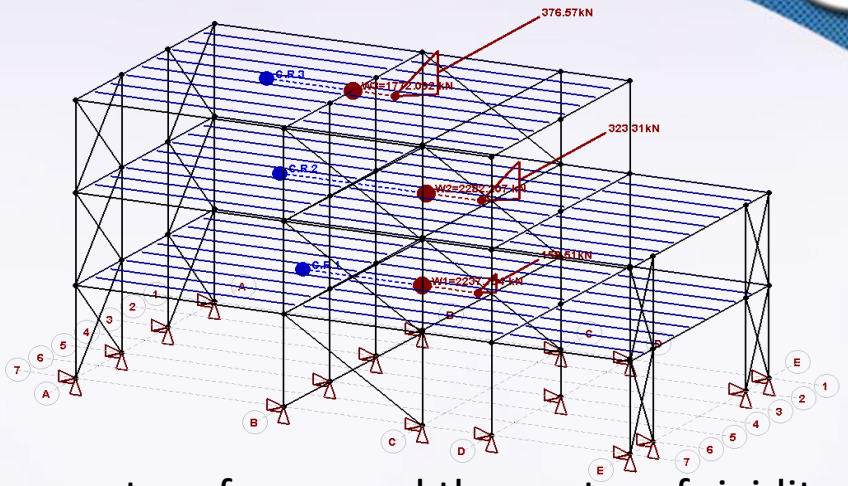
The multiplier $B_1 = C_m/(1 - \alpha P_r/P_{e1}) \geq 1$; (AISC 360-16 eq. A-8-3) can be used to account for the P-δ.

The multiplier B_2; (AISC 360-16 eq. A-8-6) is used to account for the P-Δ effects.

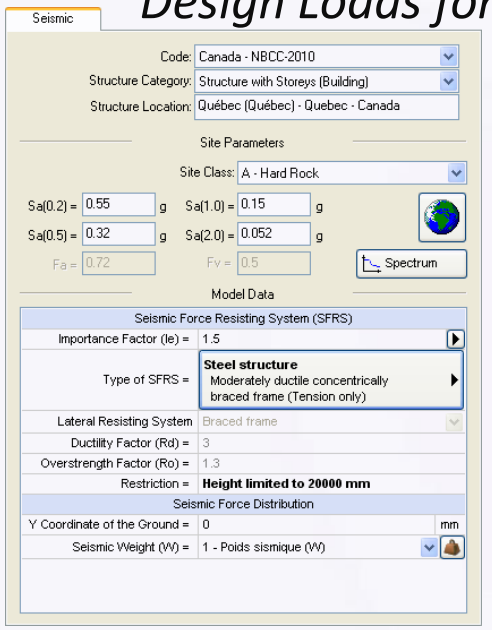
SAFI 3D: Seismic analysis

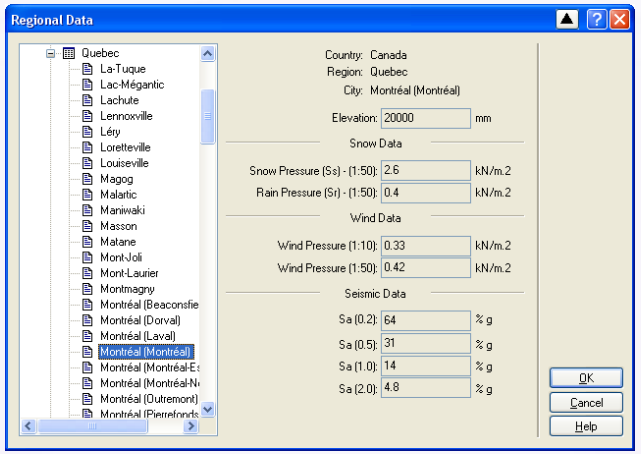
- Static Equivalent seismic analysis
- Response Spectrum seismic analysis
- Time-History seismic analysis

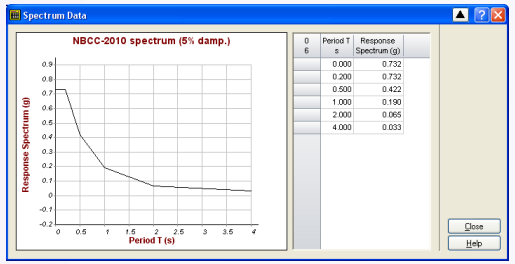
National Building Code of Canada NBCC & Minimum Design Loads for Buildings and Other Structures (ASCE 7).

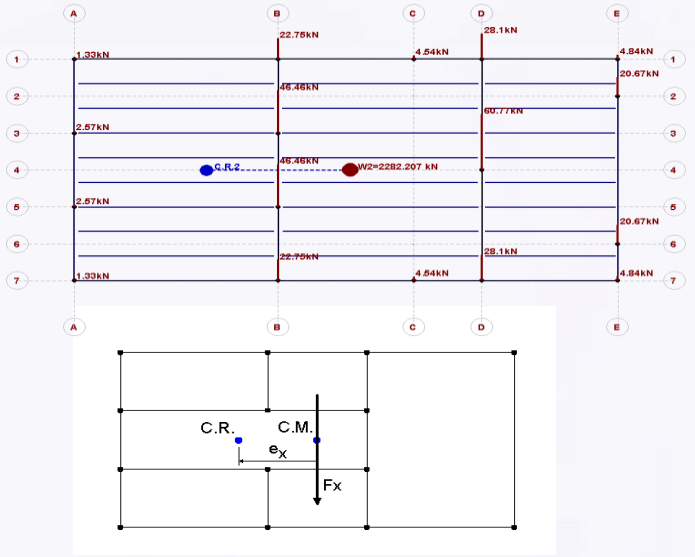


center of mass and the center of rigidity

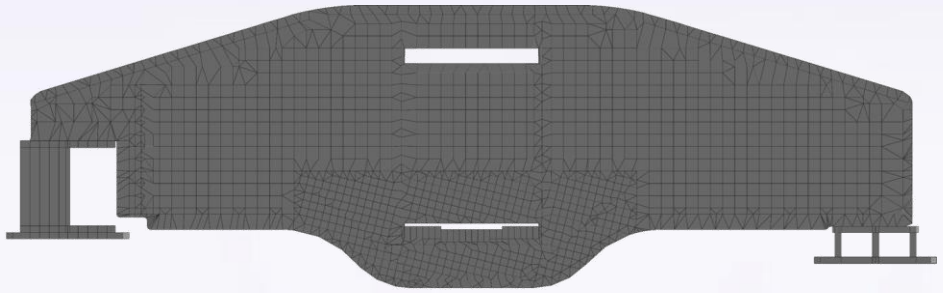


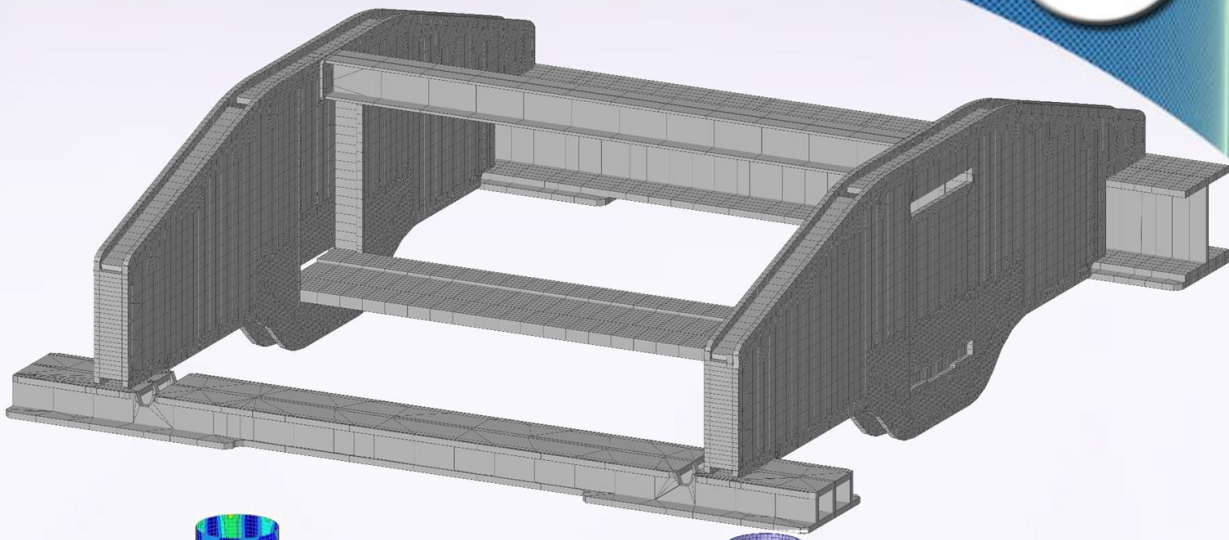


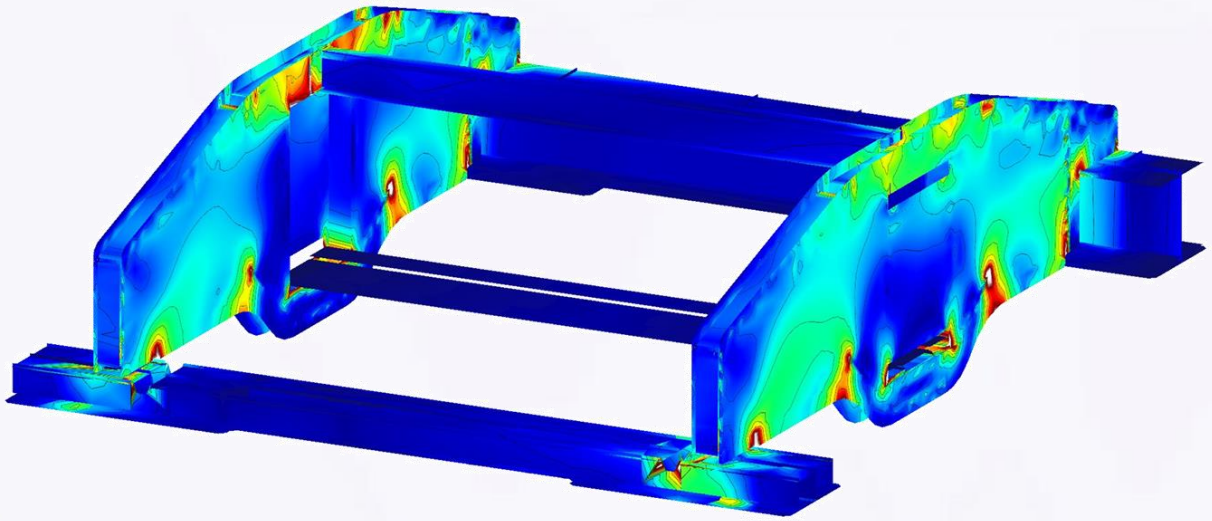


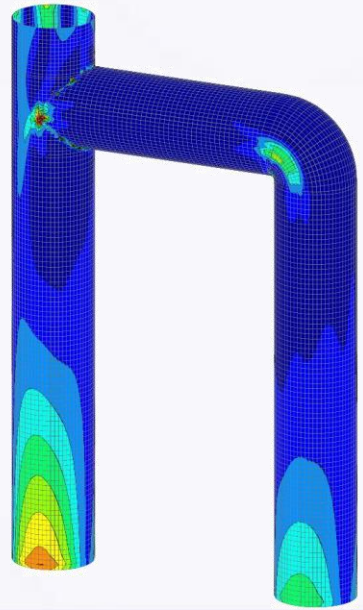


SAFI 3D: FEA





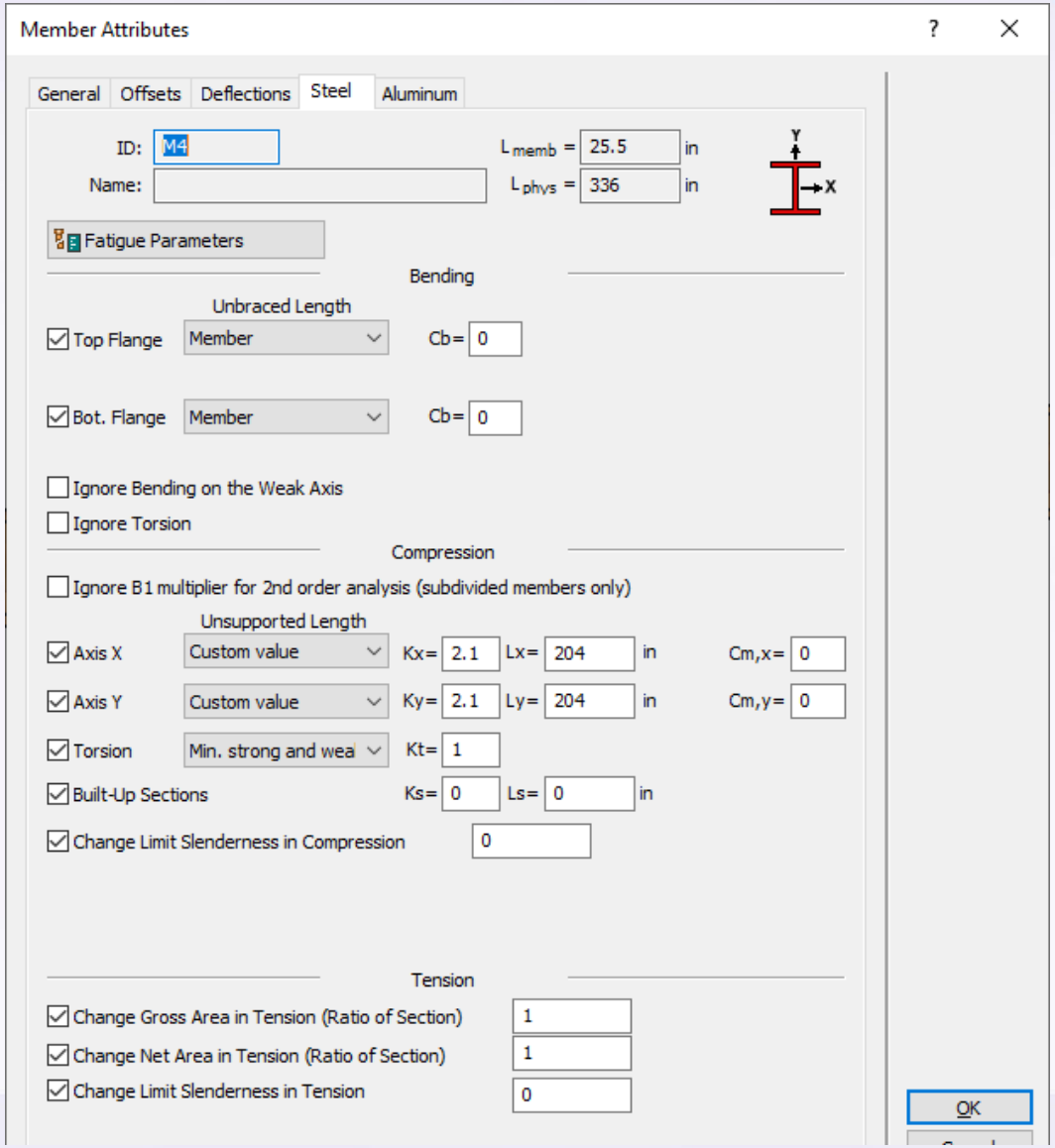




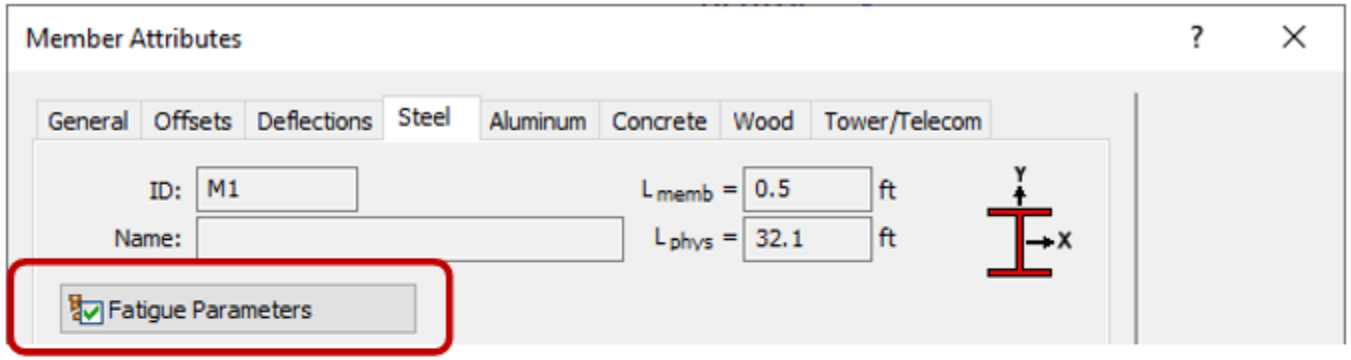
Finite Elements Mechanical Model

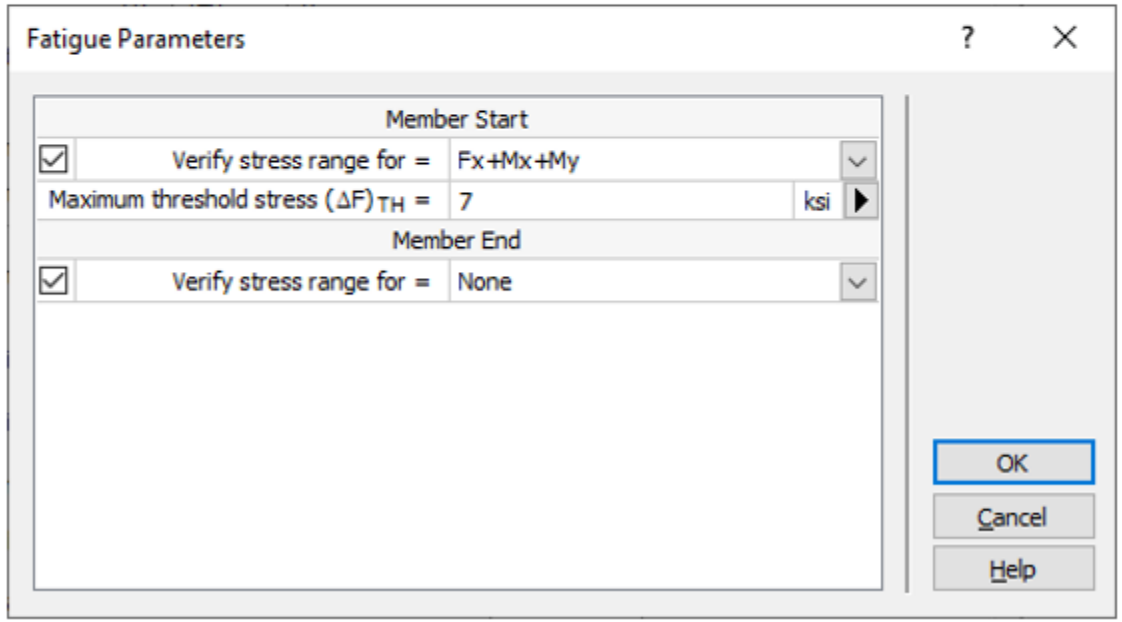
SAFI 3D: Automated and Custom Design Parameters

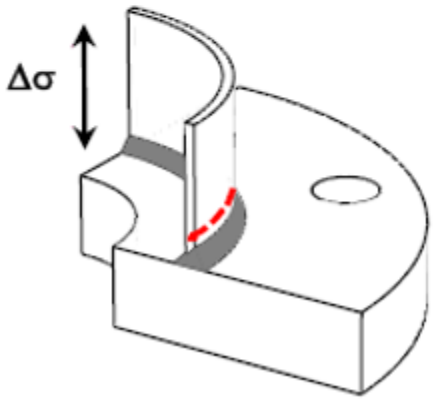
- Fatigue Threshold Stress $(\Delta F)_{TH}$
- Bending Unbraced length
- Compression “K” and “L”
- Tension net



SAFI 3D: Fatigue: Members, Base Plates and Anchor Rods







$K_I < 3.0$: 10.0
$3.0 < K_I < 4.0$: 7.0
$4.0 < K_I < 6.5$: 4.5

SAFI 3D: Calculation of KL using Buckling Analysis

Semi-Automated Buckling Factors Calculator (K)

Controling Mode Shape = Mode #1 , N/A , Fact= 7.198

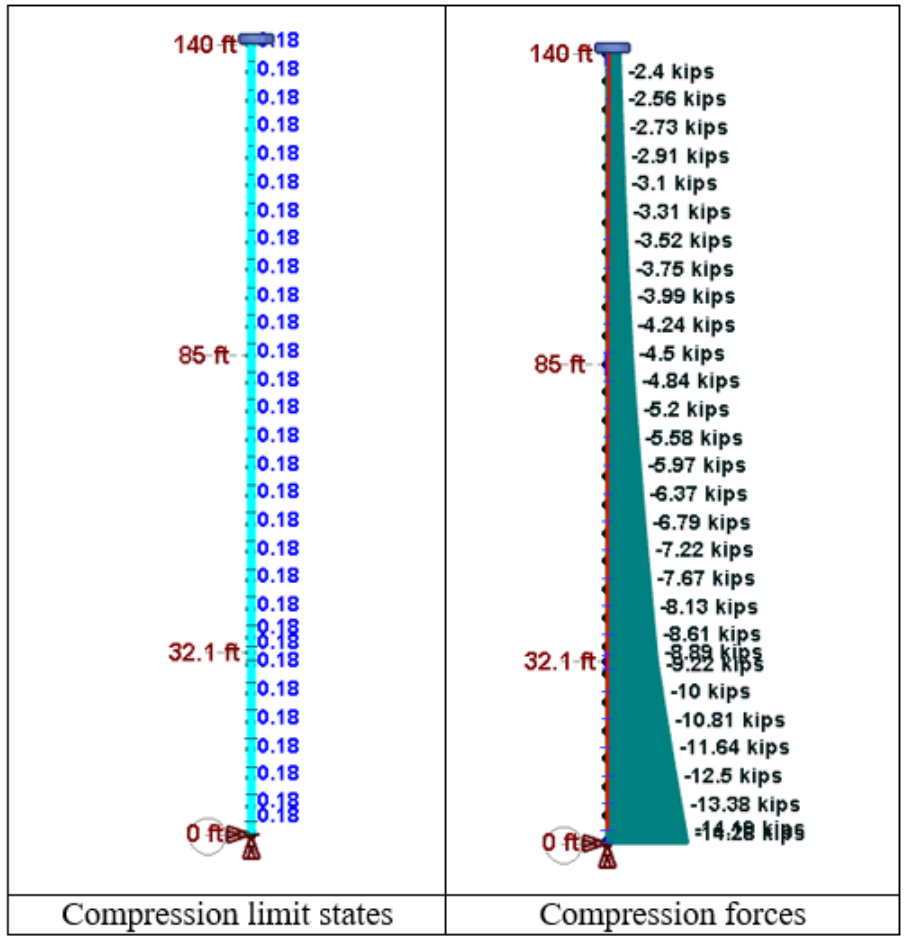
Assign to Selection

Buckling Axis = Strong (Kx, Lx) and Weak (Ky, Ly)

Display Option = Show Calculated Values

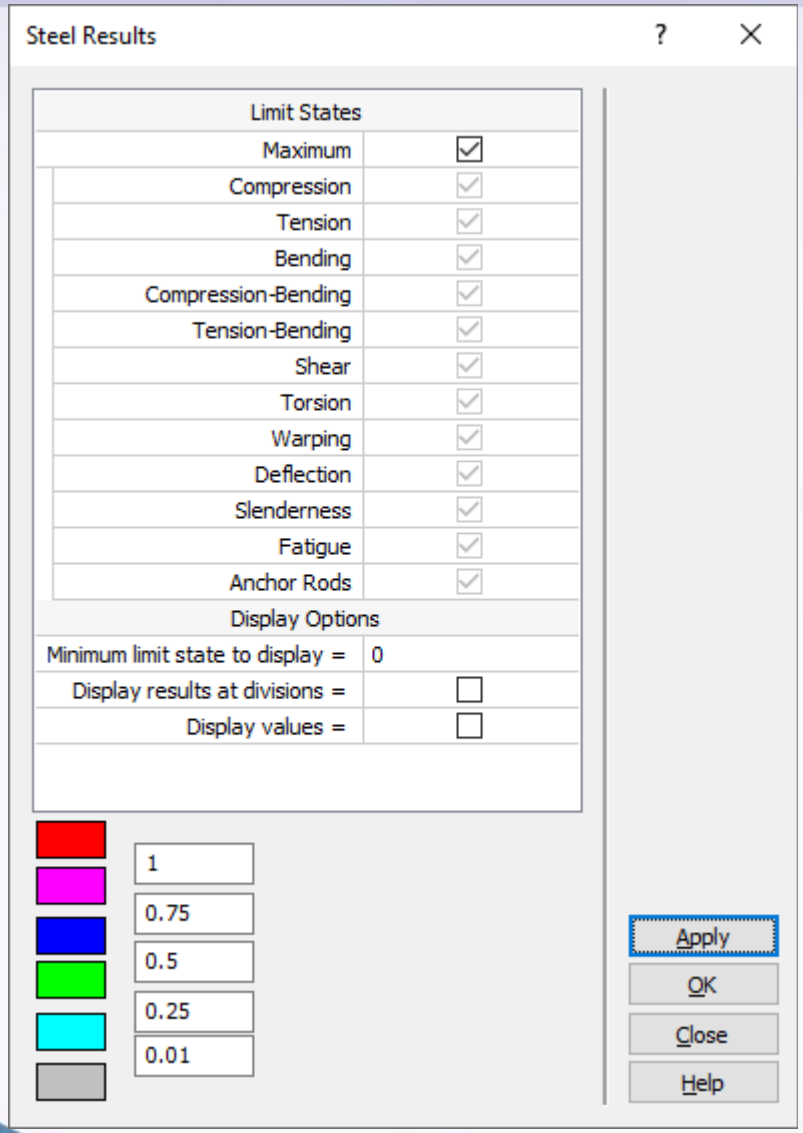
Modal Threshold = 0.01

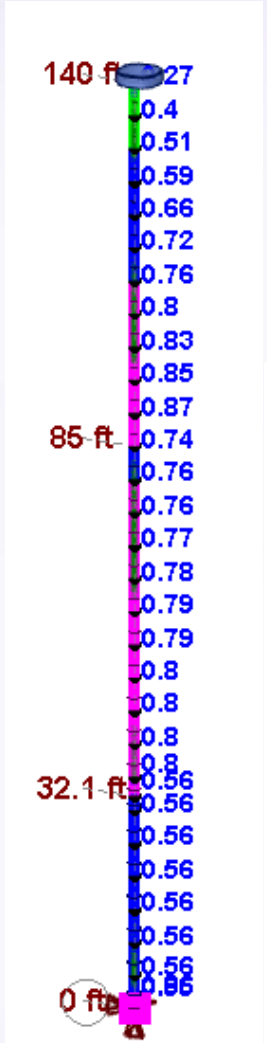
0 30	Physical Member	Member	Cf kips	λ_{cr} Cf kips	Lx ft	Ly ft	Pex kips	Pey kips	Kx ft	Ky ft	Kx Lx ft	Ky Ly ft
	1	1	14.2380	102.4851	140.0000	140.0000	400.6389	400.6389	1.9800	1.9800	277.2000	277.2000
	1	2	13.7860	99.2317	140.0000	140.0000	385.2196	385.2196	1.9700	1.9700	275.8000	275.8000
	1	3	12.9396	93.1395	140.0000	140.0000	357.0228	357.0228	1.9600	1.9600	274.4000	274.4000
	1	4	12.0713	86.8893	140.0000	140.0000	328.8651	328.8651	1.9500	1.9500	273.0000	273.0000
	1	5	11.2268	80.8102	140.0000	140.0000	302.2283	302.2283	1.9300	1.9300	270.2000	270.2000
	1	6	10.4060	74.9023	140.0000	140.0000	277.0701	277.0701	1.9200	1.9200	268.8000	268.8000
	1	7	9.6090	69.1656	140.0000	140.0000	253.3483	253.3483	1.9100	1.9100	267.4000	267.4000
	1	8	9.0551	65.1787	140.0000	140.0000	237.3545	237.3545	1.9100	1.9100	267.4000	267.4000
	2	9	8.7519	62.9959	140.0000	140.0000	157.1104	157.1104	1.5800	1.5800	221.2000	221.2000
	2	10	8.3711	60.2550	140.0000	140.0000	146.0966	146.0966	1.5600	1.5600	218.4000	218.4000
	2	11	7.9008	56.8699	140.0000	140.0000	132.9093	132.9093	1.5300	1.5300	214.2000	214.2000
	2	12	7.4453	53.5915	140.0000	140.0000	120.5405	120.5405	1.5000	1.5000	210.0000	210.0000

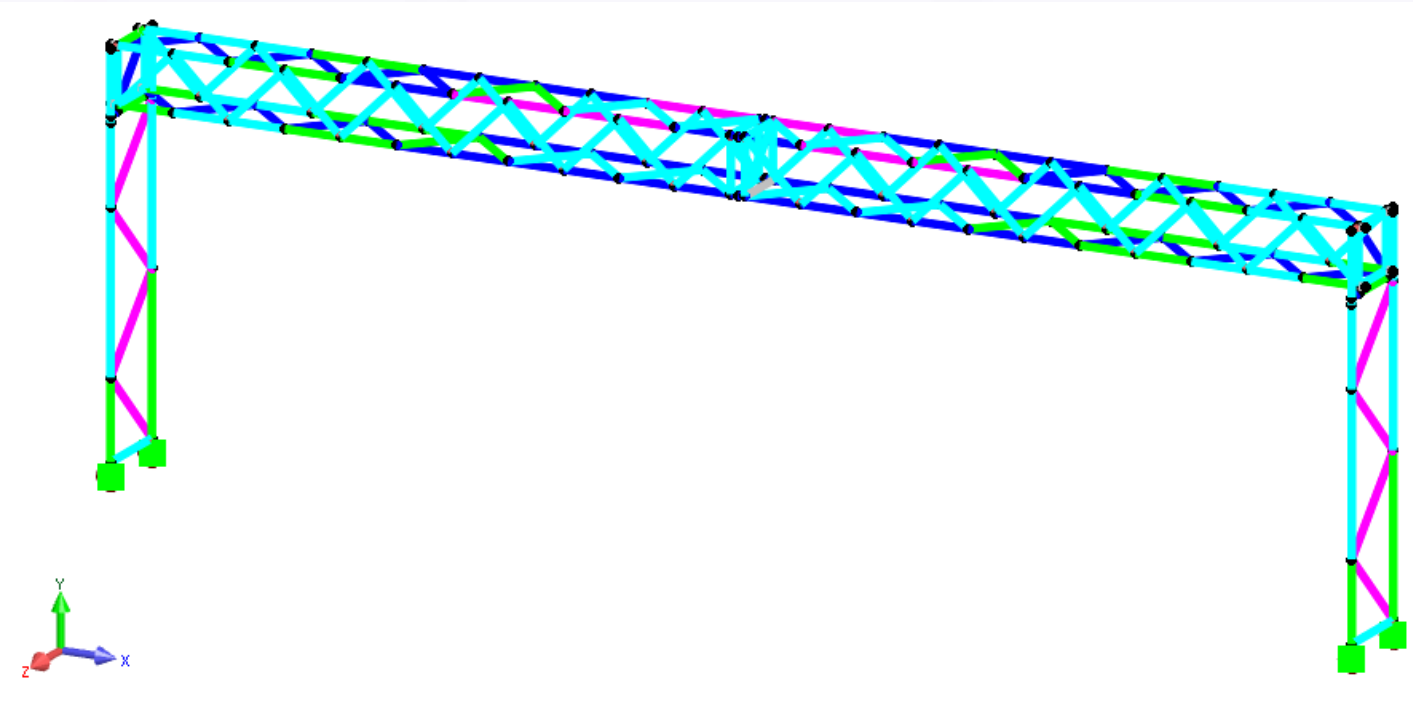


Compression limit states | Compression forces

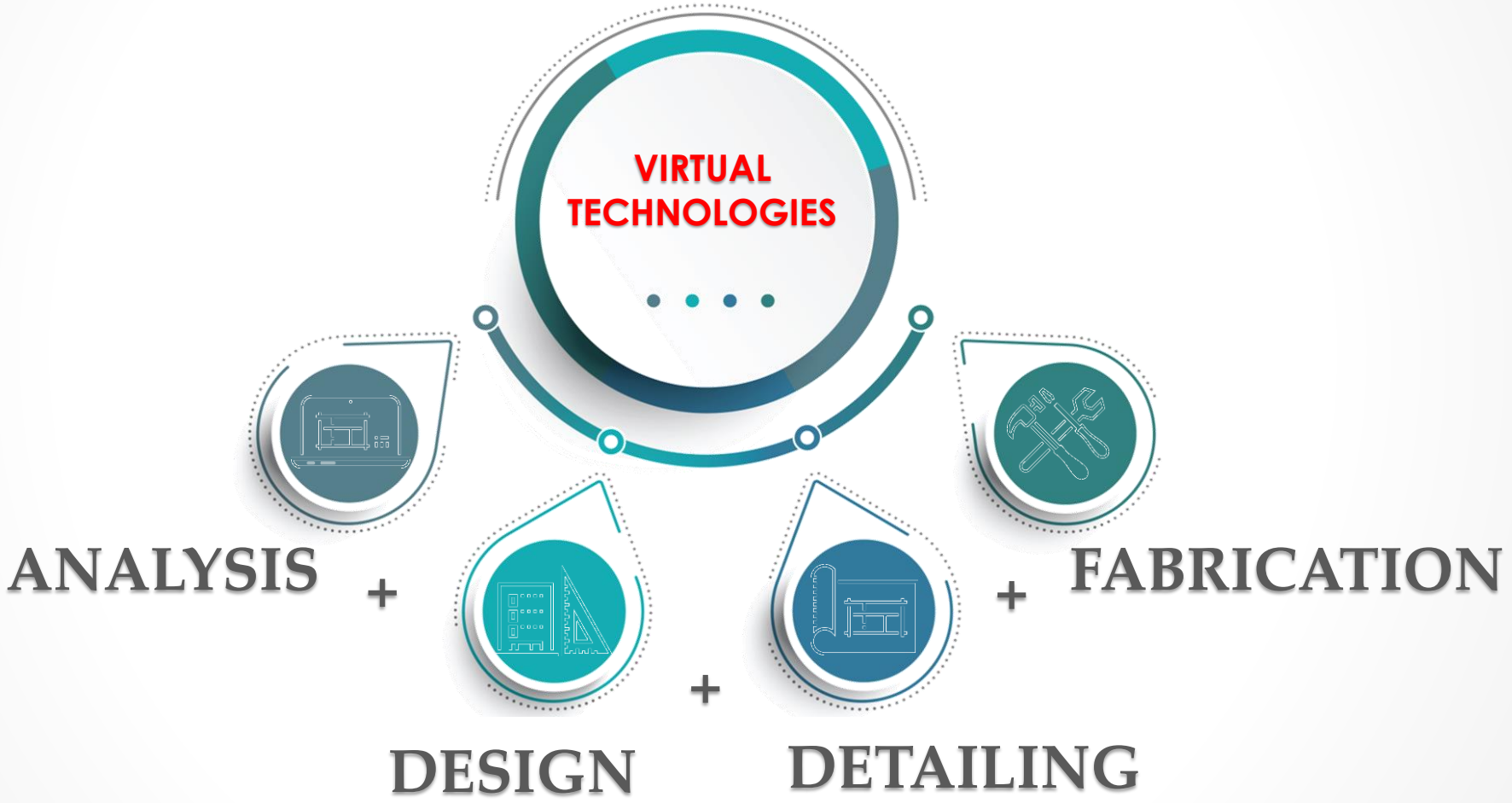
SAFI 3D: Members and Base Plates Design Results





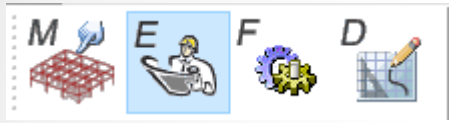


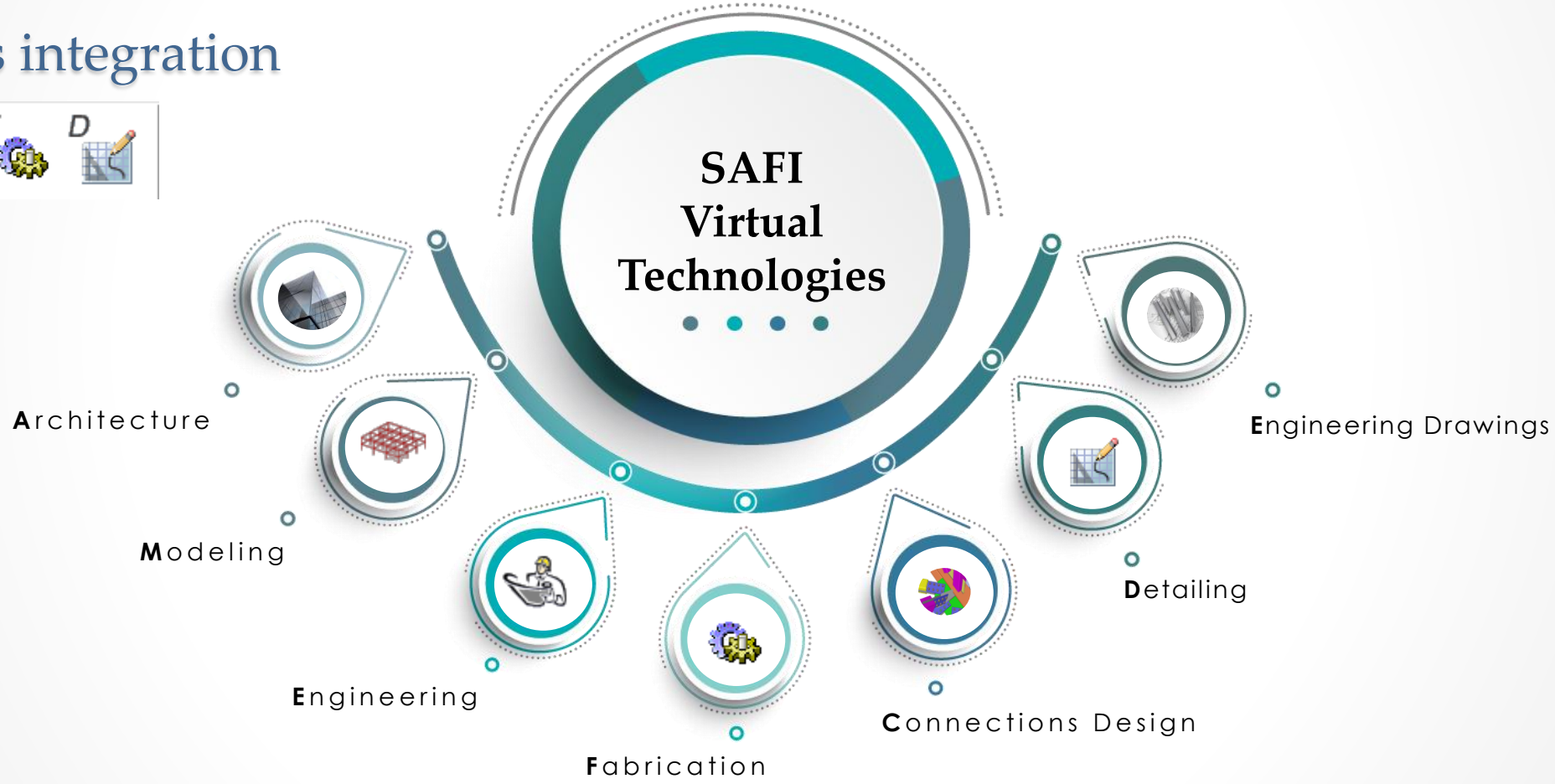
Virtual Technologies – Level III



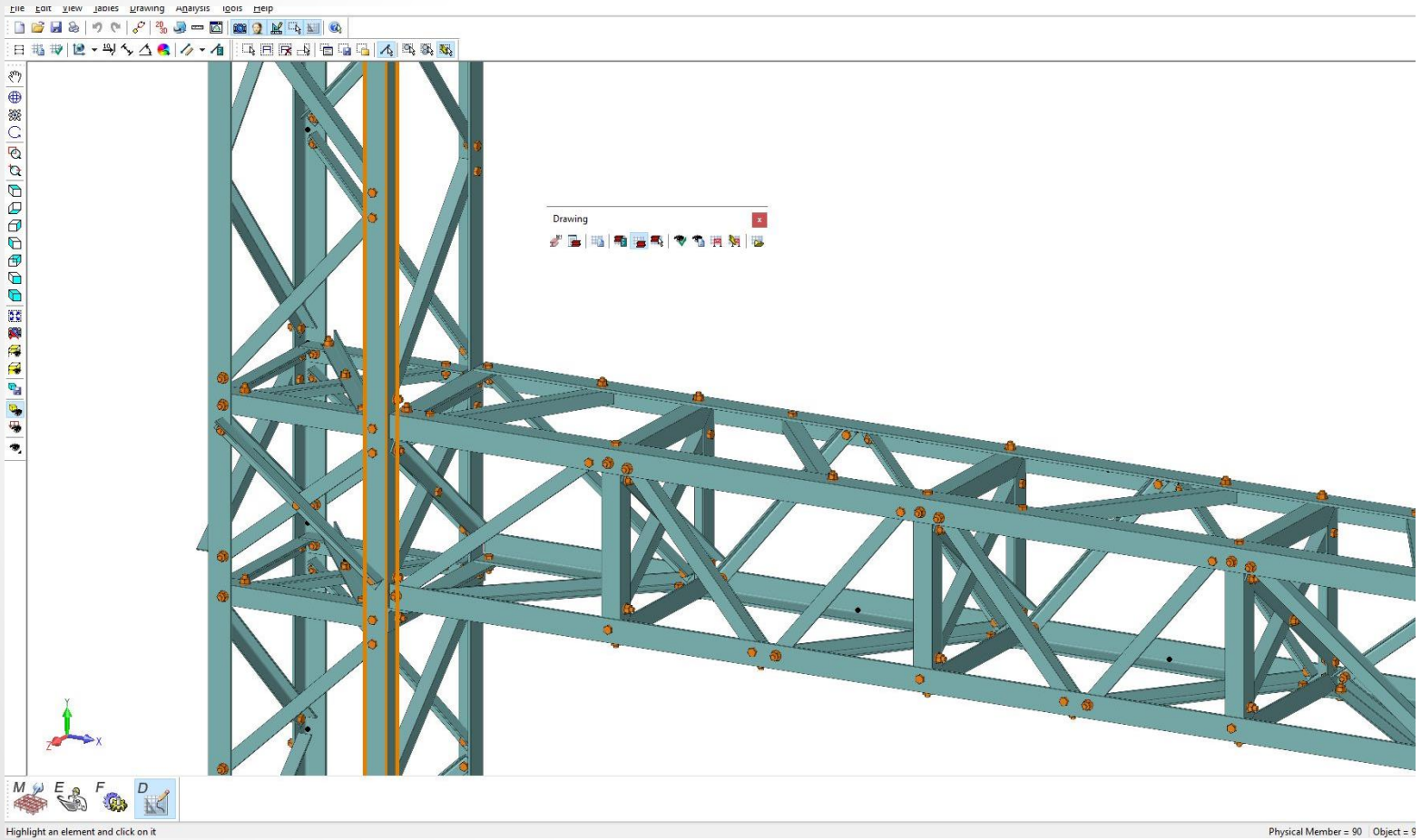
Virtual Technologies

Seamless integration

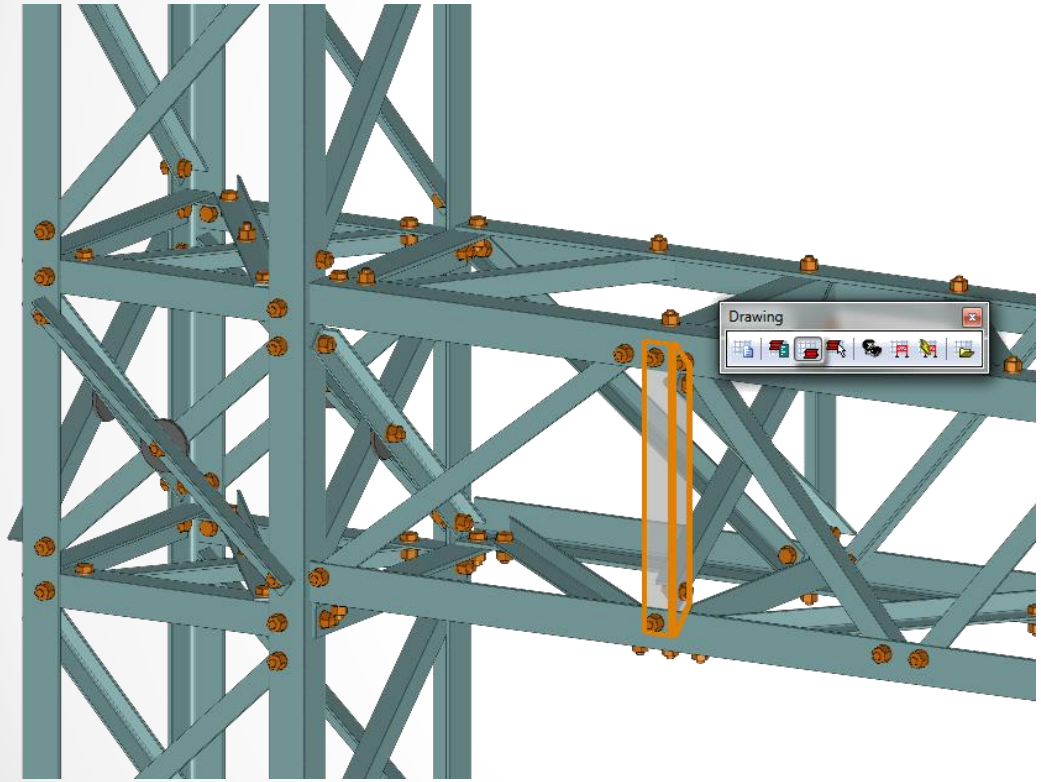


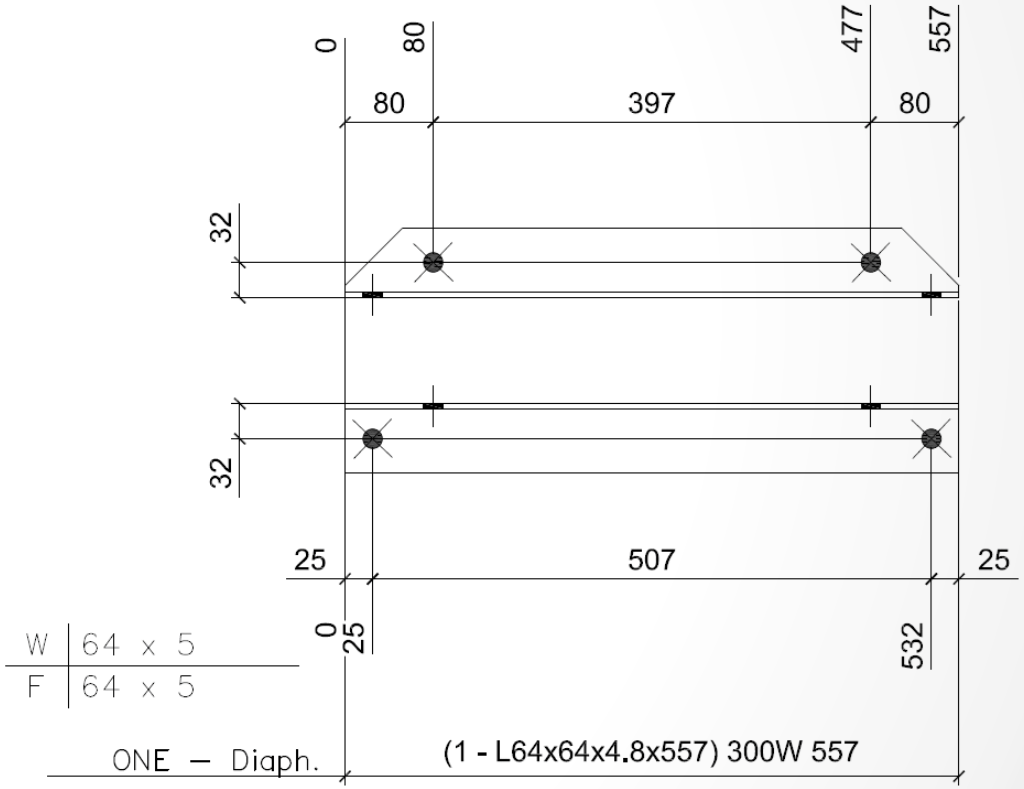


Virtual Technologies



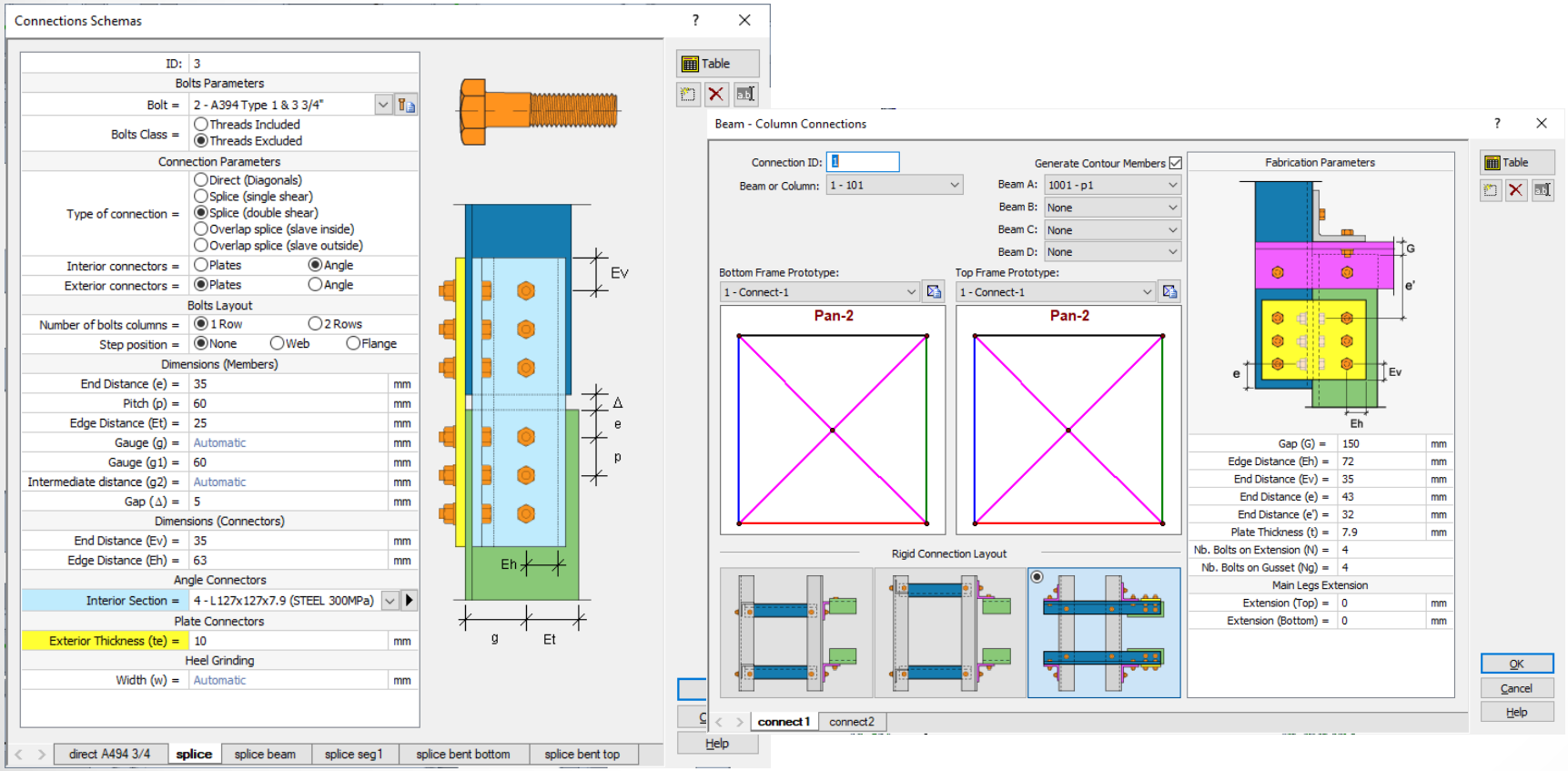
Virtual Technologies

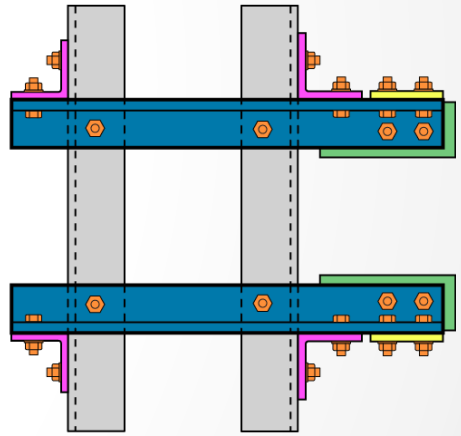




Virtual Technologies

Connection design





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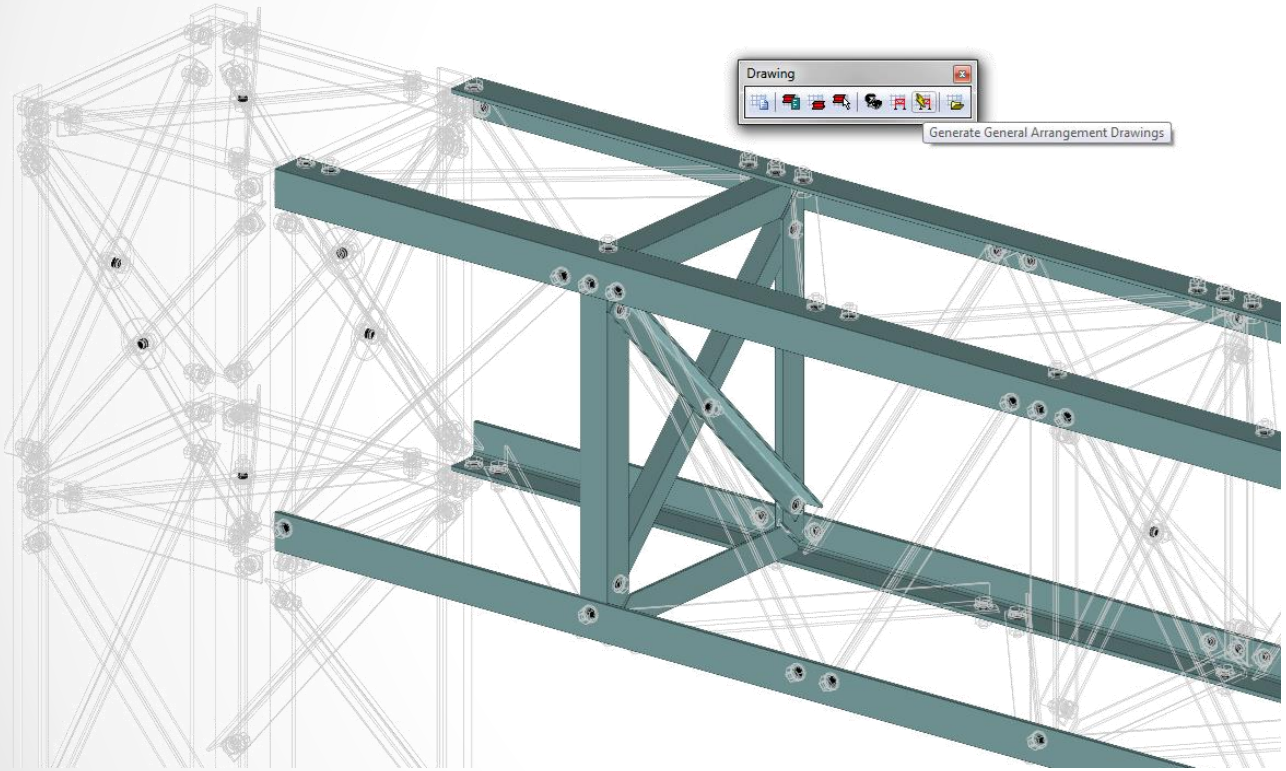

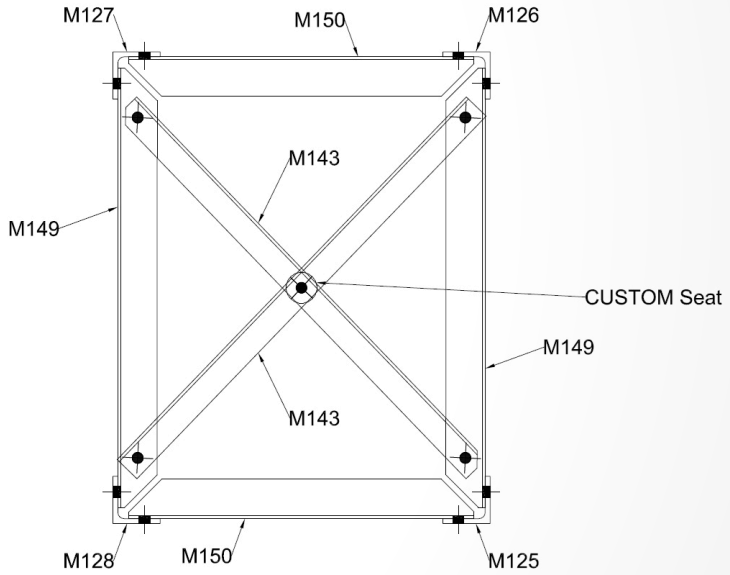

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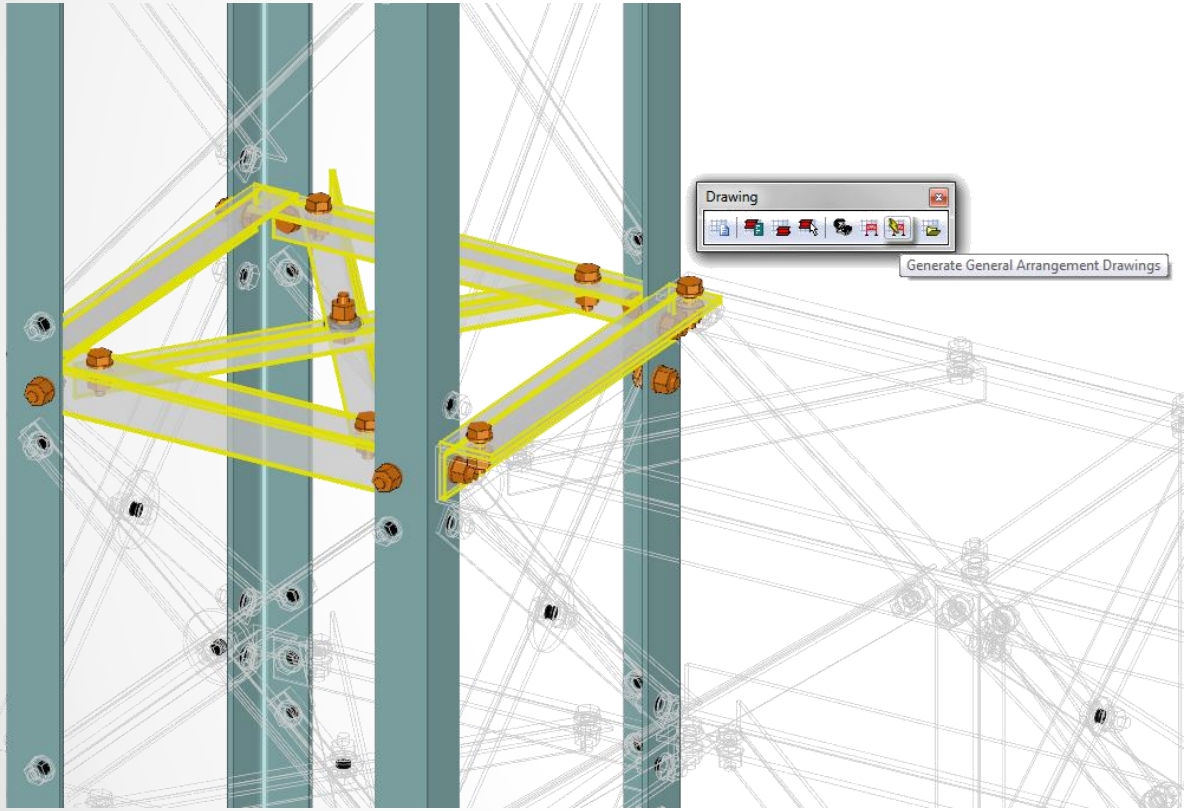

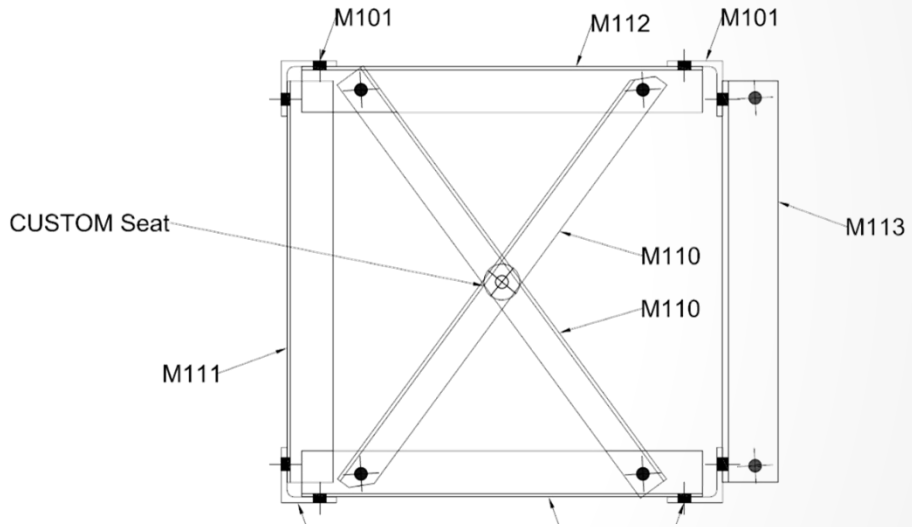

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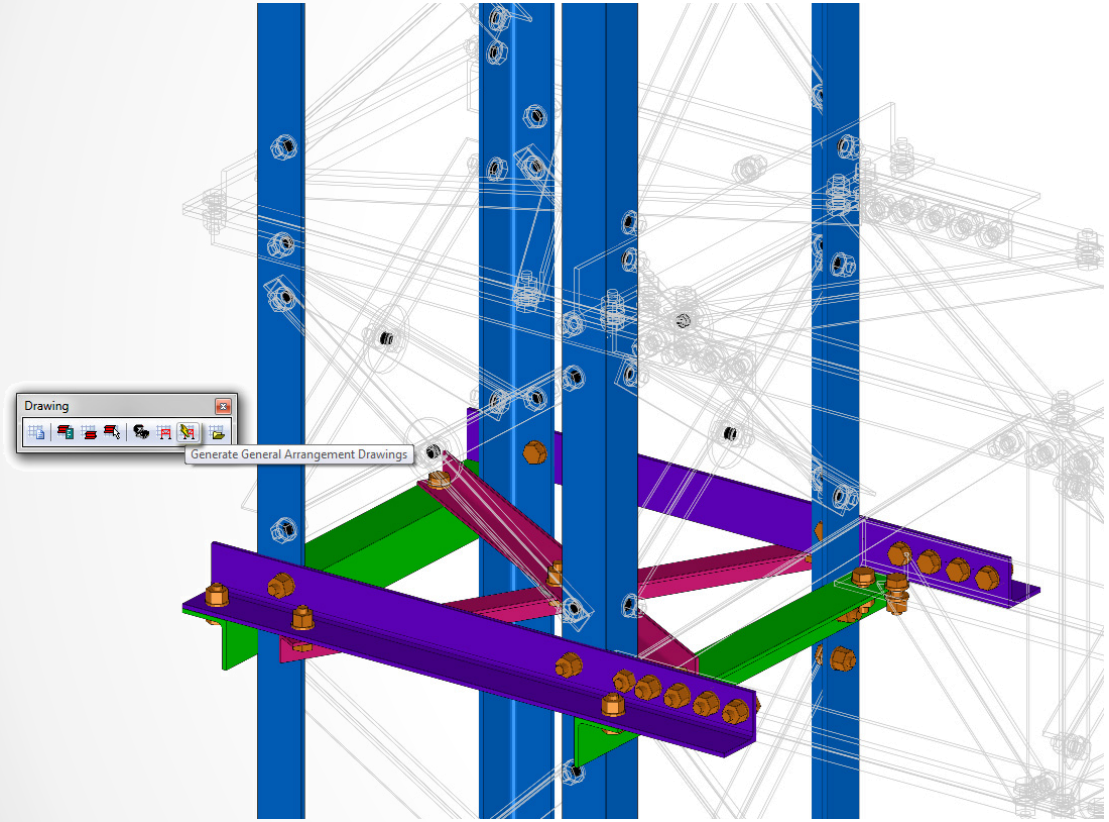

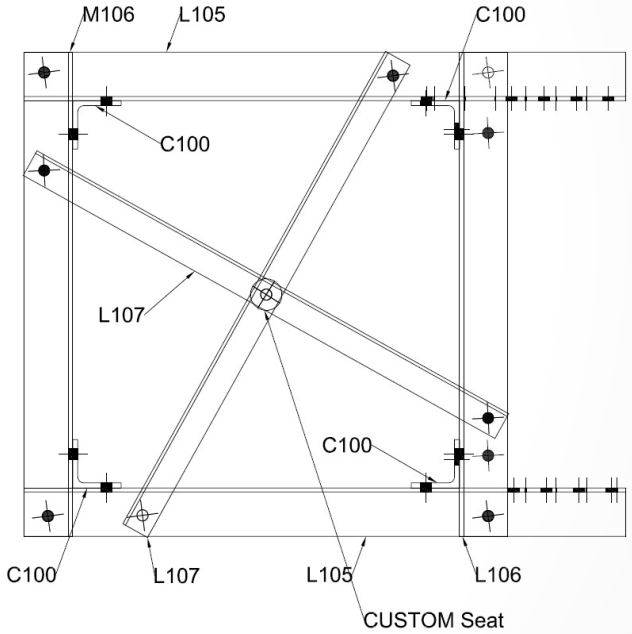

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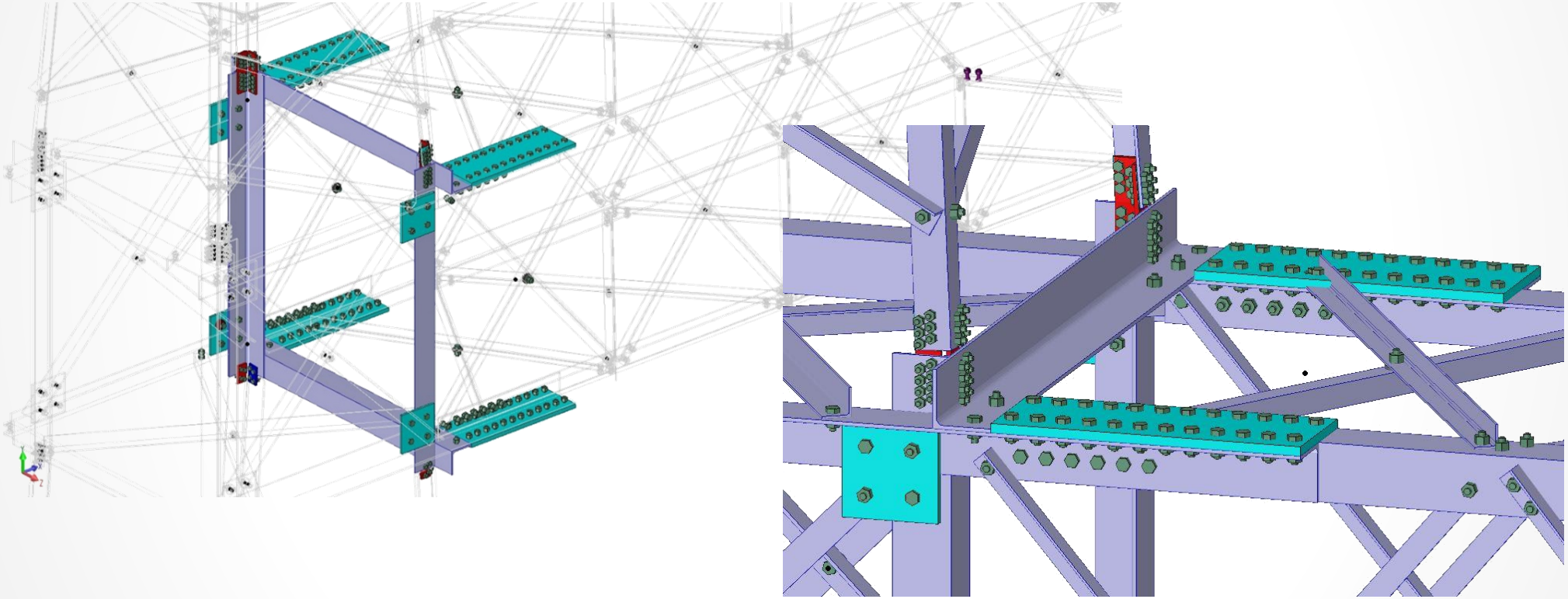
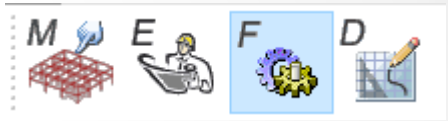
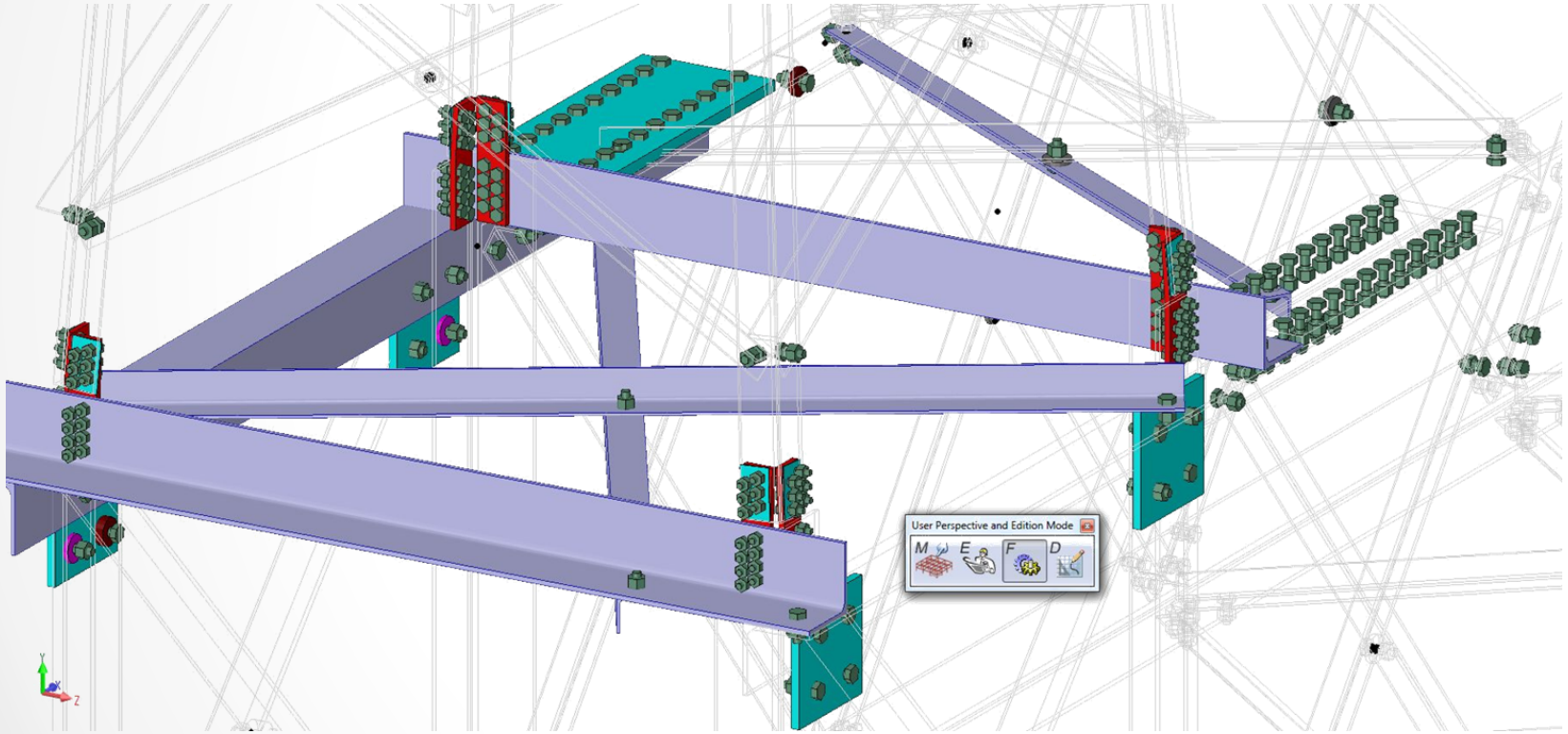


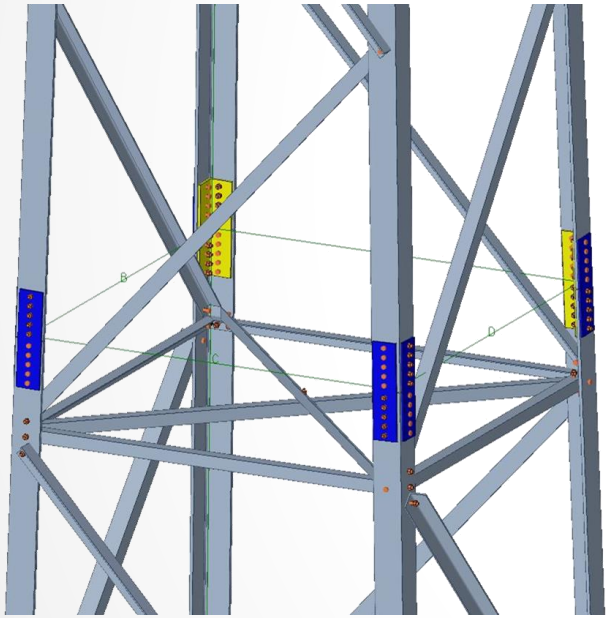
Virtual Technologies

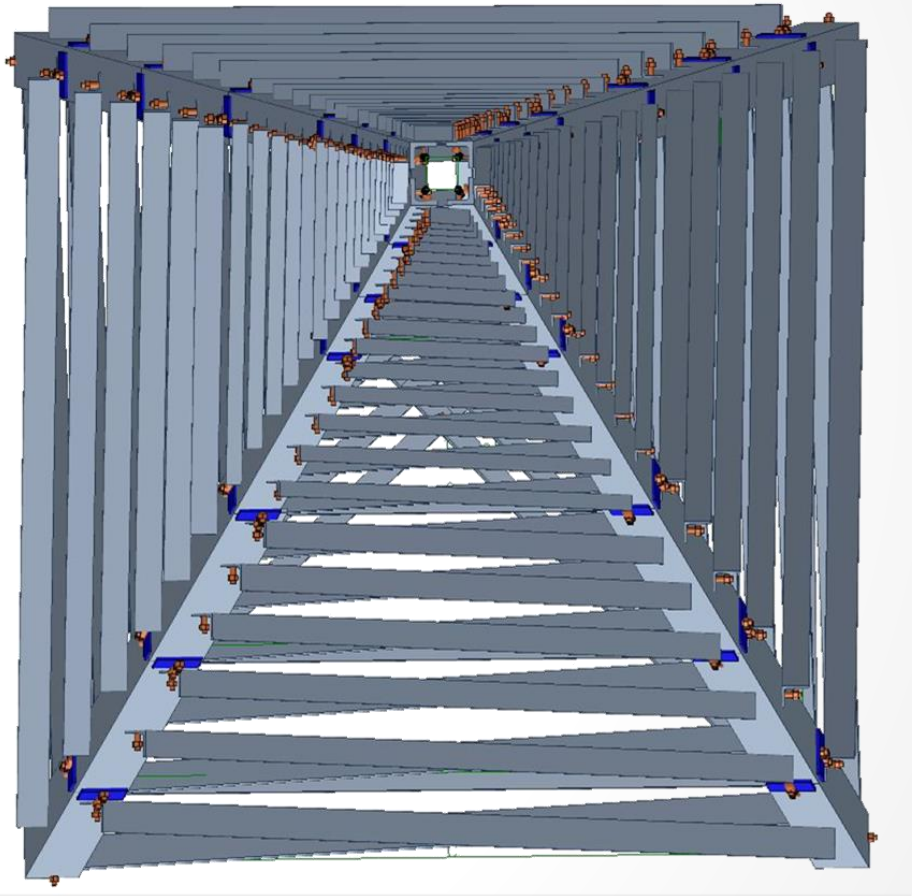




Virtual Technologies

Electrical tower

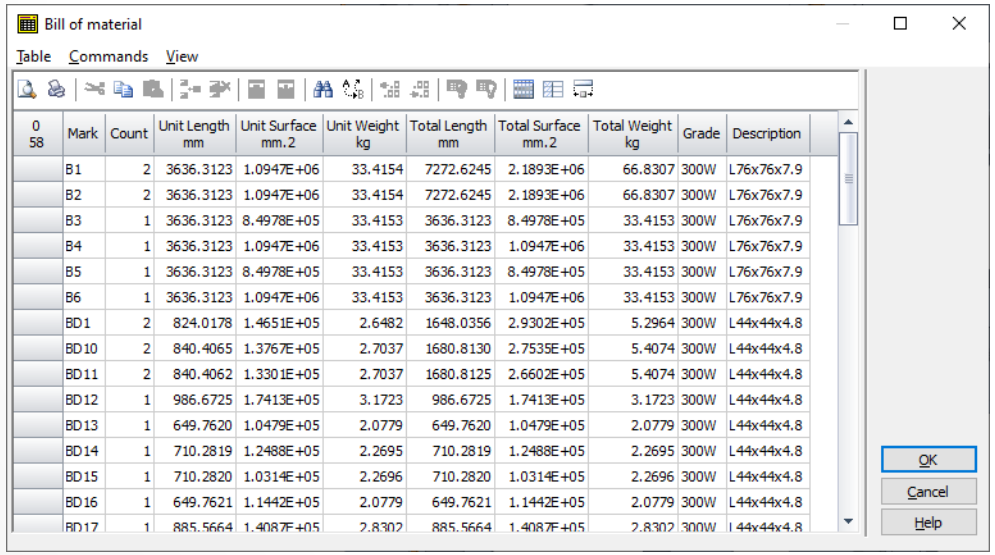




Bill of Material

When the piece marks are generated, the program also generates the **Bill of material** for the entire model.

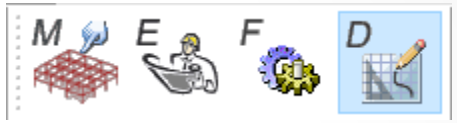
This table contains the list of all different pieces with their length, weight, and paint surface.

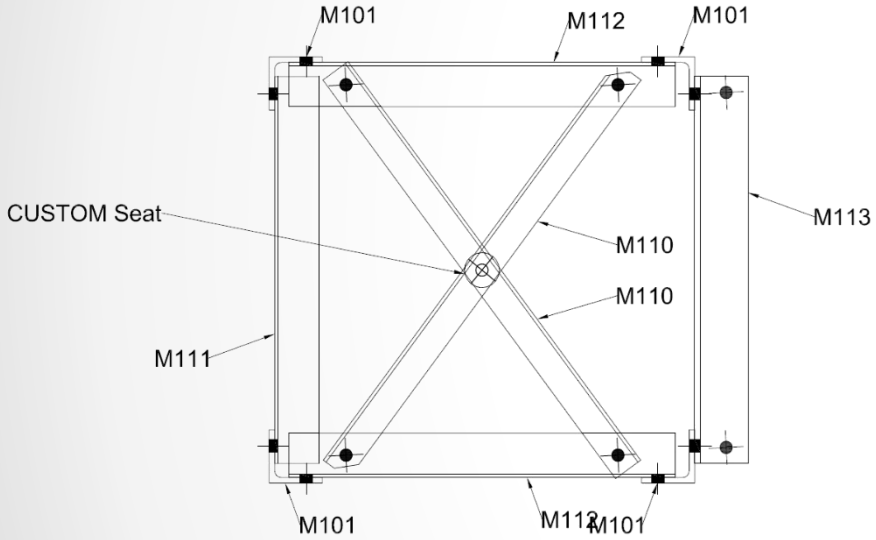


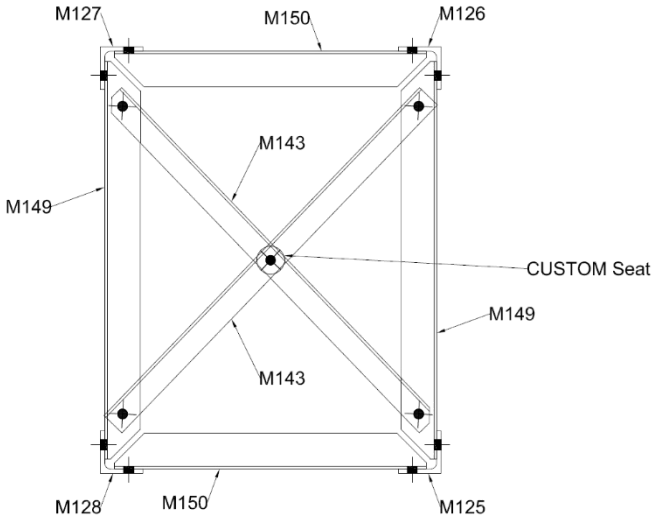
0 58	Mark	Count	Unit Length mm	Unit Surface mm.2	Unit Weight kg	Total Length mm	Total Surface mm.2	Total Weight kg	Grade	Description
	B1	2	3636.3123	1.0947E+06	33.4154	7272.6245	2.1893E+06	66.8307	300W	L76x76x7.9
	B2	2	3636.3123	1.0947E+06	33.4154	7272.6245	2.1893E+06	66.8307	300W	L76x76x7.9
	B3	1	3636.3123	8.4978E+05	33.4153	3636.3123	8.4978E+05	33.4153	300W	L76x76x7.9
	B4	1	3636.3123	1.0947E+06	33.4153	3636.3123	1.0947E+06	33.4153	300W	L76x76x7.9
	B5	1	3636.3123	8.4978E+05	33.4153	3636.3123	8.4978E+05	33.4153	300W	L76x76x7.9
	B6	1	3636.3123	1.0947E+06	33.4153	3636.3123	1.0947E+06	33.4153	300W	L76x76x7.9
	BD1	2	824.0178	1.4651E+05	2.6482	1648.0356	2.9302E+05	5.2964	300W	L44x44x4.8
	BD10	2	840.4065	1.3767E+05	2.7037	1680.8130	2.7535E+05	5.4074	300W	L44x44x4.8
	BD11	2	840.4062	1.3301E+05	2.7037	1680.8125	2.6602E+05	5.4074	300W	L44x44x4.8
	BD12	1	986.6725	1.7413E+05	3.1723	986.6725	1.7413E+05	3.1723	300W	L44x44x4.8
	BD13	1	649.7620	1.0479E+05	2.0779	649.7620	1.0479E+05	2.0779	300W	L44x44x4.8
	BD14	1	710.2819	1.2488E+05	2.2695	710.2819	1.2488E+05	2.2695	300W	L44x44x4.8
	BD15	1	710.2820	1.0314E+05	2.2696	710.2820	1.0314E+05	2.2696	300W	L44x44x4.8
	BD16	1	649.7621	1.1442E+05	2.0779	649.7621	1.1442E+05	2.0779	300W	L44x44x4.8
	BD17	1	885.5664	1.4087E+05	2.8302	885.5664	1.4087E+05	2.8302	300W	L44x44x4.8

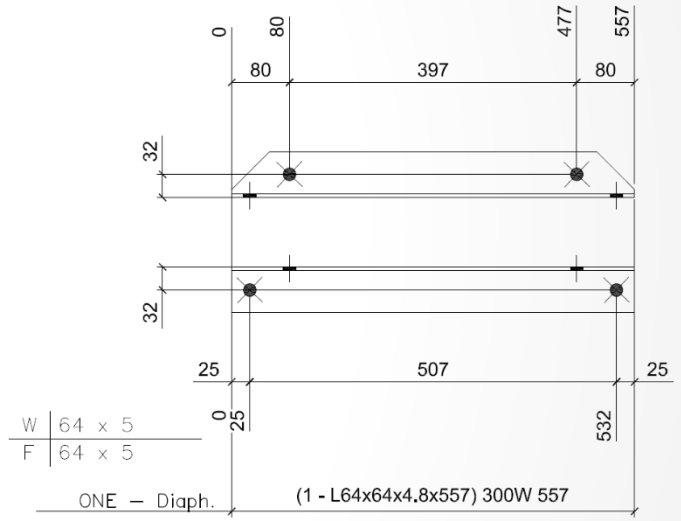
Virtual Technologies

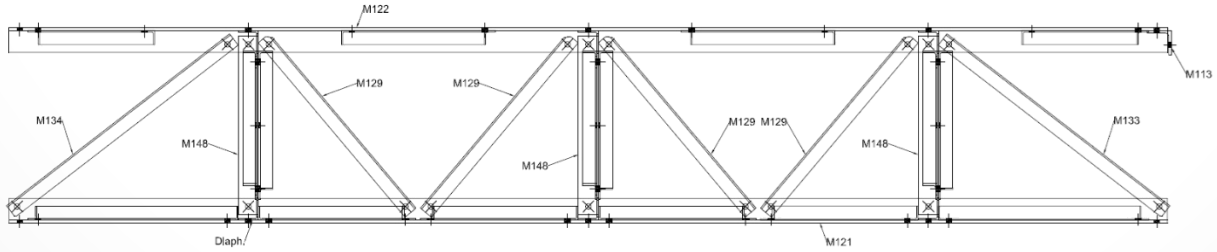
Engineering and Fabrication Drawings











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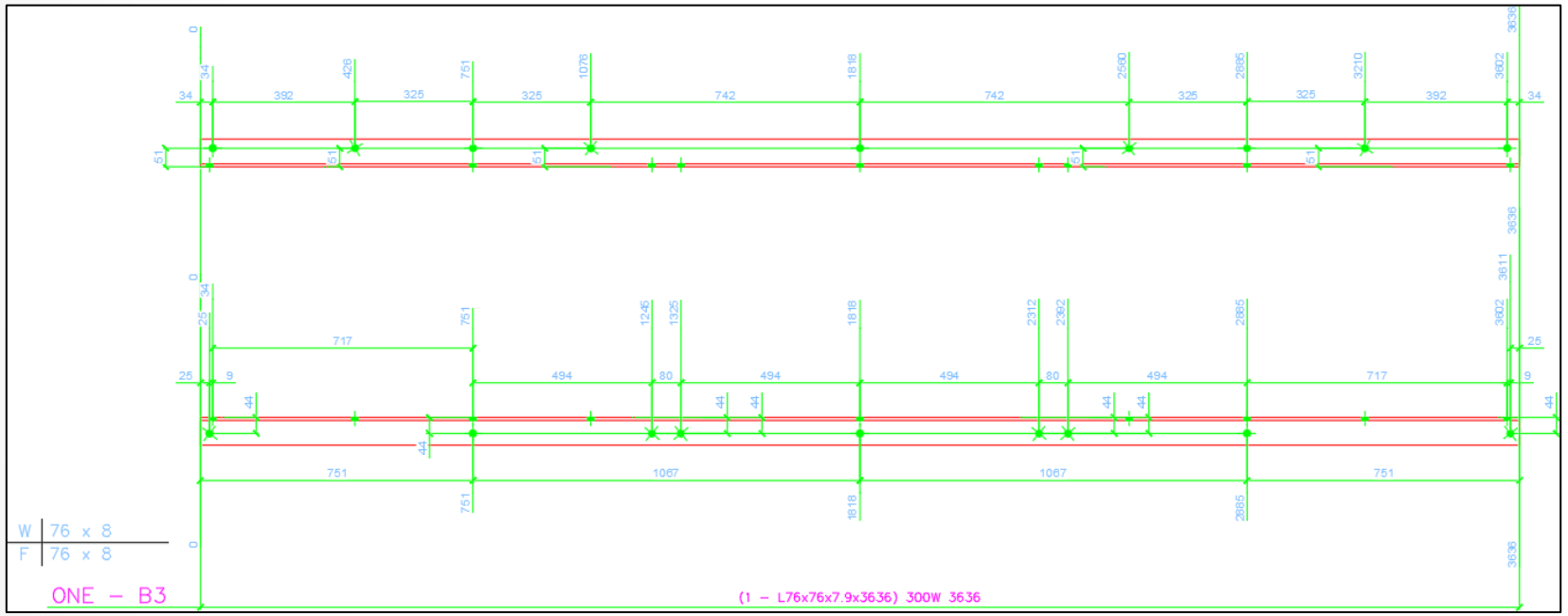
Shop Drawings



Conclusion

AlumForum 2021
Aluminum in Transport and Road Infrastructure

- The **HSE Software** advanced technology Levels I, II and III, allows users to achieve specialized analyses, design and manufacturing of crucial projects related to the bridge sign industry.

- SAFI welcomes National and International Collaboration towards the use of the HSE Software as a seamless fully integrated Software for the Analysis, Design, Detailing and Manufacturing of the **HSE Highway Sign Structures for the Bridge sign industry at large.**

BY SAFI™

HSE Highway Sign Structural Engineering

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