1 DESIGNED FOR SIMPLICITY

The OpenBrIM Platform combines design, analysis, reporting, and asset management activities in one tool through a parametric environment. It includes easy-to-use, Excel-like spreadsheets along with a vibrant 3D graphics engine and an agile tree-view to quickly create, modify, and view your project data. OpenBrIM enables a flexible design using the parametric modeling approach. With the help of the OpenBrIM parametric library concept and parametric workflows, the engineer simply needs to alter one parameter to automatically adjust the model.

2 COMPUTATION TRANSPARENCY

The open data policy conveys purely transparent and traceable information, calculations, and data exchanges throughout the life cycle stages of the platform. OpenBrIM Platform empowers engineers to get the most out of their data by enabling it to utilize the ParamML language to customize the parametric library components. It also allows you to create new ones and share, as well as provide the ability to customize the computational procedure. It gives control of your own data by enabling customization at every level. This ensures that any modifications made to the model are done with your own design approach.

3 TRUE DIGITAL/ BRIM DELIVERY

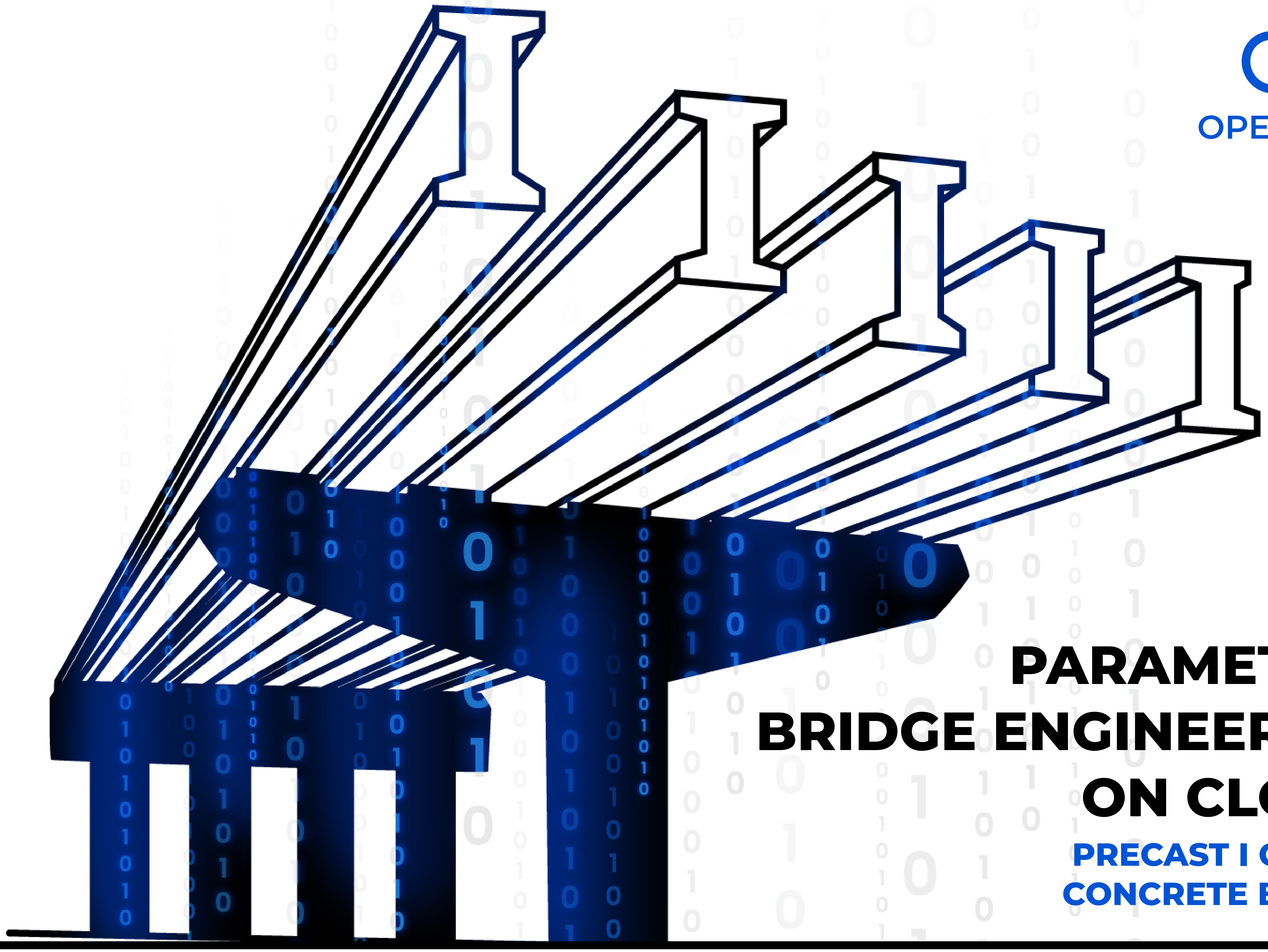
OpenBrIM Platform is designed to create a transition from a direct modeling approach to parametric modeling within the bridge engineering industry. With its unique parametric library approach, the bridge engineer defines how the component should behave when something changes at a bridge component level. This modular approach provides flexibility to use the parametric components defined for your current project in different bridge projects.

The OpenBrIM Platform is built from scratch with FHWA's digital delivery vision and aligns with the PENNDOT digital delivery directive goal of "Using 3D technology to create high-quality, data-rich models of our projects" and "Using structured, object-oriented data in digital models as the key-value provider."

The OpenBrIM model consists of (1) elements with an (2) as-built level of accuracy and (3) geometric detail that includes (4) parameters and information required by the owner.

4 BEYOND LOD 500

The same model used for design and construction can be utilized for asset management, inspection management, health monitoring, load rating, and more. Using the parametric OpenBrIM model as a project delivery method will create new possibilities for bridge owners. Potential failure mechanisms that are expected in the bridge life cycle can be defined as a parameter of the OpenBrIM model. After bridge inspection, these parameters can be updated. Within minutes of an inspection, a holistic parametric model that combines FEA, spec check, and load rating can provide more insight into the structural deficiency. BEYOND LOD 500 means the OpenBrIM model doesn't only represent the current state of the bridge but also the future state along with its structural behavior. This innovative approach provides the possibility to create a true digital twin of the bridge project that is valid for its entire life cycle. It offers model and analysis beyond the detail level with better product visualization and real-life behavior. An engineer can begin with simple objects with minimal details and build the complex model with the same approach.



OPENBrIM

PARAMETRIC BRIDGE ENGINEERING ON CLOUD

PRECAST I GIRDER CONCRETE BRIDGE

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info@openbrim.org

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New York, NY, 10036 USA

+1 212 991 89 56

OPENBrIM

DISCOVER THE RIGHT TECHNOLOGY. EMBRACE INNOVATION.

OpenBrIM is the world's first and only on-cloud, collaborative, parametric information modeling platform that combines 3D modeling, FEA, CAD, code check, load rating, inspection, asset management, and more in your web browser. Our industry-leading customers and OpenBrIM community make us the pioneers of digital transformation and innovation.

OPENBRIM WORKFLOW
AND INTEROPERABILITY

OpenBrIM Platform provide medium- and long-term asset management and engineering-hour efficiency with reusable parametric library components and parametric workflows that are designed per user and/or their customer processes. It dramatically decreases time-consuming tasks with the power of parametric automations, which leads to a quick design turnaround, reduced NRE, cycle time, and time-to-market resiliency. Moreover, the parametric library concept enables a strong asset management where the model can be recalled rather than remodeled, allowing engineers to pass the design intelligence onto other engineers and stakeholders throughout the bridge lifecycle.

LIBRARY COMPONENTS

Developed / Customized by OpenBrIM Engineers Under Your Guidance

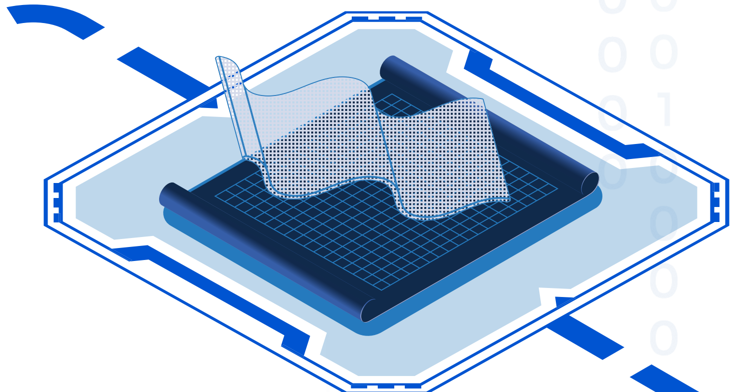
Developed / Customized by your Engineering Team

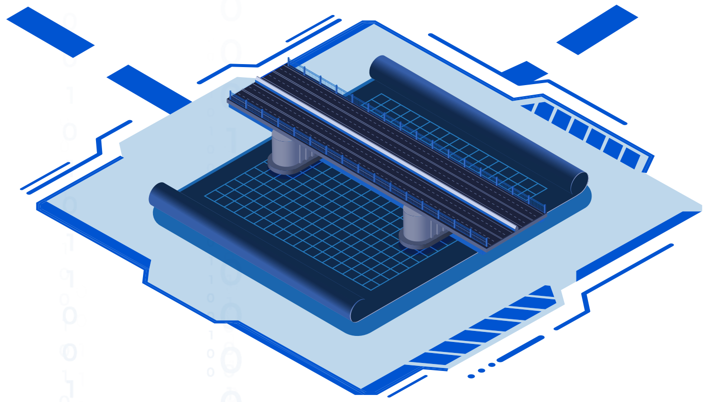
ROADWAY COMPONENTS

Road Alignment
Profile
Digital Terrain Model

PARAMETRIC WORKFLOWS

Digital twin of your bridge





SUMMARY REPORTS

FEA Results (Superstructure & Substructure & Stages Construction)

Specification Checks (AASHTO LRFD 9th Edition & DOT Amendments)

Load Rating Factors (Influence Surface Based Analysis)

Camber Diagram & Fillet Depth

Quantities

Bill of Materials (Bar, Concrete, Streel, Railing, Retaining Walls, etc.)

Earthwork (Cut & Fill Volume)

Vertical Clearance Check

FEA

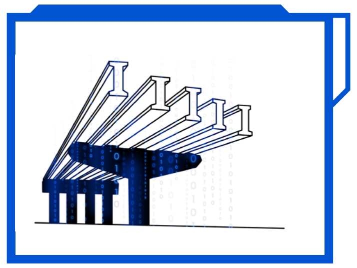
STRUCTURAL ANALYSIS

2D DRAWINGS 3D MODELS

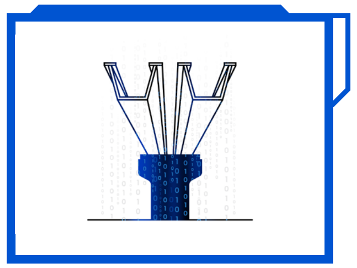
PARAMETRIC **WORKFLOW**

At OpenBrIM, our library receives daily updates to meet the diverse needs of bridge engineers. We tailor it to various bridge types, specification checks, and state-specific requirements. Our specialized library components are designed for each bridge type, streamlining engineering tasks such as 3D modeling, analytical modeling, staged construction analysis, AASHTO-compliant design, and CAD deliverable production. Our comprehensive workflows cover a wide range, accommodating both steel bridges like Steel I Girder and Steel Tub Girder, as well as concrete bridges, including Precast I Girder, Concrete U Girder, Concrete Box Girder, and Segmental Bridge. Furthermore, our system seamlessly integrates multiple workflows for projects involving more than one bridge type.

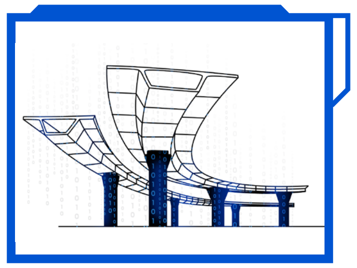
This brochure is dedicated to showcasing our library components tailored specifically for Precast I Girder bridges.



PRECAST I GIRDER CONCRETE BRIDGE



CONCRETE U GIRDER BRIDGE



SEGMENTAL BRIDGE

CABLE STAYED BRIDGE

SPLICED GIRDER BRIDGE

TRUSS BRIDGE

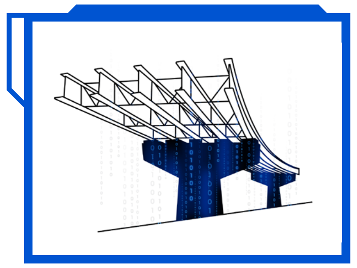
PARAMETRIC OPENBRIM TEMPLATES

OpenBrIM

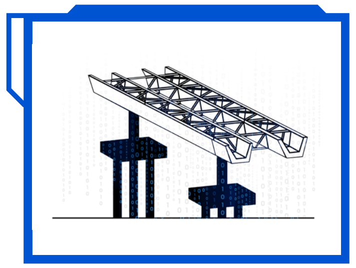
Project Templates

OpenBrIM Templates

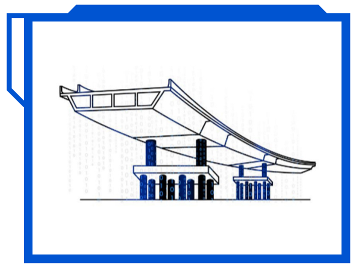
- Cable Supported Bridge Workflows
- Steel Bridge Workflows
- Concrete Bridge Workflows
- All-in-One Bridge Workflows
- Library and FEA Workflows
- Example Projects



STEEL I GIRDER BRIDGE



STEEL TUB GIRDER BRIDGE



CONCRETE BOX GIRDER BRIDGE

SUSPENSION BRIDGE

INCREMENTALLY LAUNCHED BRIDGE

AND MORE

PARAMETRIC OPENBRIM TEMPLATE: PRECAST I GIRDER BRIDGE

Precast I Girder Bridge | FEA

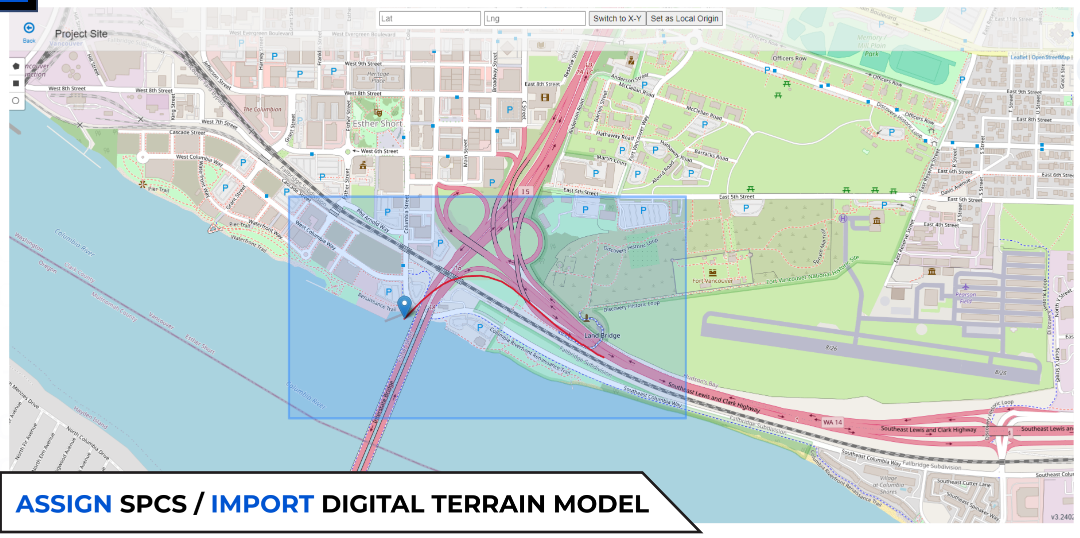
- Precast I Girder Bridge
  - Bridge Geometry
    - Roadway Alignment
    - Bridge Alignment
    - Support Lines
    - Insertion Point
    - Girder Layout
  - Properties
    - Materials
    - Rebars
    - Strands
    - Sections
    - Pushover
      - Hinge Property
      - Moment-Curvature Report
  - Superstructure
    - Bearings
    - Girders
      - Precast I Girder
    - Diaphragm
    - Deck
      - Cross-Section
      - Concrete Deck
  - Superstructure Attachments
    - Barrier
    - Roadway
    - Rail
  - Substructure
    - Cantilever L Abutment
    - End/Interior Bent
    - Pier
    - Foundation
    - Pile
    - Soil Structure Interaction
  - Tendon
    - Cap/Bent Tendon
    - Column Tendon

Precast I Girder Bridge | FEA

- Loading
  - Load Geometry Definitions
  - Loads
    - Static Loads
    - Element Loads
    - Inf. Surf Based LL/BR/CE
    - Wind Load
    - Static BR/CE Load
    - Temperature Load
    - Prestressing Load
    - Dynamic Loads
    - Pushover Load
- Combinations
  - Result Extraction Cases
  - Design Load Combinations
- Templates for Code Check and Load Rating
  - Concrete Girder Load Rating T
  - Concrete Girder Code Check T
  - Concrete Pier Cap Code Check
  - Concrete Pier Column Code Check
  - Pier Footing Code Check T
  - Pile Code Check
  - Pile Capacity Check T
- Superstructure Code Checks
  - Concrete Girder Code Check
- Substructure Code Checks
  - Concrete Pier Cap Code Check
  - Concrete Pier Column Code Check
  - Pier Footing Code Check
  - Pile Code Check
  - Pile Capacity Check
- Load Rating
- Reports
- CADD
- GIS
- Organization
- Export

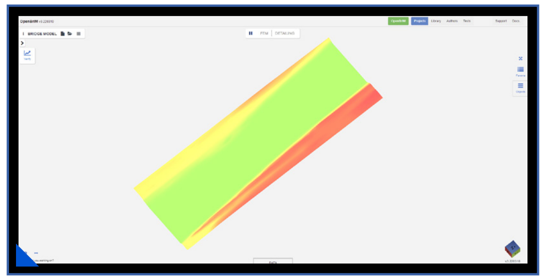
PARAMETRIC WORKFLOW

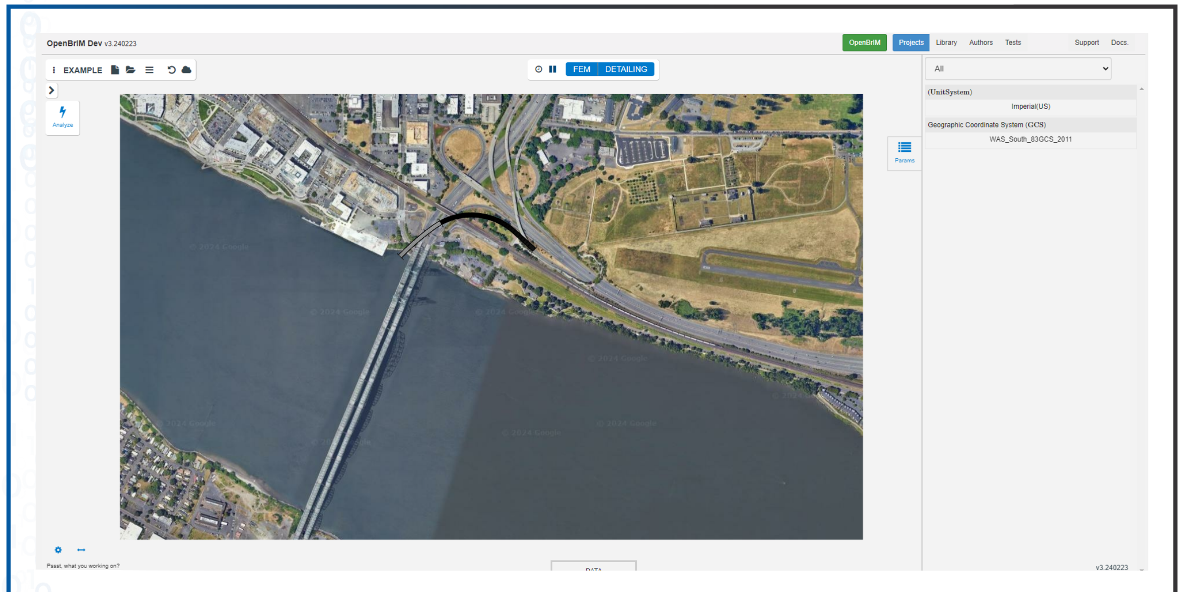
01

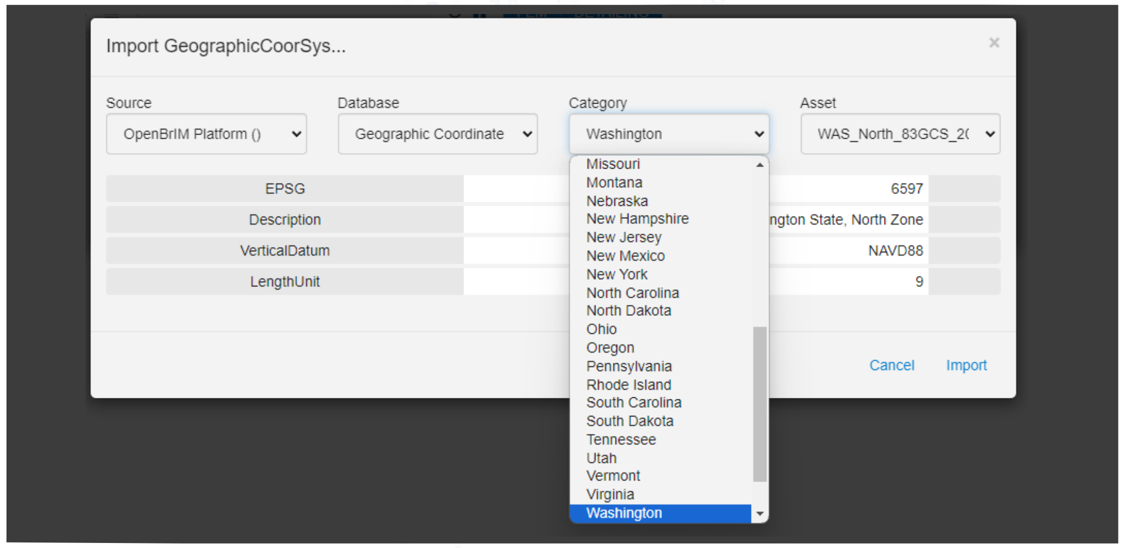


ASSIGN SPCS / IMPORT DIGITAL TERRAIN MODEL

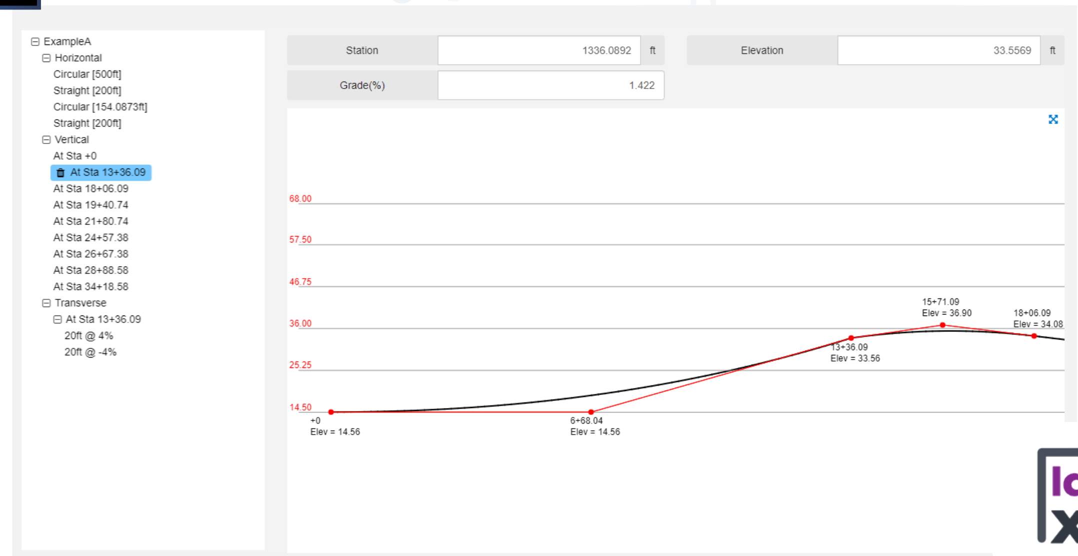
OpenBrIM fully supports the State Plane Coordinate System (SPCS), ensuring the accurate positioning of bridges and their alignment with precise geospatial data for each project. It also allows for the visualization of 3D bridges with map tiles as a background. Furthermore, users are empowered to directly import digital terrain models from LandXML files. This functionality enhances vertical clearance checks and computations related to earthwork cut and fil.







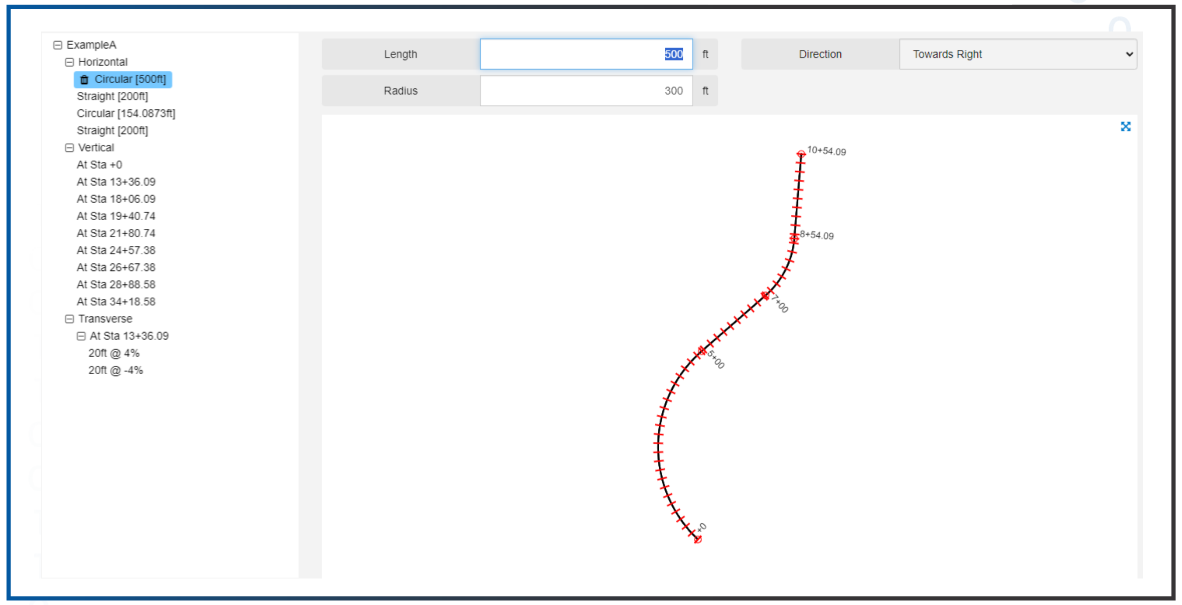
02

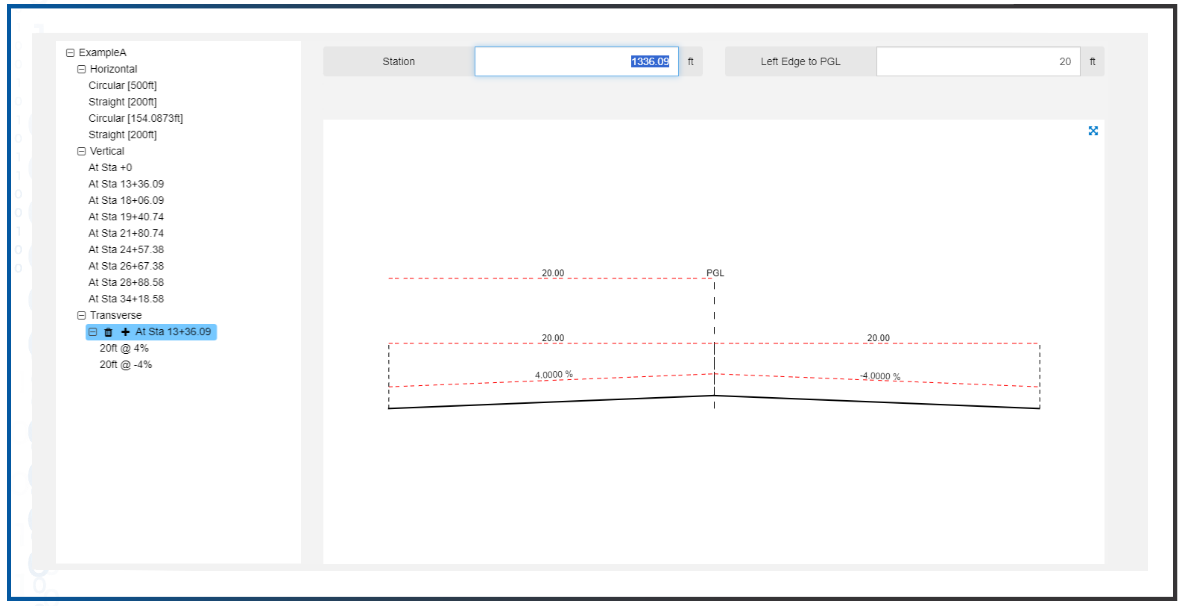


DEFINE ALIGNMENT / IMPORT ALIGNMENT

OpenBrIM offers two clear-cut approaches for defining alignment data. The initial method is accessible through an intuitive editor, as showcased in the screenshot, enabling users to precisely specify horizontal and vertical alignment data, along with cross slopes. The alternative method provides the convenience of importing land XML files, which can be effortlessly exported from a range of different software packages.

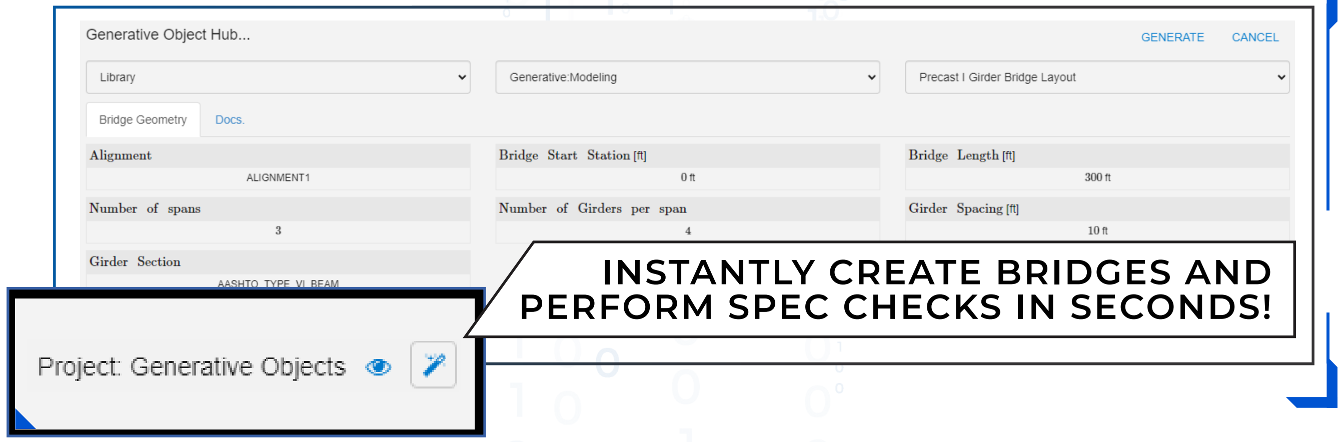
PARAMETRIC WORKFLOW





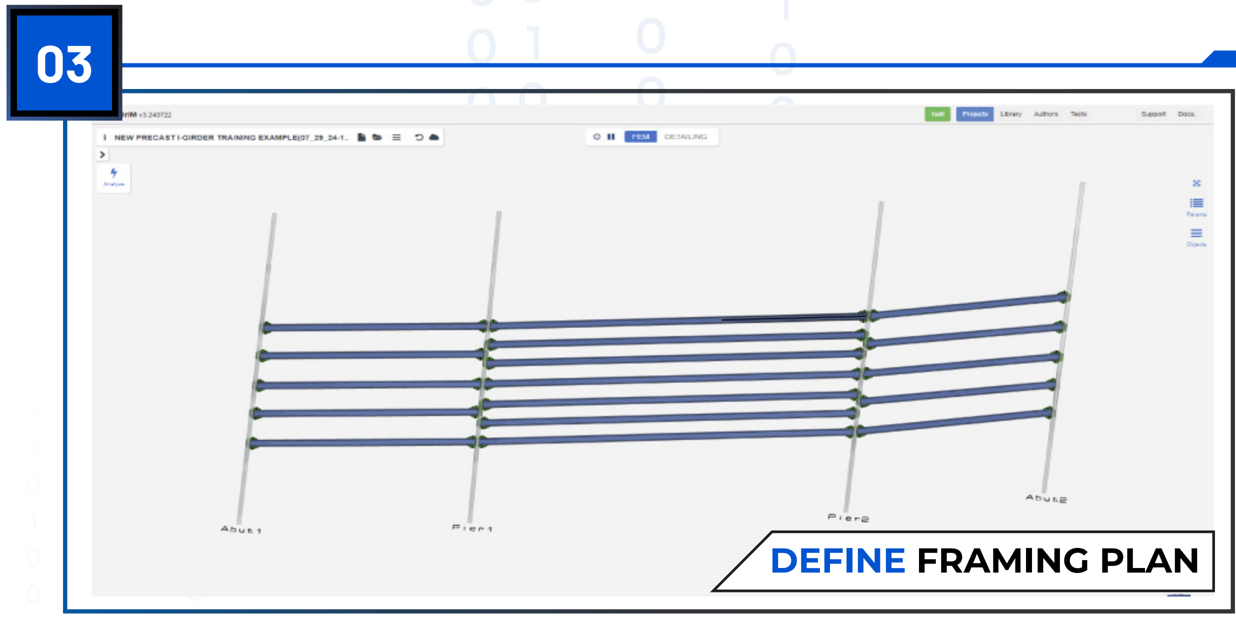
EXPERIENCE THE POWER OF GENERATIVE OBJECT HUB

Once the alignment is defined, users can harness the power of generative object hub library components to rapidly generate bridges with minimal input requirements, completing the process in a matter of seconds. For instance, by simply specifying the number of spans and girders, as well as the girder section, the bridge superstructure can be automatically generated. Users can then navigate to the corresponding spreadsheets to fine-tune the parameters, such as adjusting span lengths by modifying support line stations, which can be easily accomplished. Users can choose to develop their own generative object hub library components, enabling them to generate bridges with their customized parameters.



PARAMETRIC MODELING

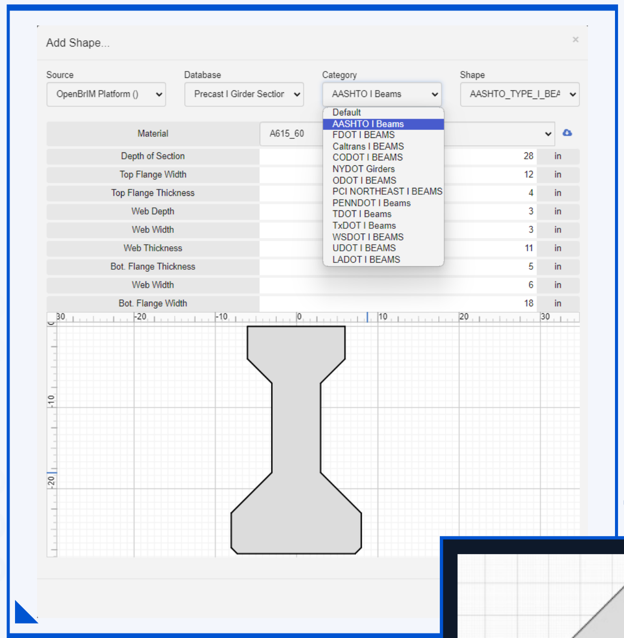
The OpenBrIM platform provides an intuitive and flexible approach to parametric modeling. It allows you to define your own parameters to control your model and use them to input your project data into the spreadsheets – much like entering formulas in Excel. As you change these parameters, your project (e.g., geometry, properties, loading) changes. Parameters can depend on other parameters, while repetition and guarding data rows are also possible. OpenBrIM is making even the most complex parametric studies a breeze to set up.

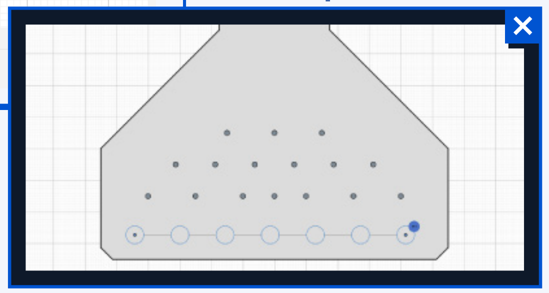


After defining the alignment, workflows begin with the definition of bridges and the assignment of alignments. Subsequently, support lines, insertion points, and girder layout sections can be utilized to define the framing plan of the superstructure.

PARAMETRIC WORKFLOW

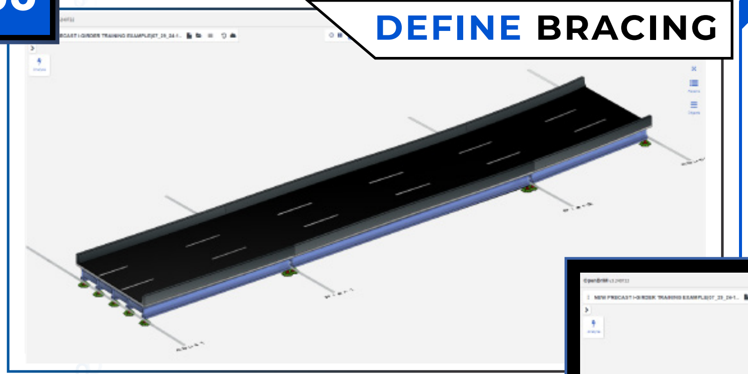
04 DEFINE GIRDER SECTION





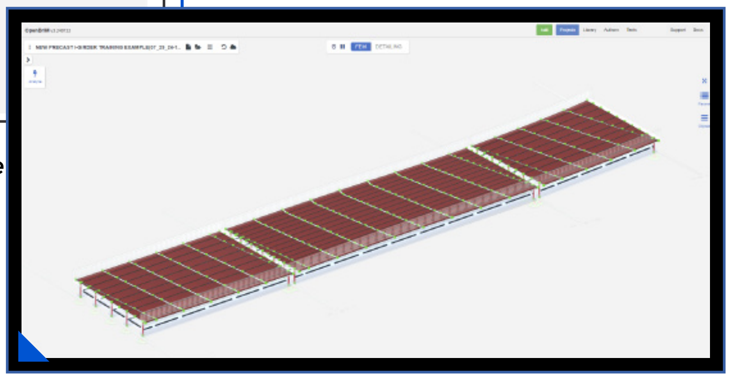
To define a Precast I Girder, users need a girder section. The OpenBrIM Platform offers an extensive database of PIG Girder sections, including all AASHTO sections and state-specific sections. Thanks to its library approach and parametric capabilities, users can easily create new sections or modify existing ones.

05 DEFINE BRACING

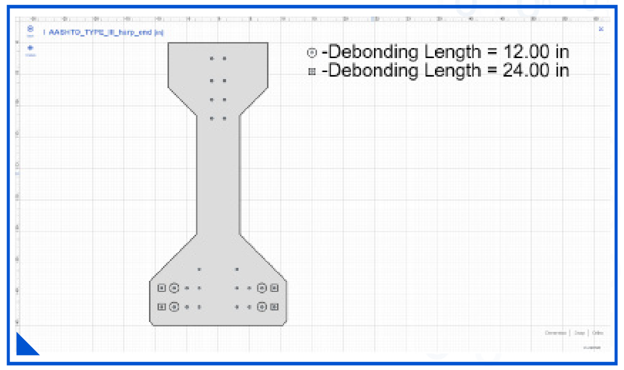


Parametric methods simplify the definition of internal cross frames, internal and external diaphragms, and lateral bracing, with the superstructure mesh automatically updating based on their respective positions.

As seen in the screenshot, beam elements are used for precast i girder and diaphragm modeling, while shell elements are employed for the deck.

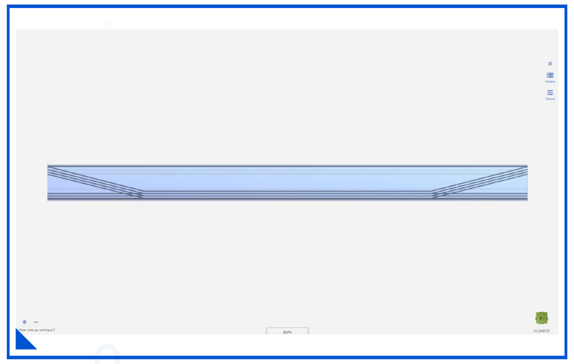


06 DEFINE TENDONS



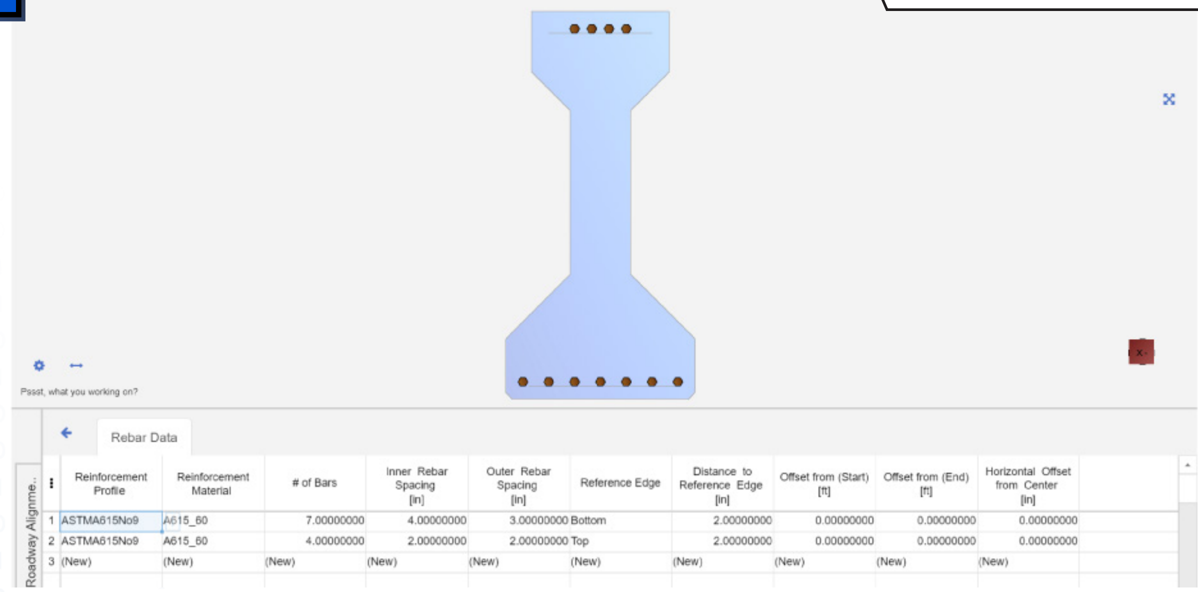
Tendons can be introduced through the section editor. In OpenBrIM, tendon definitions are parametric, just like any other component. Users can enter geometric parameters such as 'Reference Edge,' 'Distance,' and 'Spacing' to define tendons. Additionally, OpenBrIM supports freeform parametric definitions through its CADD drawing capabilities, ensuring that even the most complex sections can be detailed in the OpenBrIM Section Editor.

OpenBrIM supports both straight and harped tendon layouts. To define a harped tendon layout, users need to specify two sections: one for the girder ends and one for the mid-span of the girder, and provide the harped region. OpenBrIM automatically generates a 3D representation of the tendon layout.



OpenBrIM offers various 3D visualization utilities, such as isolating, hiding, and changing the opacity of objects. These tools empower users to easily validate their 2D designs.

07 DEFINE REBARS



In OpenBrIM, rebars can be defined in the same way as tendons using the section editor. Additionally, there is an option to define rebars parametrically using the Precast Girder Spreadsheet.

PARAMETRIC WORKFLOW

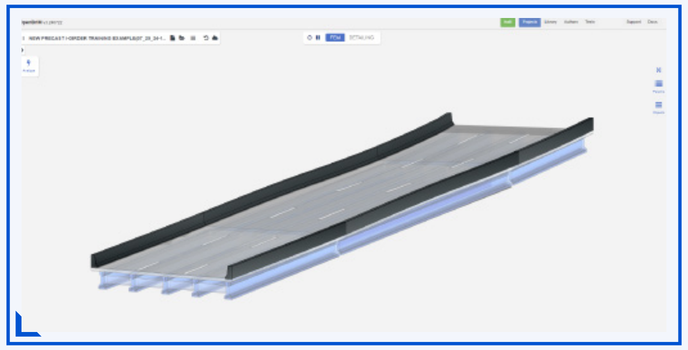
08 DEFINE ROADWAY / BARRIERS

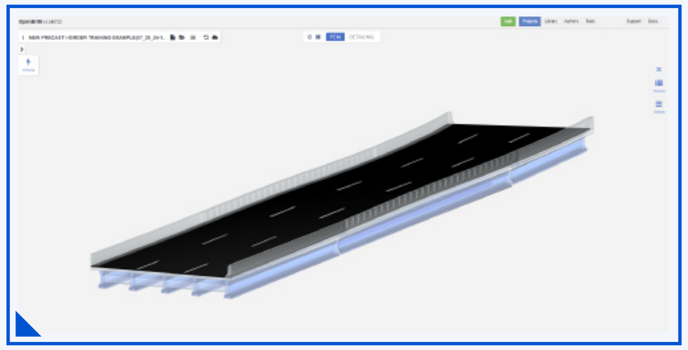
Users can define the deck by entering distances from PGL to the left edge and PGL to the right edge. Parabolic and linear variations are both supported.

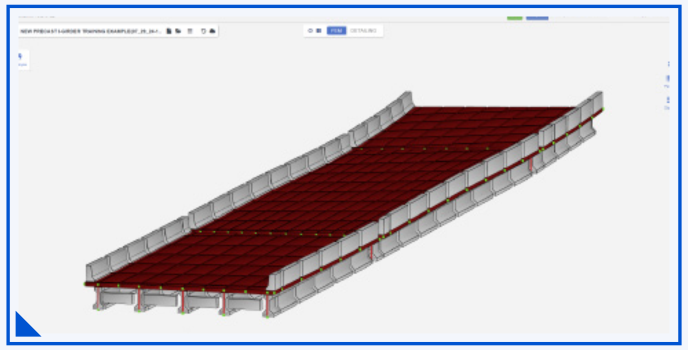
Barriers can be effortlessly imported from the barrier library, followed by the input of their transverse locations along the PGL. Barriers can be automatically included in the analysis, whether their stiffness is considered or if they are simply applied as loads. Wind loads are automatically determined based on their geometry.

Reinforcements of the deck defined parametrically and then utilized for quantity takeoff and specification checking purposes.

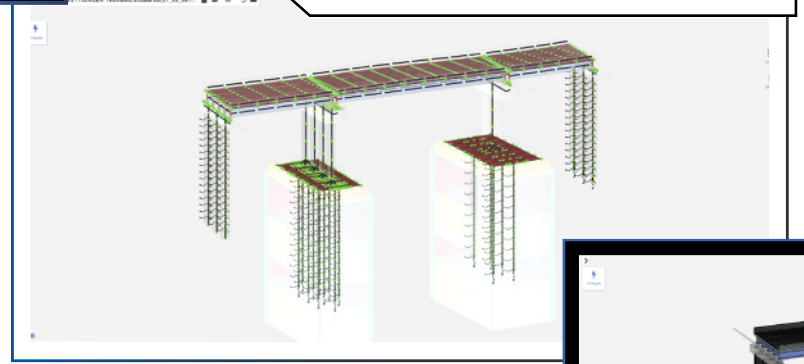
The roadway definition is employed for conducting live load analysis based on influence surfaces.



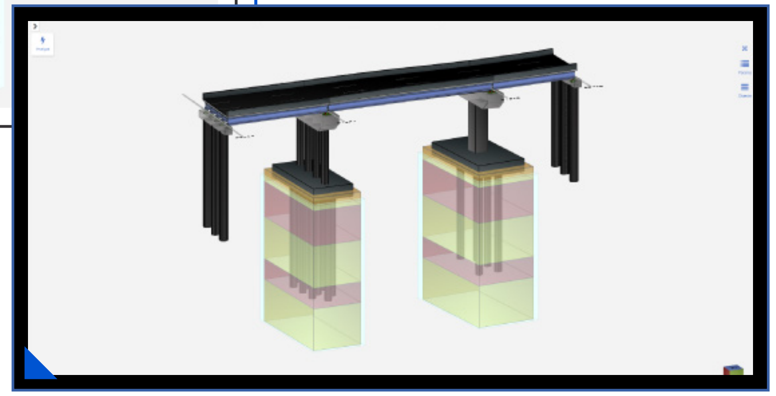




09 DEFINE SUBSTRUCTURE

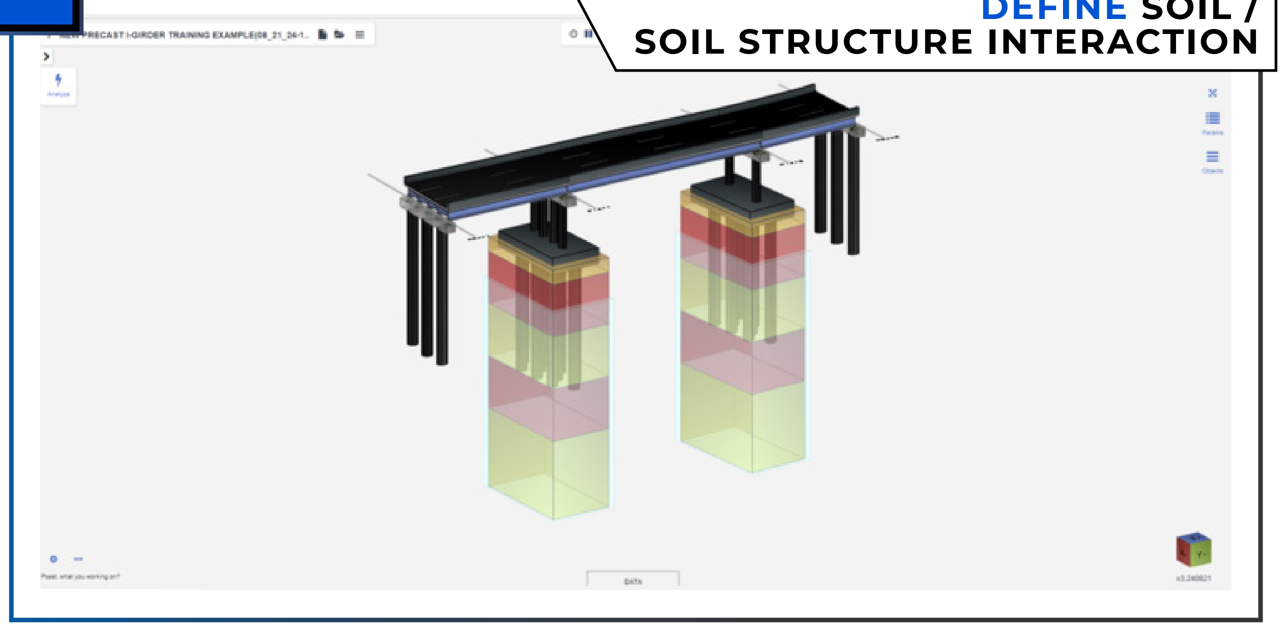


One of the benefits of using OpenBrIM is the ability to conduct finite element analysis and code checks for both superstructure and substructure within the same model. There's no need to separately transfer superstructure bearing forces to your substructure model.



Users can effortlessly define straddle bents, multi-column piers, hammerhead piers, and more parametrically. The software also supports the creation of arbitrary sections through the section editor, with circular, parabolic, and linear

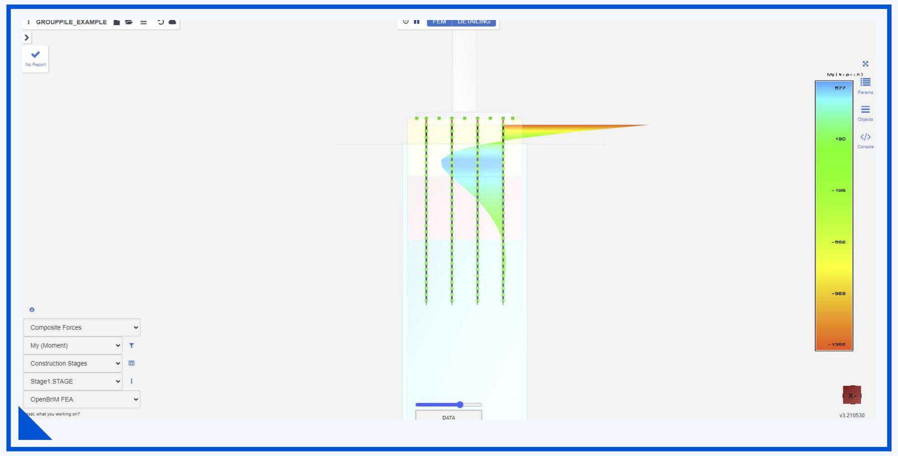
10 DEFINE SOIL / SOIL STRUCTURE INTERACTION

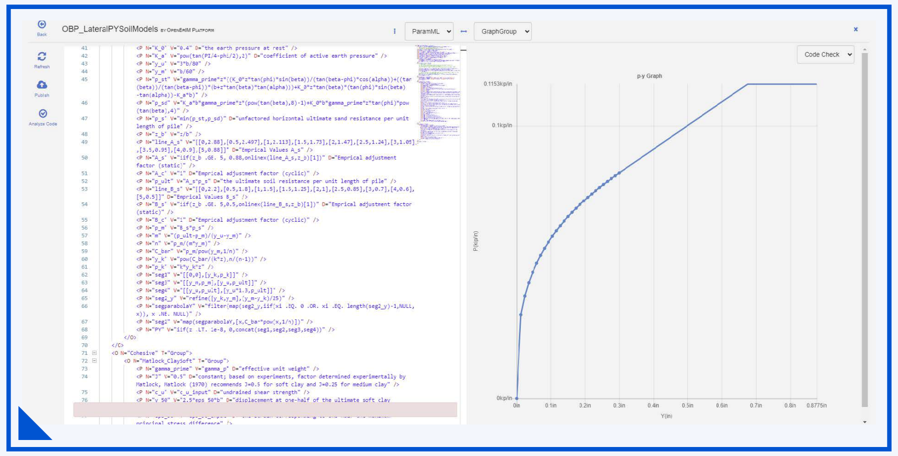


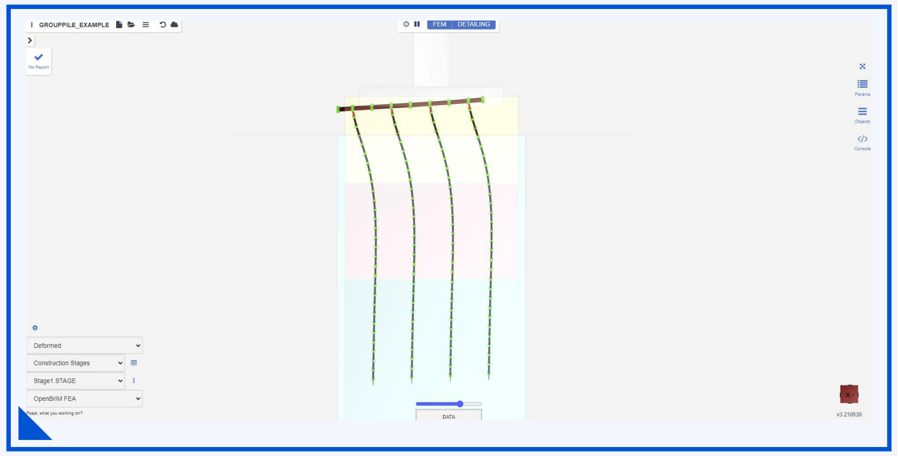
The OpenBrIM Platform utilizes nonlinear finite element analysis to model soil-structure interaction, employing the p-y and t-z curve methods. Within OpenBrIM.FEA, the bridge's stiffness is calculated at each iteration based on the resolved displacements. Internally, p-y and t-z curves are generated according to established recommendations in the literature. Users have the option to select from various types of soils or specify custom curves. Analyses are performed for both axially and laterally loaded piles, as well as grouped piles, integrated with the entire bridge structure, thereby eliminating the need to transfer data between different software packages.

PARAMETRIC WORKFLOW

DEFINE SOIL / SOIL STRUCTURE INTERACTION







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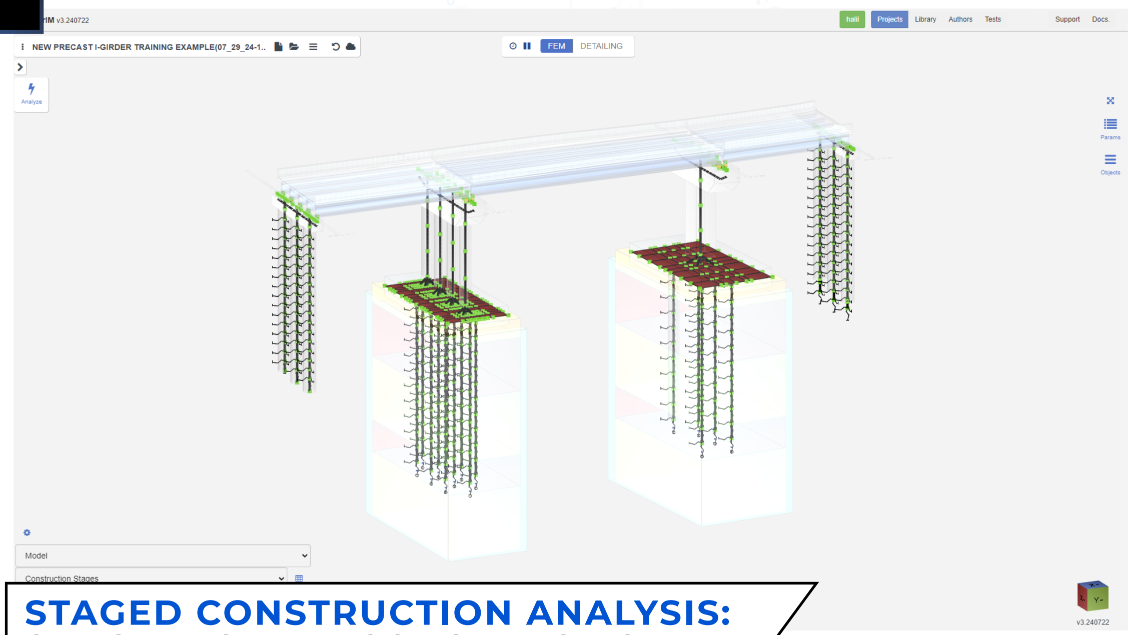
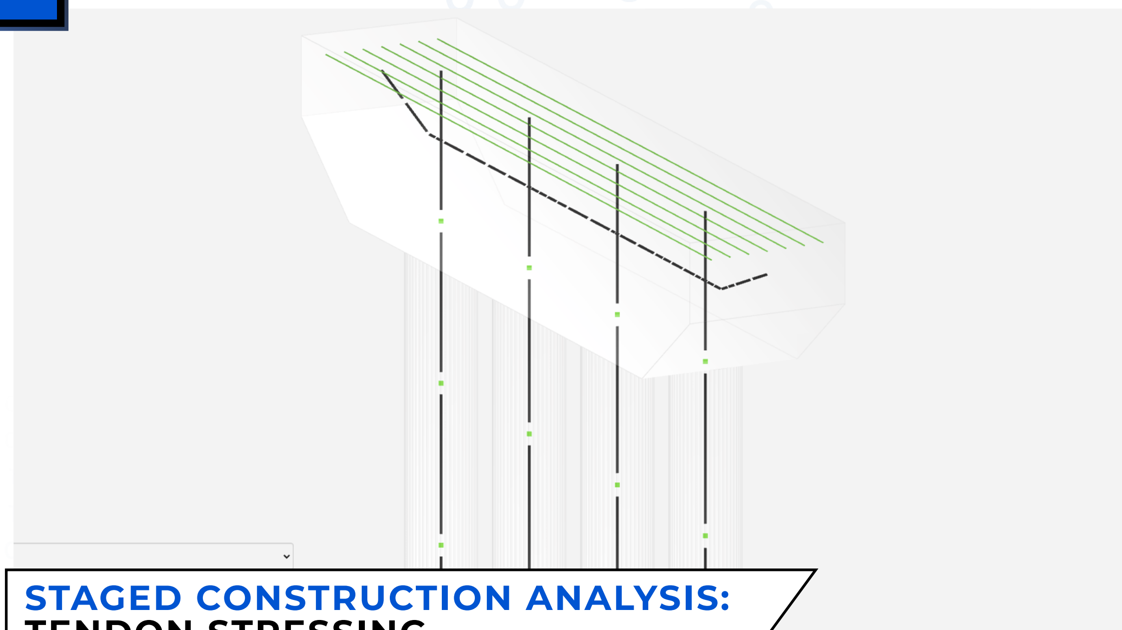


STAGED CONSTRUCTION ANALYSIS: SUBSTRUCTURE CONSTRUCTION

12

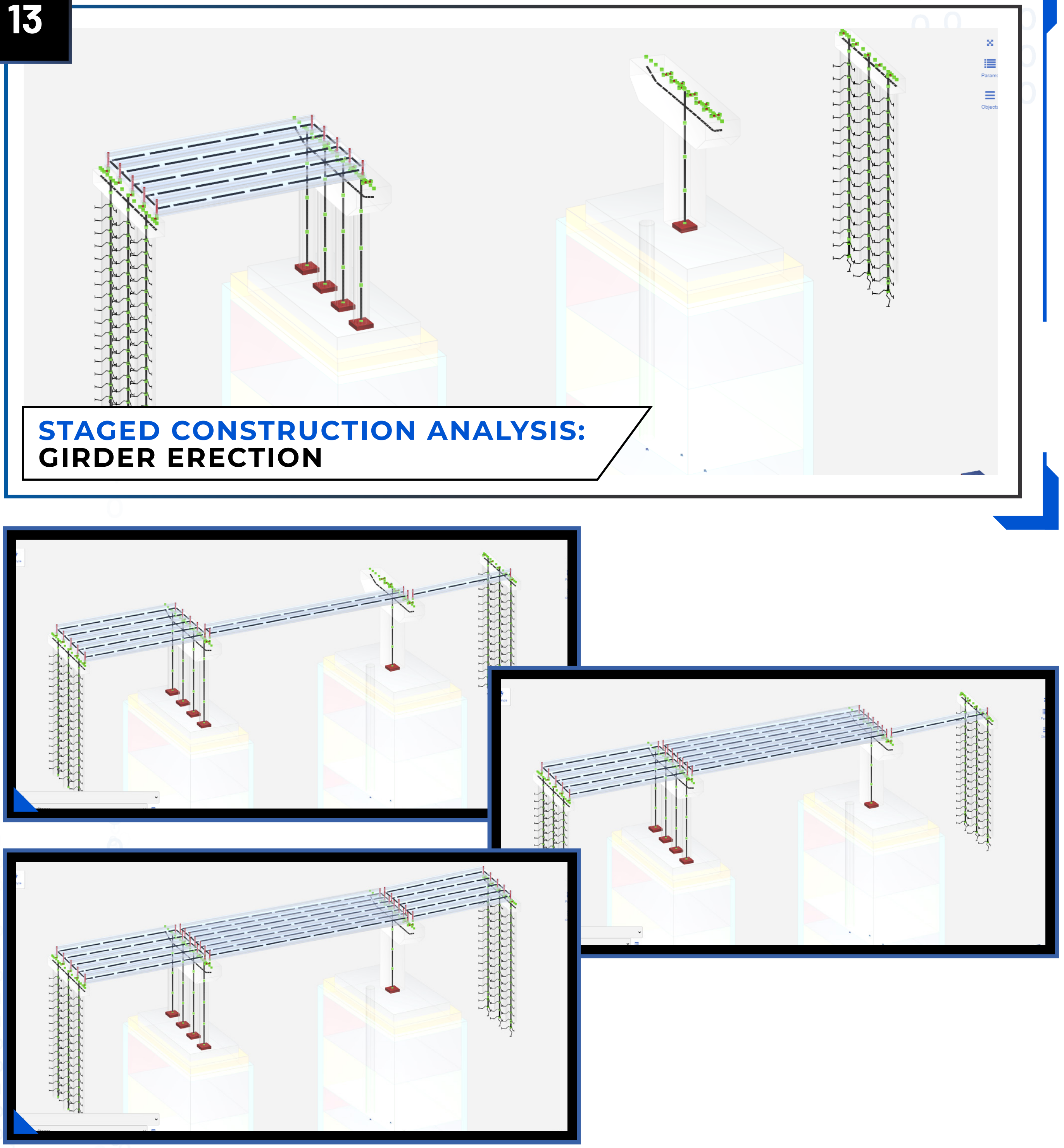


STAGED CONSTRUCTION ANALYSIS: TENDON STRESSING

OpenBrIM enables users to conduct time-dependent staged construction analysis. In cases where caps include tendons, users can parametrically model them, stress them, and utilize OpenBrIM.FEA to calculate both short-term and long-term losses, accounting for factors such as creep, shrinkage, elastic shortening, and relaxation.

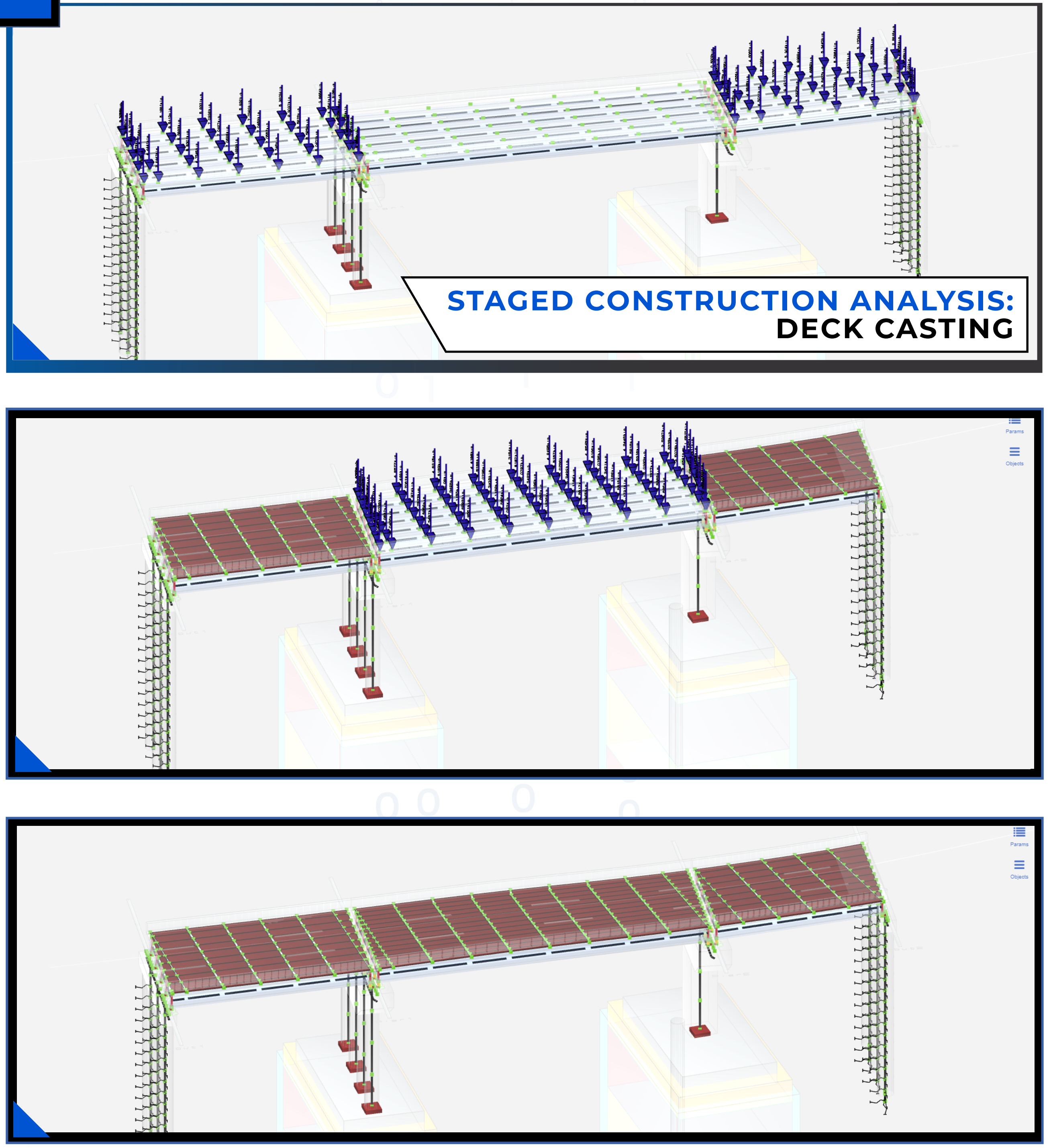
PARAMETRIC WORKFLOW

13



Users can select the girders and diaphragms they want to construct for each stage. Different construction scenarios can be modeled within the same project. Subsequently, users can utilize the AASHTO wind load library component to generate wind loads from various directions after each construction stage, thus enabling constructability assessment.

14

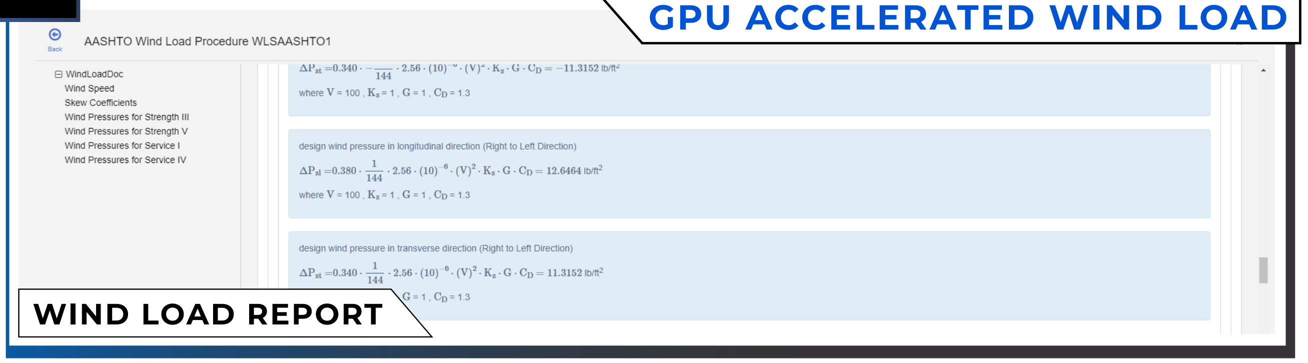


OpenBrIM streamlines the process of generating deck casting scenarios by collecting only longitudinal station and stage information from you. Whether you're embarking on a rehabilitation project or require a multi-step transverse deck pour, OpenBrIM easily adapts by collecting the transverse offset to the PGL. Initially, deck loads are applied to the girders in one stage, followed by the deck gaining stiffness in another stage. Additionally, OpenBrIM automatically updates the superstructure mesh based on your user-defined deck pouring station inputs. You can effortlessly compare and analyze different deck casting scenarios within a single project, giving you control over your construction planning.

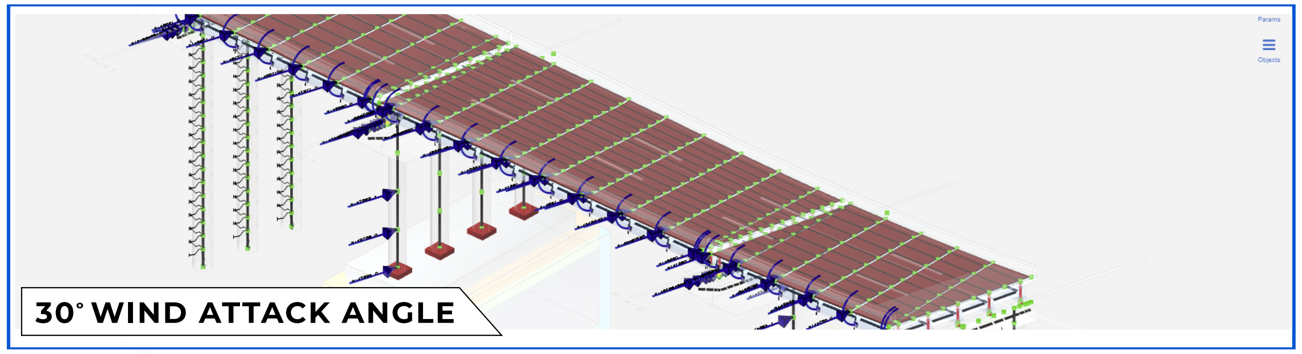
PARAMETRIC WORKFLOW

15

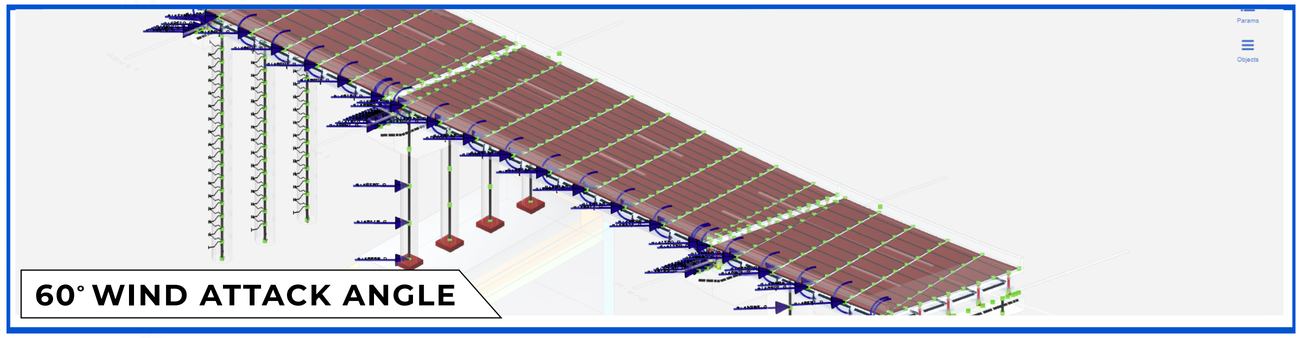
GPU ACCELERATED WIND LOAD



WIND LOAD REPORT



30° WIND ATTACK ANGLE



60° WIND ATTACK ANGLE

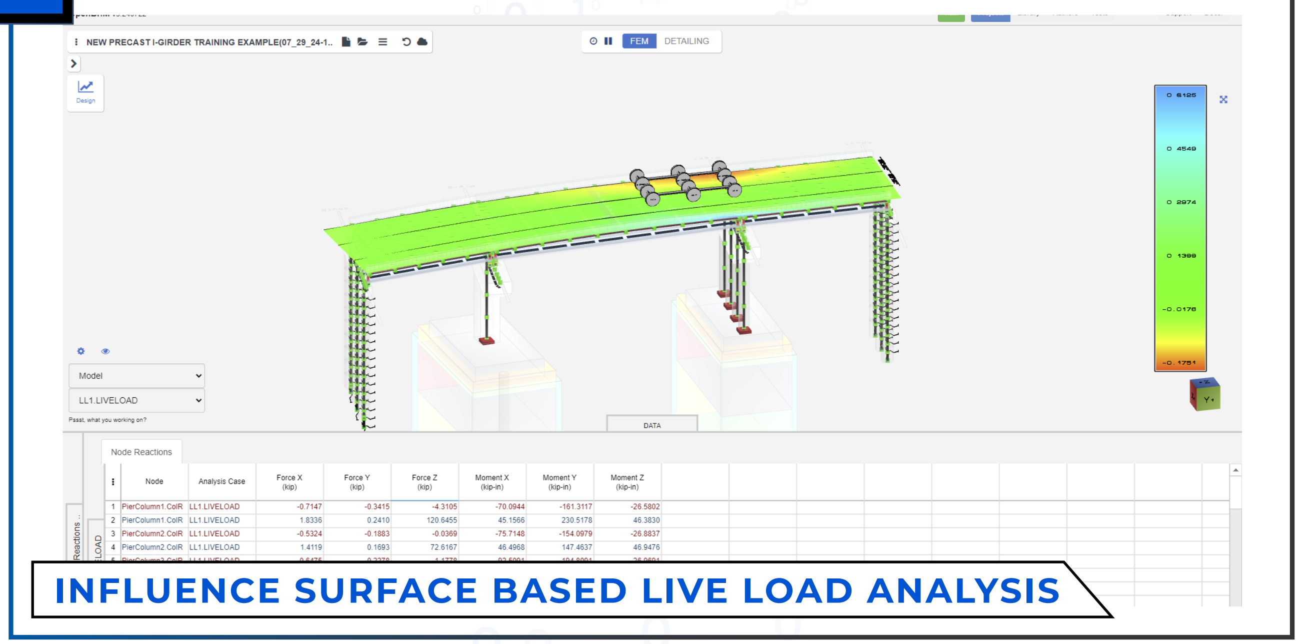
This essential component is designed to calculate wind pressures for each structural element and apply loads in various directions in accordance with AASHTO 3.8.1.2 guidelines. It achieves this by collecting critical input parameters, including structural height from the ground line, gust effect factor, drag coefficient, surface roughness, and the design wind speed for the Strength 3 limit state.

This versatile tool addresses nine cases (-60, -45, -30, -15, 0, 15, 30, 45, and 60 degrees) for both right-to-left and left-to-right wind directions, totaling 18 cases. Automatically generated envelopes cover Strength III, Strength V, Service I, and Service IV limit states for each of these 18 scenarios. Additionally, the component efficiently determines the center of gravity for the girder, deck, and barrier while accurately applying both forces and moments.

Any changes affecting geometry, such as alterations to web depth, alignment, barrier modifications, or substructure adjustments, trigger the automatic generation of wind loads without the need for additional user input.

The resulting nodal loads are computed by translating the wind pressure values based on their respective tributary areas, while considering different angles of attack.

16

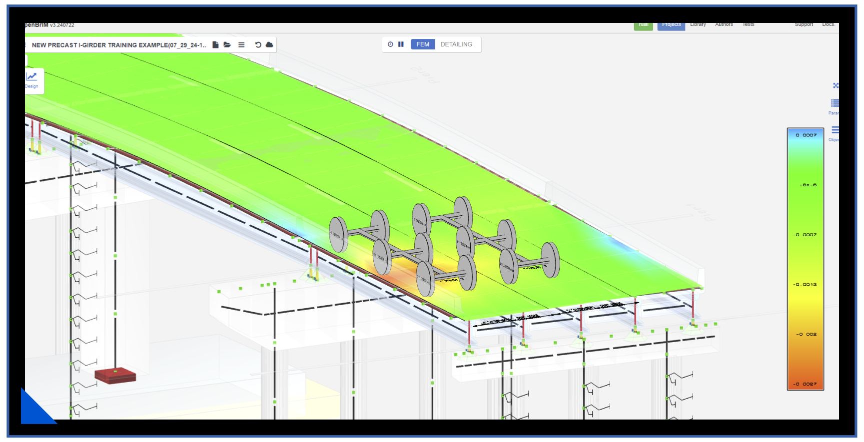


INFLUENCE SURFACE BASED LIVE LOAD ANALYSIS

During an influence surface-based live load analysis, the stiffness matrix and active elements are captured at the selected stage. Subsequently, a unit load is applied to the roadway surface. The analysis then determines the influence surface coefficients, which are used to assess the maximum load effect on the structure. Additionally, the effects of braking and centrifugal forces on the structure can be computed based on influence coefficients in both longitudinal and transverse directions. For centrifugal loads, the user only needs to input the highway design speed and centrifugal force factor. OpenBrIM automatically aligns and positions the influence coefficients correctly based on the alignment.

TRANSVERSE LANE / VEHICLE PLACEMENT

Upon receiving roadway dimensions from the user, OpenBrIM seamlessly manages lane placement in the transverse direction for influence surface-based live load analysis. In a 50-foot roadway, for instance, it can accommodate 4, 3, 2, or 1 lane(s), with multiple presence factors of 1.2, 1, 0.85, and 0.65. OpenBrIM rapidly explores these alternatives, shifting lanes by one foot in the transverse direction and assessing billions of potential configurations within seconds, thanks to its efficient, multi-threaded GPU-based architecture.



PARAMETRIC WORKFLOW

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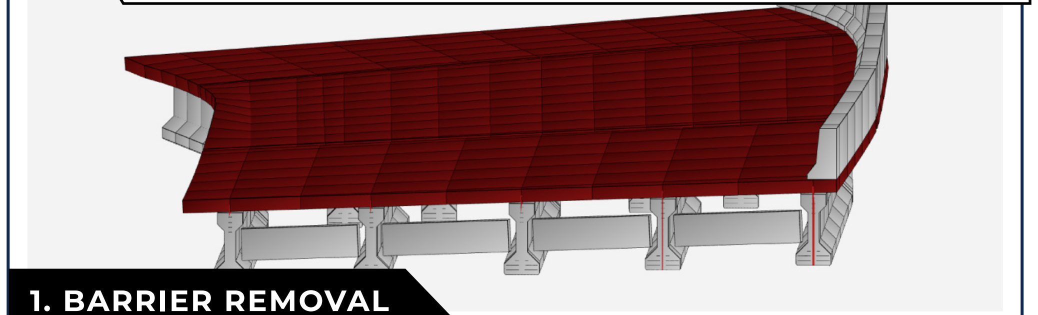
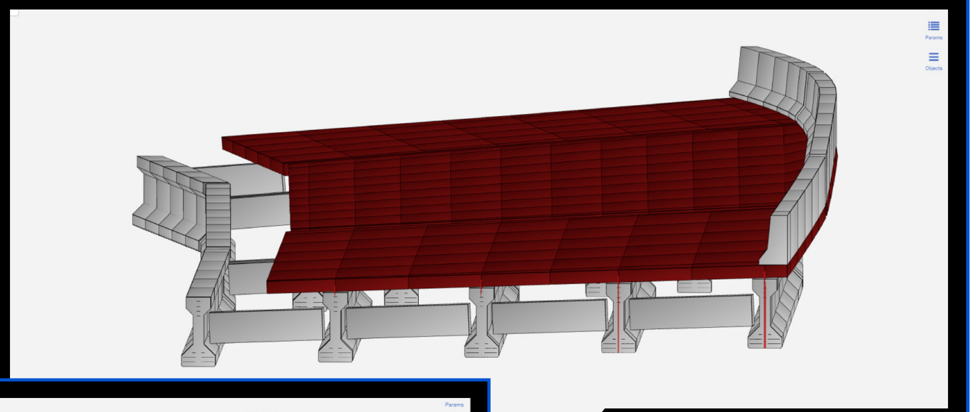
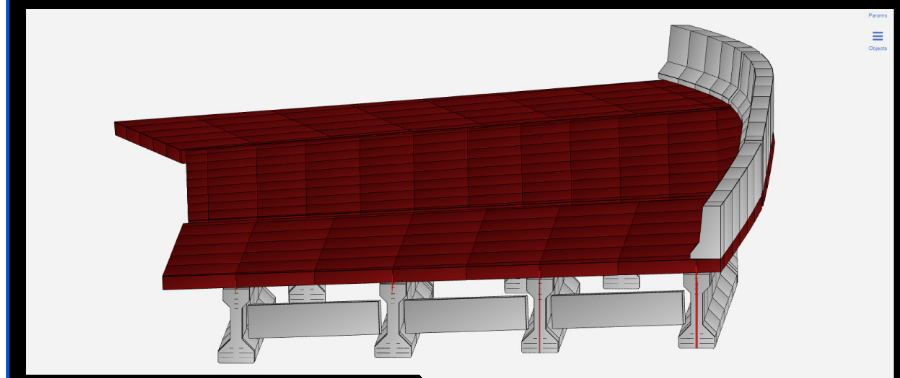
ADDITIONAL STAGED CONSTRUCTION ANALYSIS CAPABILITIES FOR REHABILITATION PROJECTS:



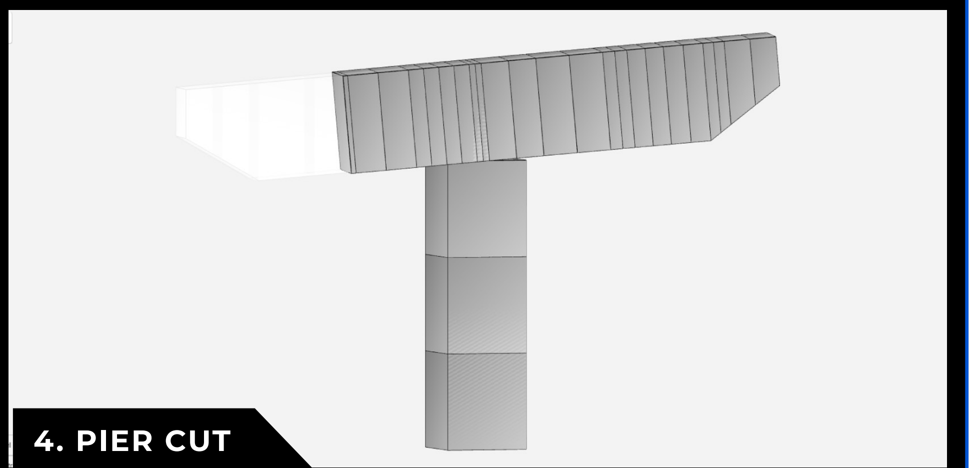
1. BARRIER REMOVAL



2. DECK REMOVAL



3. GIRDER REMOVAL



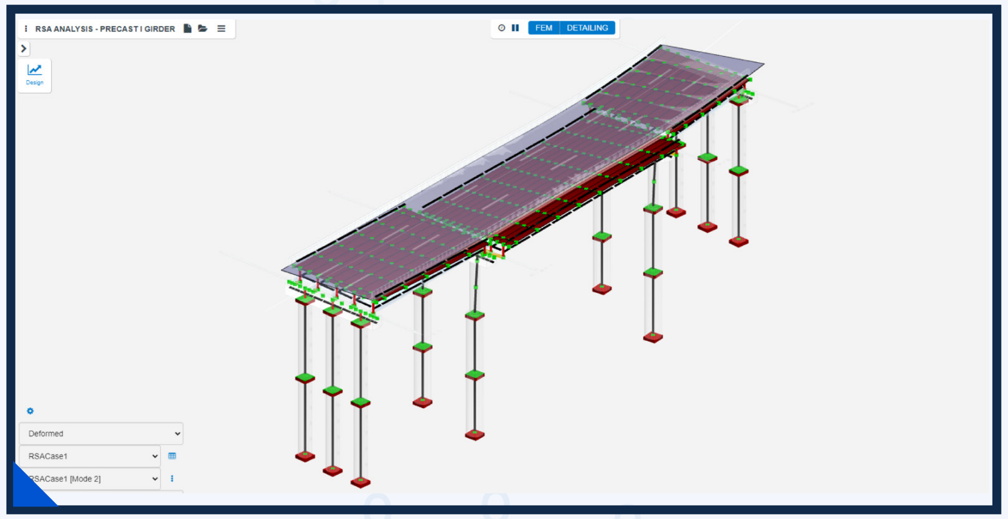
4. PIER CUT

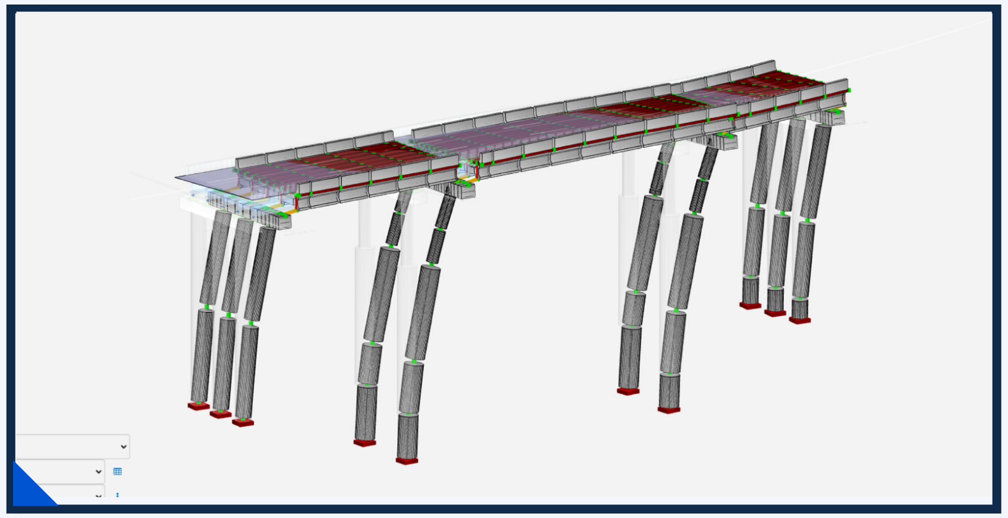
SEISMIC ANALYSIS

If your bridge is in a seismic zone, OpenBrIM's RSA and Pushover analysis can meet your needs. A full bridge model is used to compute displacement demand through response-spectrum analysis. After calculating displacement demand with RSA in staged construction analysis, which captures stiffness and mass at the selected stage, moment curvature analysis for pier sections is performed using transverse and longitudinal reinforcement data. Hinge locations are then computed automatically, followed by pushover analysis to determine the capacity.

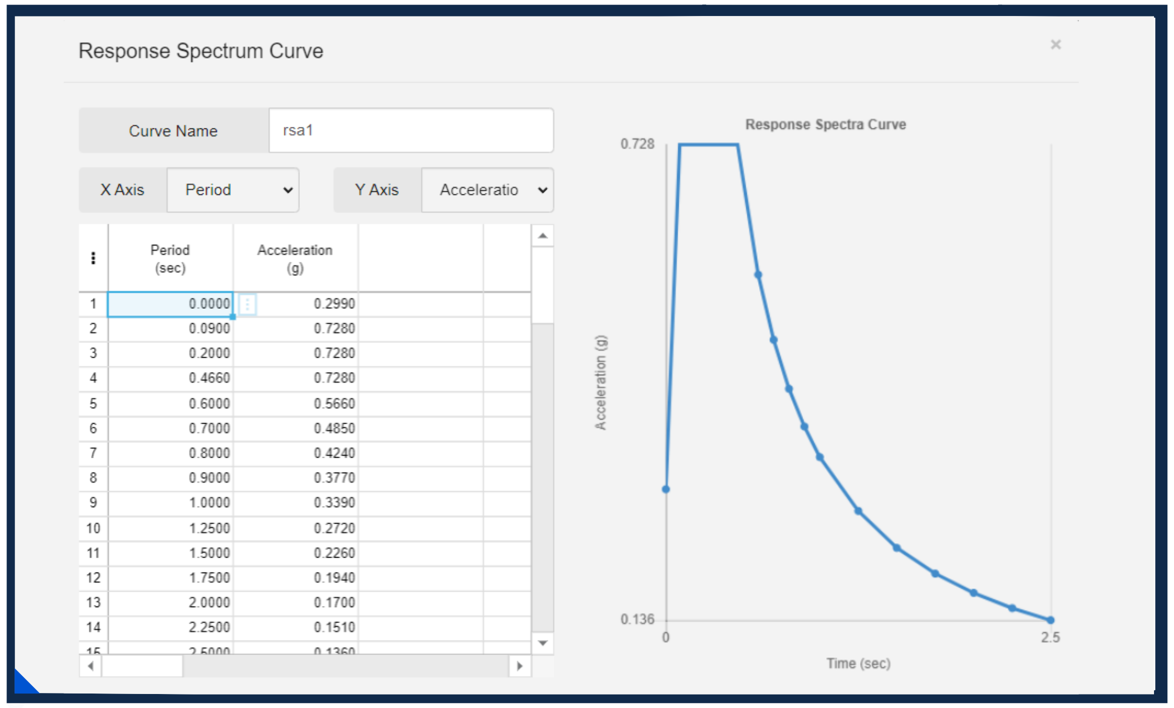
18

EIGENVALUE / RSA ANALYSIS





PARAMETRIC **WORKFLOW**

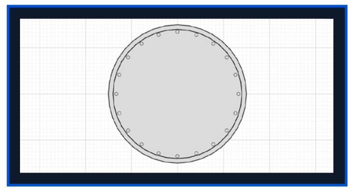


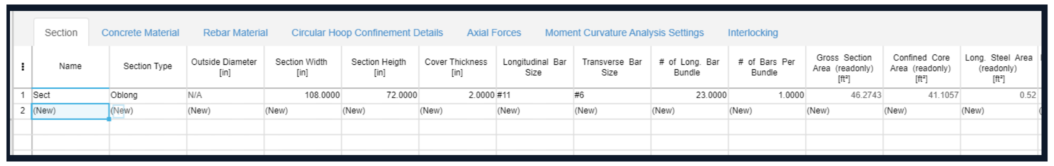
	Period (sec)	Acceleration (g)
1	0.0000	0.2990
2	0.0900	0.7280
3	0.2000	0.7280
4	0.4660	0.7280
5	0.6000	0.5660
6	0.7000	0.4850
7	0.8000	0.4240
8	0.9000	0.3770
9	1.0000	0.3390
10	1.2500	0.2720
11	1.5000	0.2260
12	1.7500	0.1940
13	2.0000	0.1700
14	2.2500	0.1510
15	2.5000	0.1360

Utilizing the Full Eigenvalue or Ritz Method (LWYD, QSRV), engineers can perform comprehensive modal analysis to determine natural frequencies and mode shapes with high precision. Coupled with our Response Spectra feature (CQC, SRSS), users can seamlessly conduct seismic analysis and compute seismic demands prior to pushover analysis.

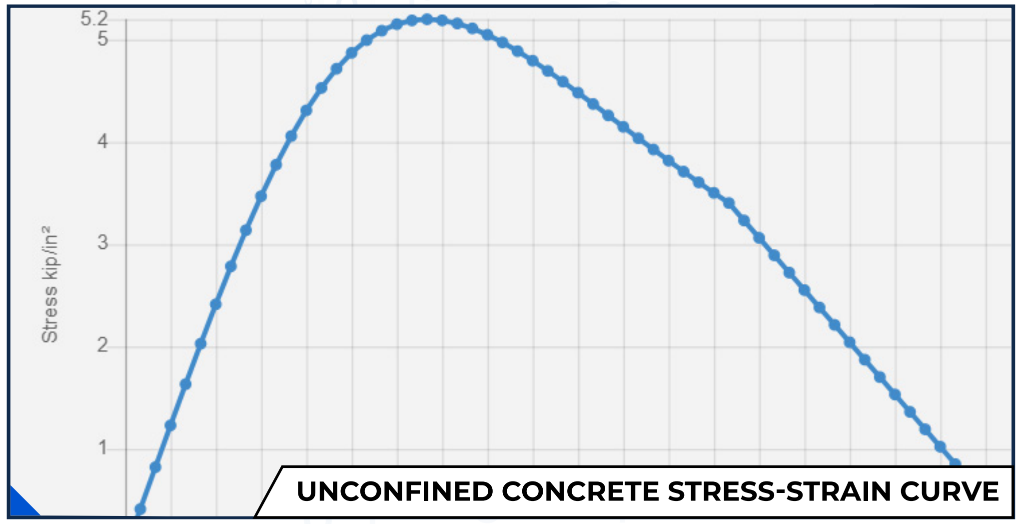
19 MOMENT CURVATURE

Using our parametric moment curvature report, engineers can efficiently enter section dimensions for oblong, circular, and rectangular sections, confined zone information, longitudinal rebars, and transverse reinforcement. Based on this input and following the Mander stress-strain curve for confined and unconfined concrete, OpenBrIM computes the confined concrete compressive strength and the concretecrushing strain limit. With the generated stress-strain curves for both concrete and rebar, moment curvature analysis is performed. Idealized curves, based on the "area under and below the curve will equal" logic, are then created for different axial forces. These curves are subsequently assigned to hinge locations for nonlinear pushover analysis in staged construction analysis.

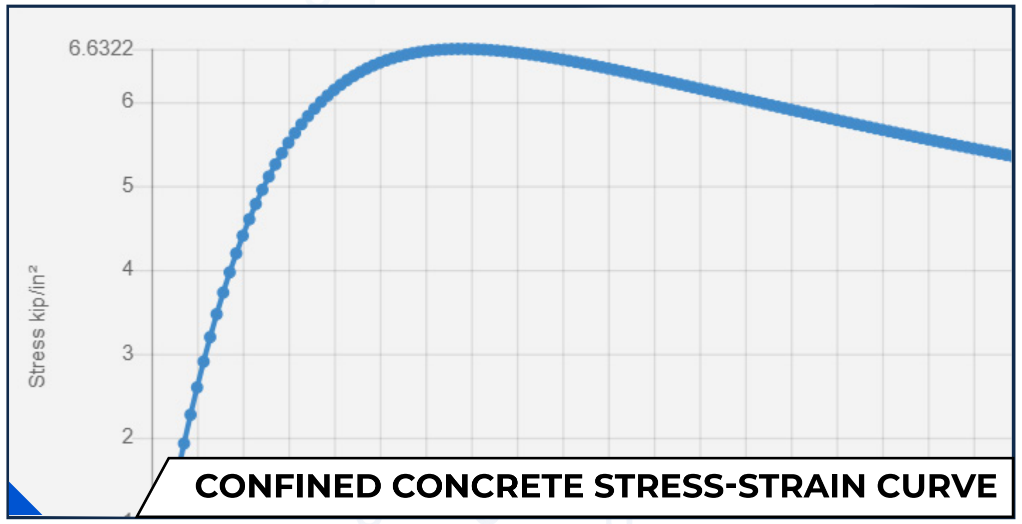




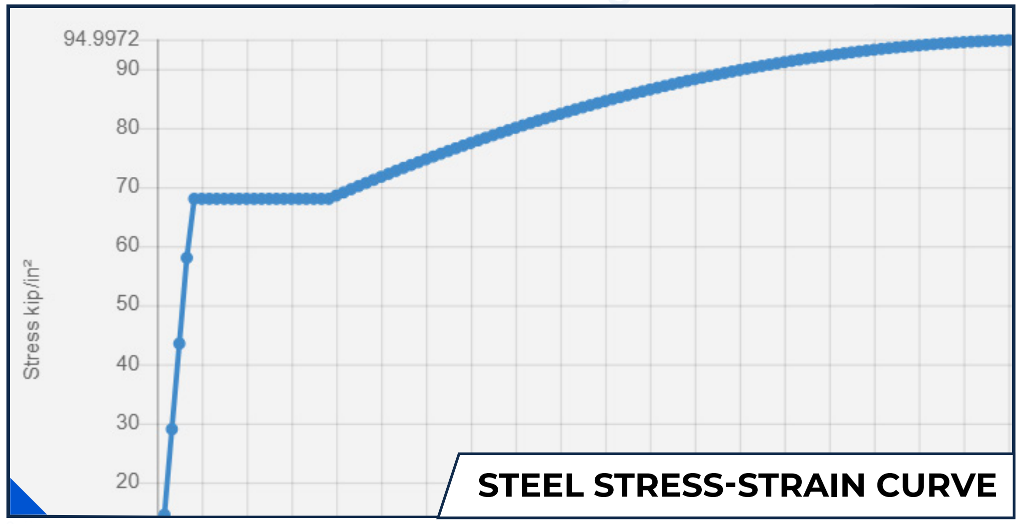
	Name	Section Type	Outside Diameter [in]	Section Width [in]	Section Heigth [in]	Cover Thickness [in]	Longitudinal Bar Size	Transverse Bar Size	# of Long. Bar Bundle	# of Bars Per Bundle	Gross Section Area (readonly) [ft²]	Confined Core Area (readonly) [ft²]	Long. Steel Area (readonly) [ft²]
1	Sect	Oblong	N/A	108.0000	72.0000	2.0000	#11	#6	23.0000	1.0000	46.2743	41.1057	0.52
2	(New)	(New)	(New)	(New)	(New)	(New)	(New)	(New)	(New)	(New)	(New)	(New)	(New)



UNCONFINED CONCRETE STRESS-STRAIN CURVE

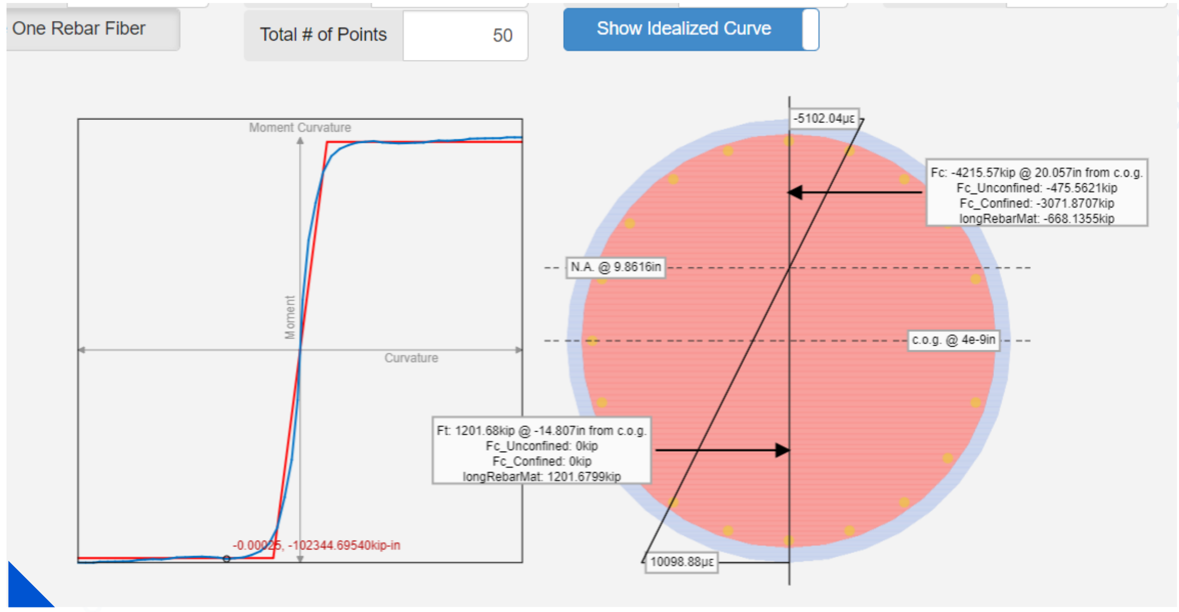


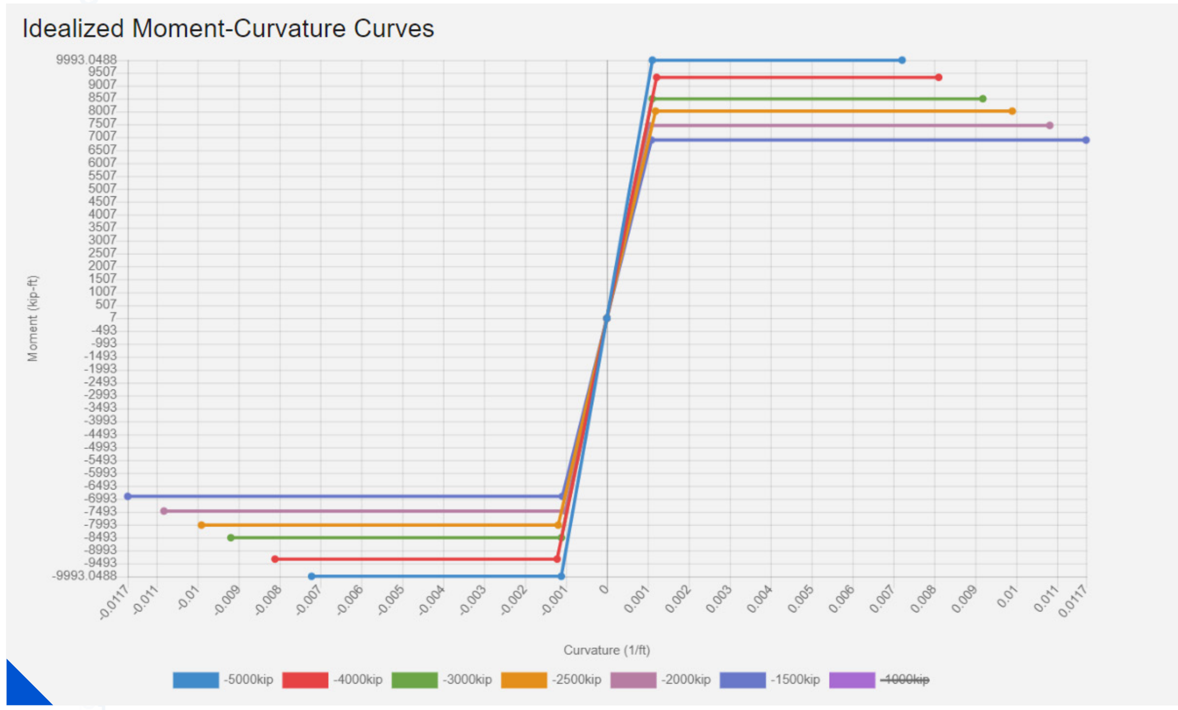
CONFINED CONCRETE STRESS-STRAIN CURVE



STEEL STRESS-STRAIN CURVE

PARAMETRIC WORKFLOW





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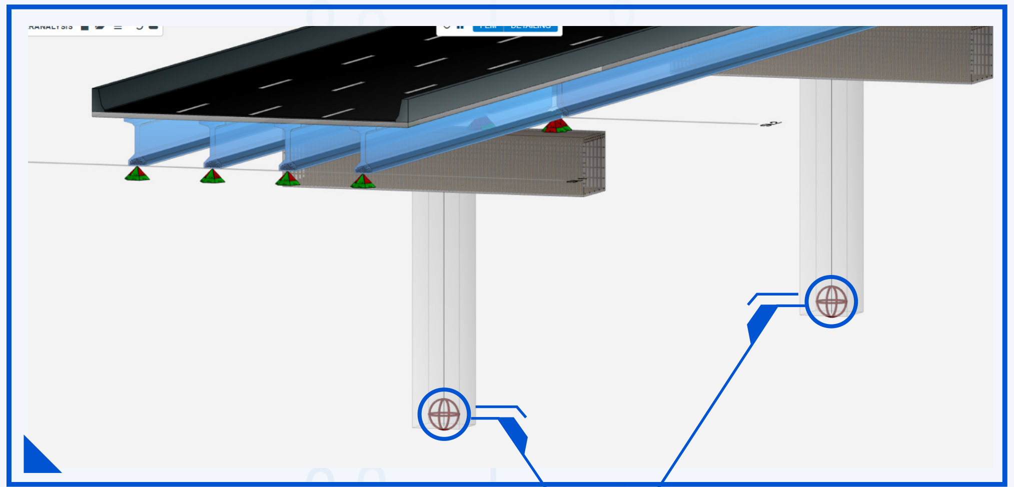
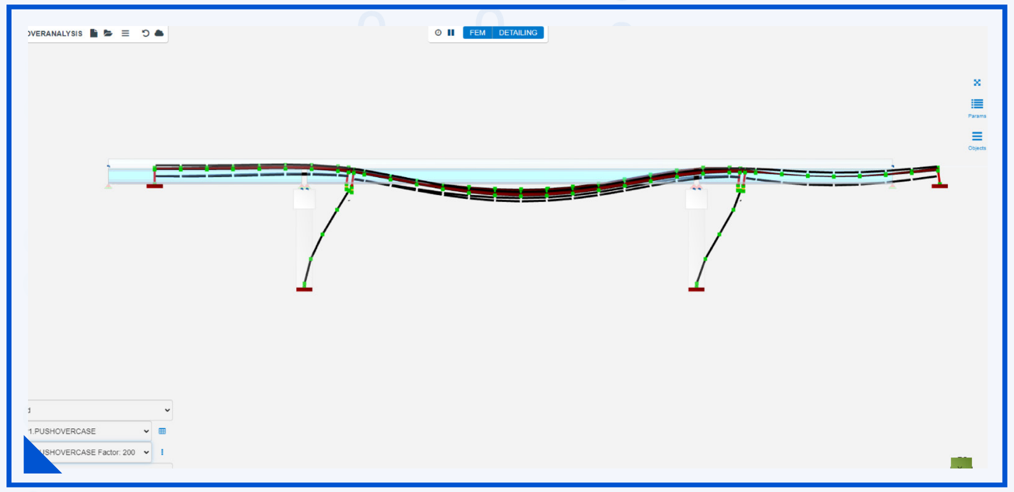
PUSHOVER ANALYSIS

OpenBrIM has the ability to run Pushover Analysis within staged construction analysis and report base shear and displacement values. Then, those that correspond to maximum base shear will be used for capacity, and the structures' D/C ratio will be reported for each pier by comparing these displacements with RSA



HINGE LOCATION



PARAMETRIC WORKFLOW

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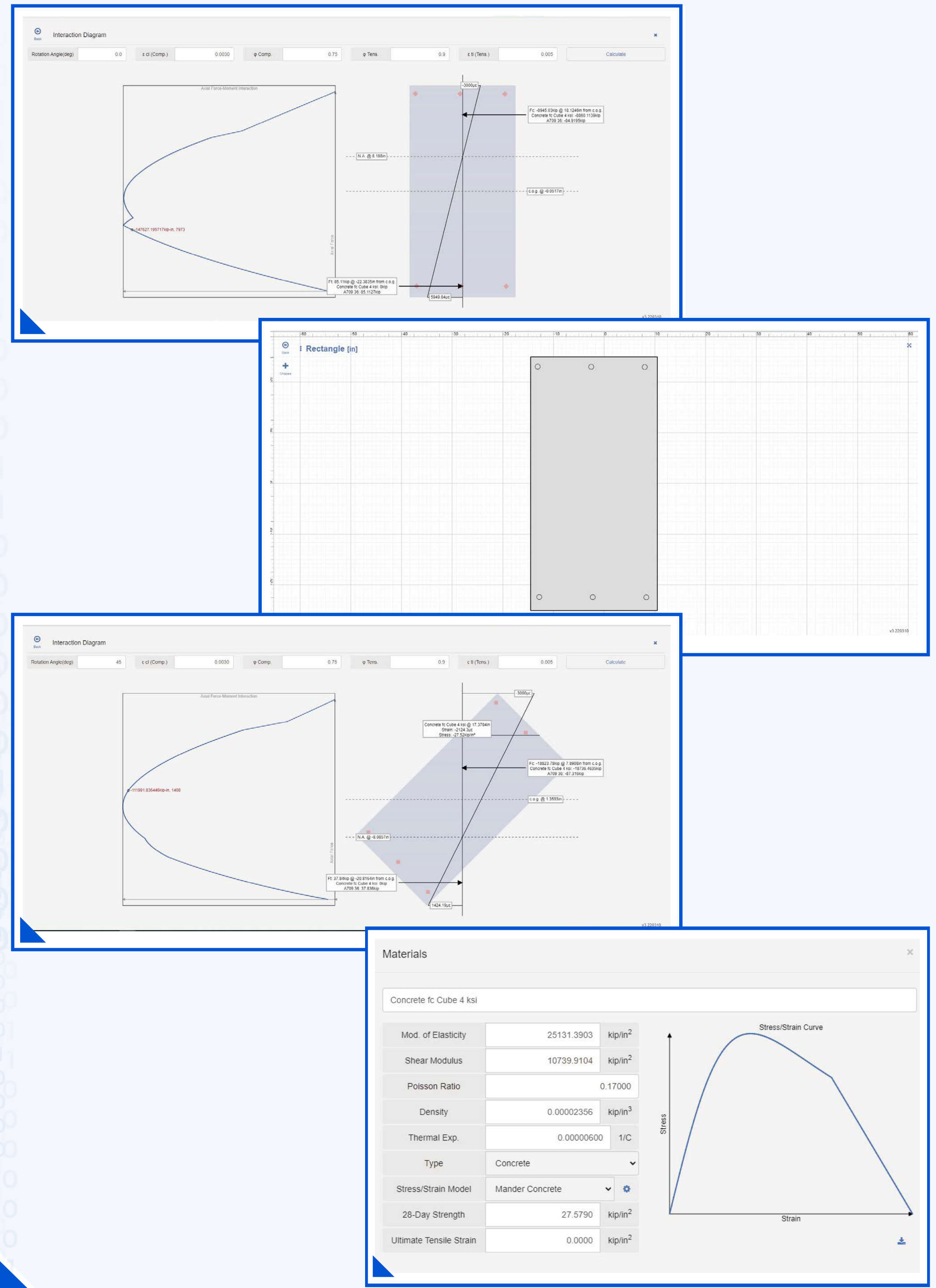
BIAXIAL INTERACTION DIAGRAM TO CHECK PIER CAPACITIES



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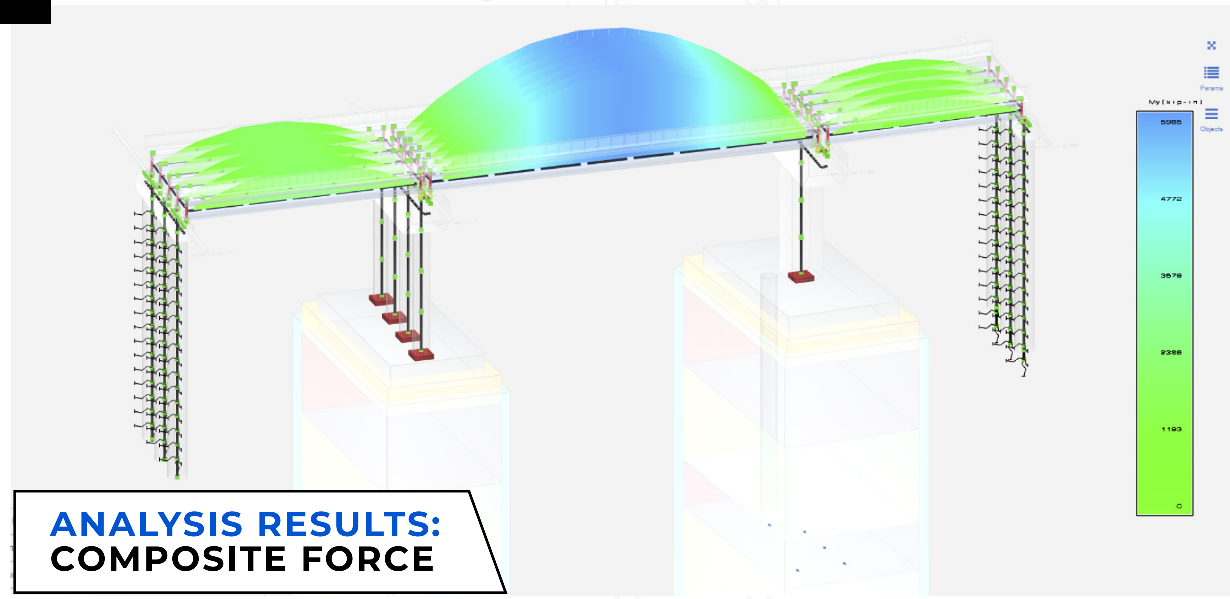

ANALYSIS RESULTS: COMPOSITE FORCE

Given that a girder is modeled as a beam element and a deck consists of two shell elements, it is essential to compute resultant forces at the section's center of gravity. Subsequently, these forces should be transformed to the center of gravity and reported as resultant forces, referred to as FEComposite forces. When conducting a live load analysis, dynamic influence coefficients are calculated to determine the critical force effect that produces the maximum force at the centroid. FEComposite forces is crucial for code-checking purposes, as single-element forces cannot be used for code-checking purposes.

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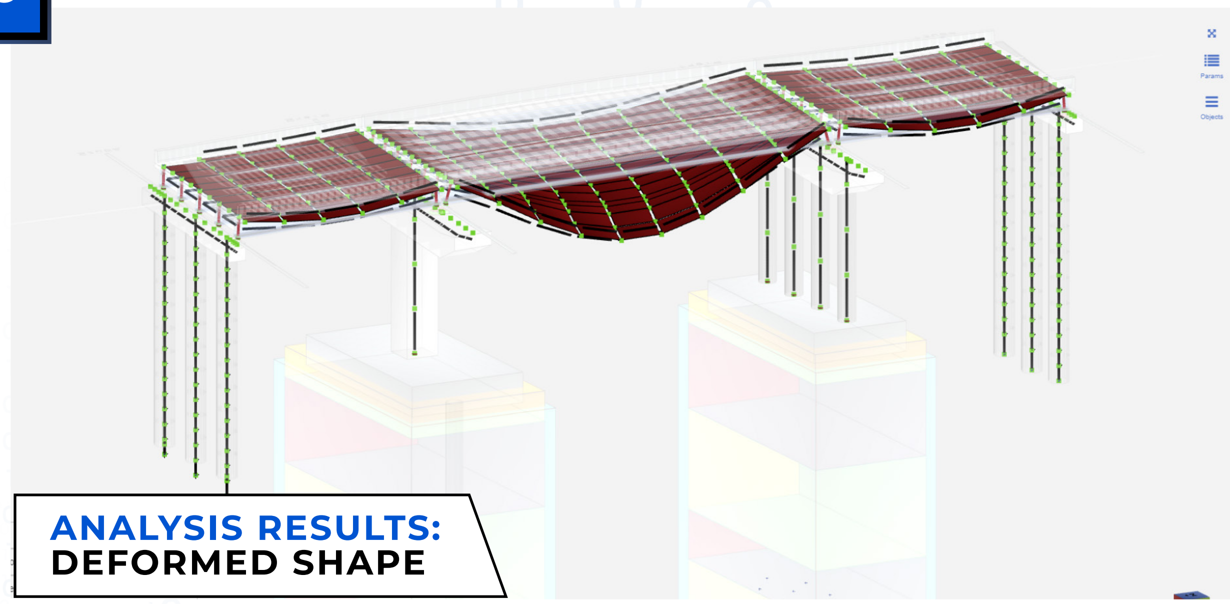


ANALYSIS RESULTS: DEFORMED SHAPE

PARAMETRIC **WORKFLOW**

24 STAGED CONSTRUCTION ANALYSIS FOR CODE CHECK AND LOAD RATING

For a typical load rating or design project, a staged construction analysis is performed in the following stages:

01 **Stage 1:**
Construction of girders and cross frames, followed by the application of non-composite loads such as deck loads and stay-in-place formwork loads on the non-composite girder.

02 **Stage 2** (or more):
The deck gains stiffness based on the deck pouring sequence.

03 **Stage 3:**
Barrier loads or wearing surface loads are applied on the deck.

04 **Stage 4:**
Influence surface-based live load analysis is conducted using various vehicles.

When conducting a load rating for pre/post-tensioned concrete girder bridges, the following rating factors are calculated: The flexural capacity for both positive and negative bending moments is determined using the strain compatibility method. Shear capacity is calculated using various methods, such as the Simplified Method, General Method, and Appendix B5 Table Method for shear parameters Beta and Theta. The Vs value can be obtained either from time-dependent staged construction analysis or from AASHTO equations for simply supported prestressed I-Girder bridges. The service limit state rating factor is computed for both tensile and compressive stresses.

Additionally, OpenBrIM supports continuous deck behavior for live load analysis and employs influence surface-based live load analysis to determine the live load demand for flexure, shear, and stress. Users can define their own permit trucks, and we offer an extensive library for each

Positive Flexure

6A.4.2 - General Load-Rating Equation

Capacity
$C = \varphi_c \cdot \varphi_s \cdot R_n \cdot \varphi_f = 577313.4259$
where φ_c = 1 , φ_s = 1 , $R_n \cdot \varphi_f$ = 577313.4259 kip-in

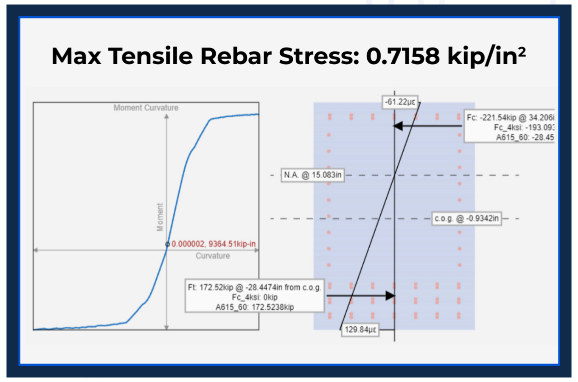
[6A.4.2.1-1] Load Rating Factor
$$RF = \frac{C - \gamma_{DC} \cdot DC - \gamma_{DW} \cdot DW - \gamma_p \cdot P}{\gamma_{LL} \cdot LL} = 7.2284$$
where C = 577313.4259 , γ_{DC} = 1.25 , DC = 90861.7558 kip-in, γ_{DW} = 1.5 , DW = 11290.4893 kip-in, γ_p = 1 , P = 0 kip-in, γ_{LL} = 1.75 , LL = 35321.2703 kip-in

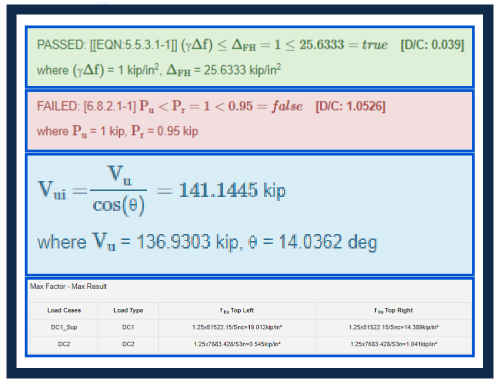
PASSED: [Load Rating Check] $RF \geq 1 = true$
where RF = 7.2284

Detailed Report	Girder - Station	Rating Level	Vehicle	Vehicle Weight Tons ST	Positive Flexure (Strength)		Negative Flexure (Strength)		Shear (Strength)		Tensile Stress (Service)		Compressive Stress (Service)	
					Rating Factor	Posting Load Capacity ST	Rating Factor	Posting Load Capacity ST	Rating Factor	Posting Load Capacity ST	Rating Factor	Posting Load Capacity ST	Rating Factor	Posting Load Capacity ST
≡	CGLR26 - G2 - 2680ft Span 3 0.5L	Inventory	HL93DesignTruck	36	7.23	260.22	24.2	871.27	27.55	991.77	1.56	56.16	7.15	257.48
		Operating	HL93DesignTruck	36	9.37	337.32	31.37	1129.43	35.71	1285.62	12.48	449.3	57.22	2059.8
		Legal	ILPS2_21	21	22.92	481.25	116.19	2439.89	70.53	1481.11	2.94	61.68	13.44	282.27
		Legal	ILPS3_31	31	15.74	487.82	79.74	2471.9	49.77	1542.93	2.02	62.52	9.21	285.44
		Legal	ILPS4_34_75	34.75	14.4	500.48	73.21	2544.16	49.99	1737.17	1.85	64.15	8.42	292.46
		Legal	ILPS4_28	28	18.28	511.71	93.04	2605.08	58.99	1651.61	2.34	65.6	10.67	298.76
		Legal	ILPS5_36	36	15.62	562.32	65.17	2346.08	60.94	2193.77	2	72.11	9.17	330.29
		Legal	ILPS6_35_75	35.75	14.59	521.76	60.39	2158.85	55.89	1998.16	1.87	66.89	8.55	305.67
		Legal	ILPS7_39_75	39.75	13.37	531.6	68.21	2711.5	50.48	2006.39	1.71	68.16	7.84	311.54
		Legal	ILPC3_31	31	18.69	579.45	93.45	2896.84	66.12	2049.61	2.4	74.34	10.92	338.53
		Legal	ILPC4_41	41	13.14	538.63	66.57	2729.41	48.2	1976.22	1.68	69.06	7.69	315.28
		Legal	ILPC5_41	41	12.99	532.39	66.06	2708.38	47.61	1952	1.67	68.27	7.6	311.73
		Legal	ILPD6_40	60	17.51	1050.33	73.14	4388.68	72.89	4373.36	2.25	135.27	10.22	613
		Emergency	EV2	28.75	18.1	520.37	75.77	2178.46	57.87	1663.83	2.32	66.7	10.62	305.32
		Emergency	EV3	43	12.12	521.07	61.77	2655.96	38.72	1665.12	1.55	66.81	7.07	304.02

25 AASHTO CODE CHECKS STATE SPECIFICATIONS

OpenBrIM conducts structural assessments in accordance with the AASHTO 9th edition. Furthermore, our engineers continuously enhance our capabilities by creating custom library objects that accommodate state-specific requirements for our enterprise clients. This state specification library evolves annually, driven by client requests from states such as FDOT, CALTRANS, PENNDOT, and NYSDOT, among others, with which our engineers have collaborated thus far.





PASSED: [[EQN:5.5.3.1-1]] $(\gamma\Delta f) \leq \Delta_{FH} = 1 \leq 25.6333 = true$ [D/C: 0.039]
where $(\gamma\Delta f)$ = 1 kip/in², Δ_{FH} = 25.6333 kip/in²

FAILED: [6.8.2.1-1] $P_u < P_r = 1 < 0.95 = false$ [D/C: 1.0526]
where P_u = 1 kip, P_r = 0.95 kip

$$V_{ui} = \frac{V_u}{\cos(\theta)} = 141.1445 \text{ kip}$$
where V_u = 136.9303 kip, θ = 14.0362 deg

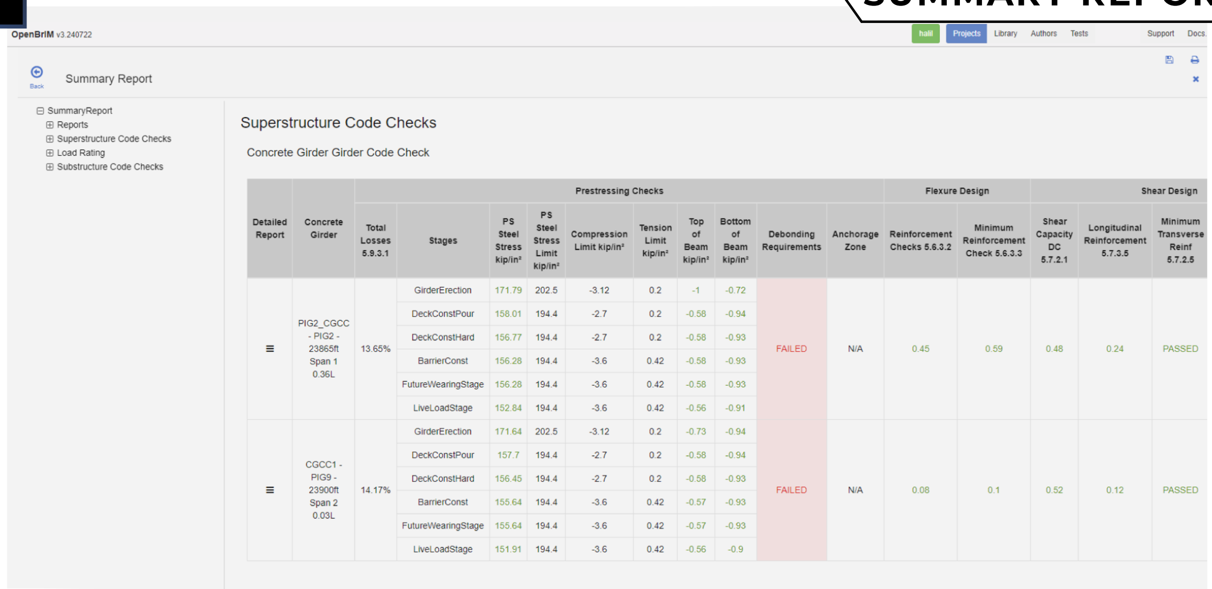
Max Factor - Max Result

Load Cases	Load Type	f_{bu} Top Left	f_{bu} Top Right
DC1_Sup	DC1	1.25x81522.15/Snc=19.012kip/in²	1.25x81522.15/Snc=14.389kip/in²
DC2	DC2	1.25x7683.428/S3n=0.545kip/in²	1.25x7683.428/S3n=1.041kip/in²

Digital Twin of Bridge Design Codes: All AASHTO chapters have been digitized, allowing you to access and review all code requirements directly in your web browser. Take the time to thoroughly explore the digital version of the code requirements. Share your comments or propose specific modifications to the design procedure. Adjust the input parameters and evaluate their impact accordingly.
Digital Twin of Code Check & Load Rating Procedures For Structural Elements such as Girders, Splices: Our code check routines are engineered to operate in a manner akin to an engineer's thought process. When specific bridge code requirements are referenced, our routines retrieve the relevant bridge code chapters, clauses, and equations from digitalized sections of the bridge design code as required and employ them in the computational process.

PARAMETRIC WORKFLOW

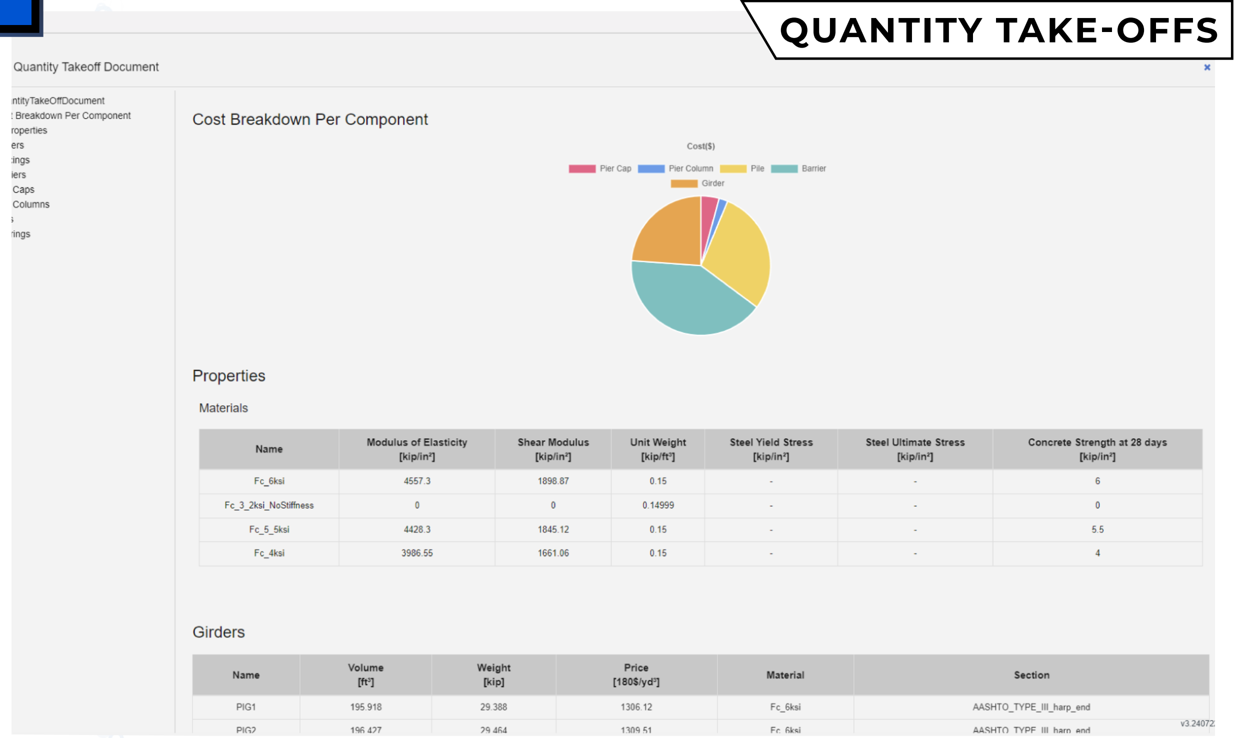
26 SUMMARY REPORT



Detailed Report	Concrete Girder	Prestressing Checks										Flexure Design		Shear Design		
		Total Losses 5.9.3.1	Stages	PS Steel Stress kip/in²	PS Steel Stress Limit kip/in²	Compression Limit kip/in²	Tension Limit kip/in²	Top of Beam kip/in²	Bottom of Beam kip/in²	Debonding Requirements	Anchorage Zone	Reinforcement Checks 5.6.3.2	Minimum Reinforcement Check 5.6.3.3	Shear Capacity DC 5.7.2.1	Longitudinal Reinforcement 5.7.3.5	Minimum Transverse Reinf 5.7.2.5
≡	PIG2_CGCC - PIG2 - 23865ft Span 1 0.36L	13.65%	GirderErection	171.79	202.5	-3.12	0.2	-1	-0.72	FAILED	N/A	0.45	0.59	0.48	0.24	PASSED
			DeckConstPour	158.01	194.4	-2.7	0.2	-0.58	-0.94							
			DeckConstHard	156.77	194.4	-2.7	0.2	-0.58	-0.93							
			BarrierConst	156.28	194.4	-3.6	0.42	-0.58	-0.93							
			FutureWearingStage	156.28	194.4	-3.6	0.42	-0.58	-0.93							
			LiveLoadStage	152.84	194.4	-3.6	0.42	-0.56	-0.91							
≡	CGCC1 - PIG9 - 23900ft Span 2 0.03L	14.17%	GirderErection	171.64	202.5	-3.12	0.2	-0.73	-0.94	FAILED	N/A	0.08	0.1	0.52	0.12	PASSED
			DeckConstPour	157.7	194.4	-2.7	0.2	-0.58	-0.94							
			DeckConstHard	156.45	194.4	-2.7	0.2	-0.58	-0.93							
			BarrierConst	155.64	194.4	-3.6	0.42	-0.57	-0.93							
			FutureWearingStage	155.64	194.4	-3.6	0.42	-0.57	-0.93							
			LiveLoadStage	151.91	194.4	-3.6	0.42	-0.56	-0.9							

In our structural component code checks, we categorize our reports into two types: detailed reports and summary reports. The summary report provides a quick overview of the D/C ratios and relevant AASHTO clauses, while the detailed reports offer comprehensive insights into each calculation contributing to these D/C ratios. In the detailed reports, we meticulously document every AASHTO clause, describe each parameter, and specify the parameter values employed in the equations.

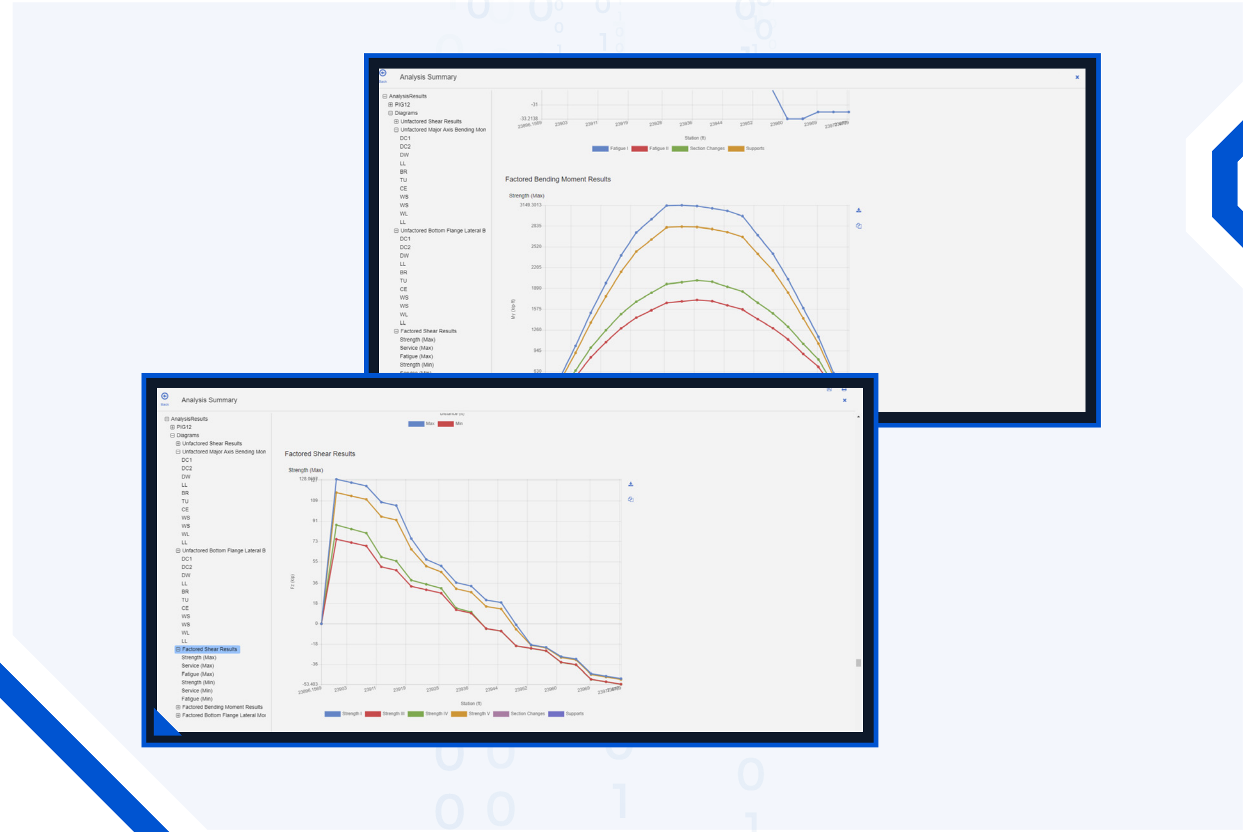
27 QUANTITY TAKE-OFFS



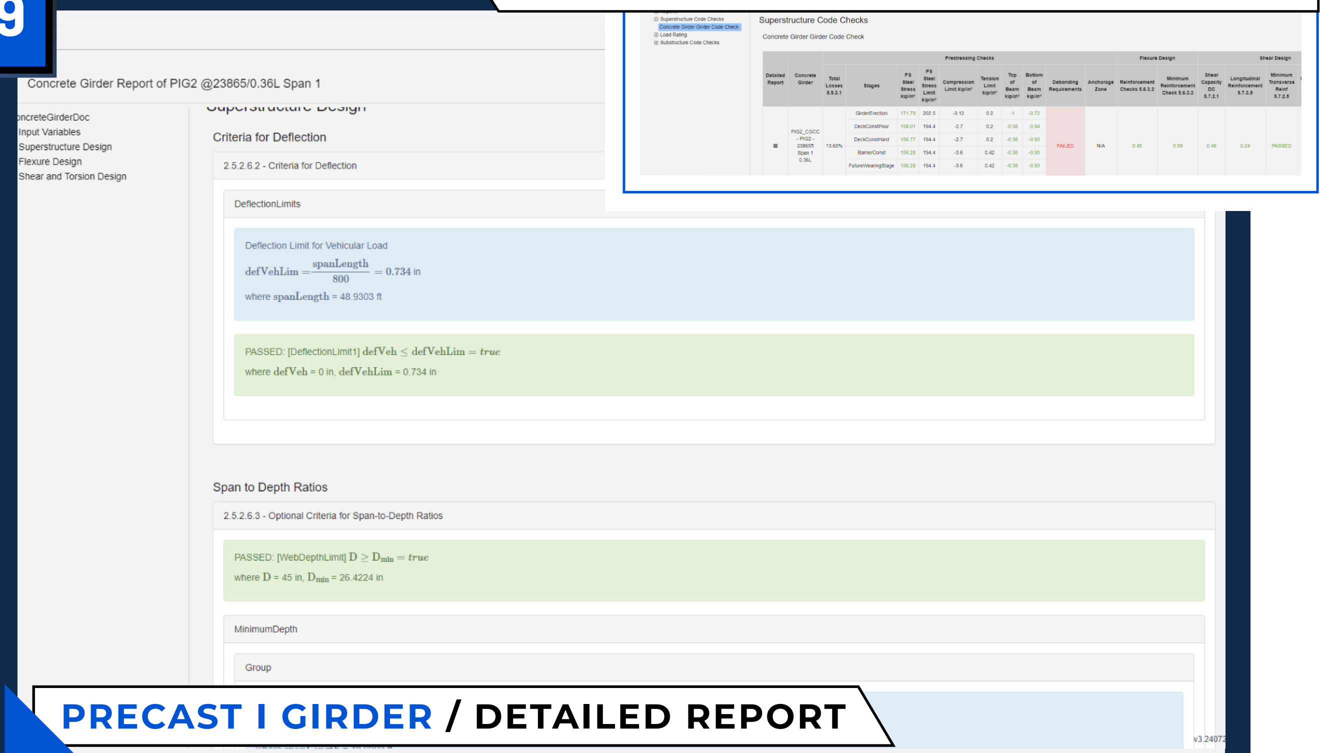
Name	Modulus of Elasticity [kip/in²]	Shear Modulus [kip/in²]	Unit Weight [kip/ft³]	Steel Yield Stress [kip/in²]	Steel Ultimate Stress [kip/in²]	Concrete Strength at 28 days [kip/in²]
Fc_6ksi	4557.3	1898.87	0.15	-	-	6
Fc_3_2ksi_NoStiffness	0	0	0.14999	-	-	0
Fc_5_5ksi	4428.3	1845.12	0.15	-	-	5.5
Fc_4ksi	3986.55	1661.06	0.15	-	-	4

Name	Volume [ft³]	Weight [kip]	Price [180$/yd³]	Material	Section
PIG1	195.918	29.388	1306.12	Fc_6ksi	AASHTO_TYPE_III_harp_end
PIG2	196.427	29.464	1309.51	Fc_6ksi	AASHTO_TYPE_III_harp_end

28 GIRDER ANALYSIS SUMMARY



29 PRECAST I GIRDER / SUMMARY REPORT



PRECAST I GIRDER / DETAILED REPORT

PARAMETRIC WORKFLOW

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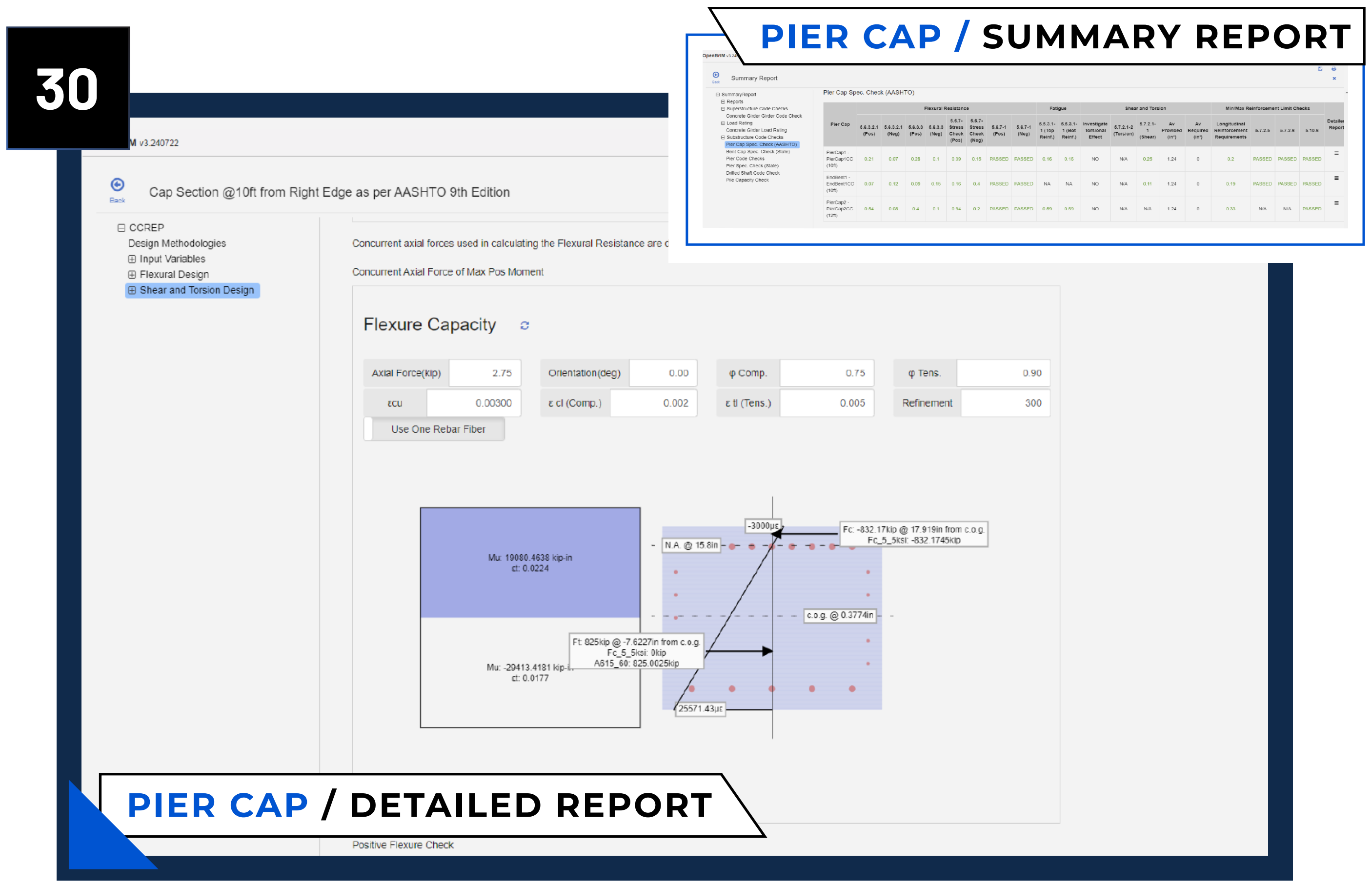

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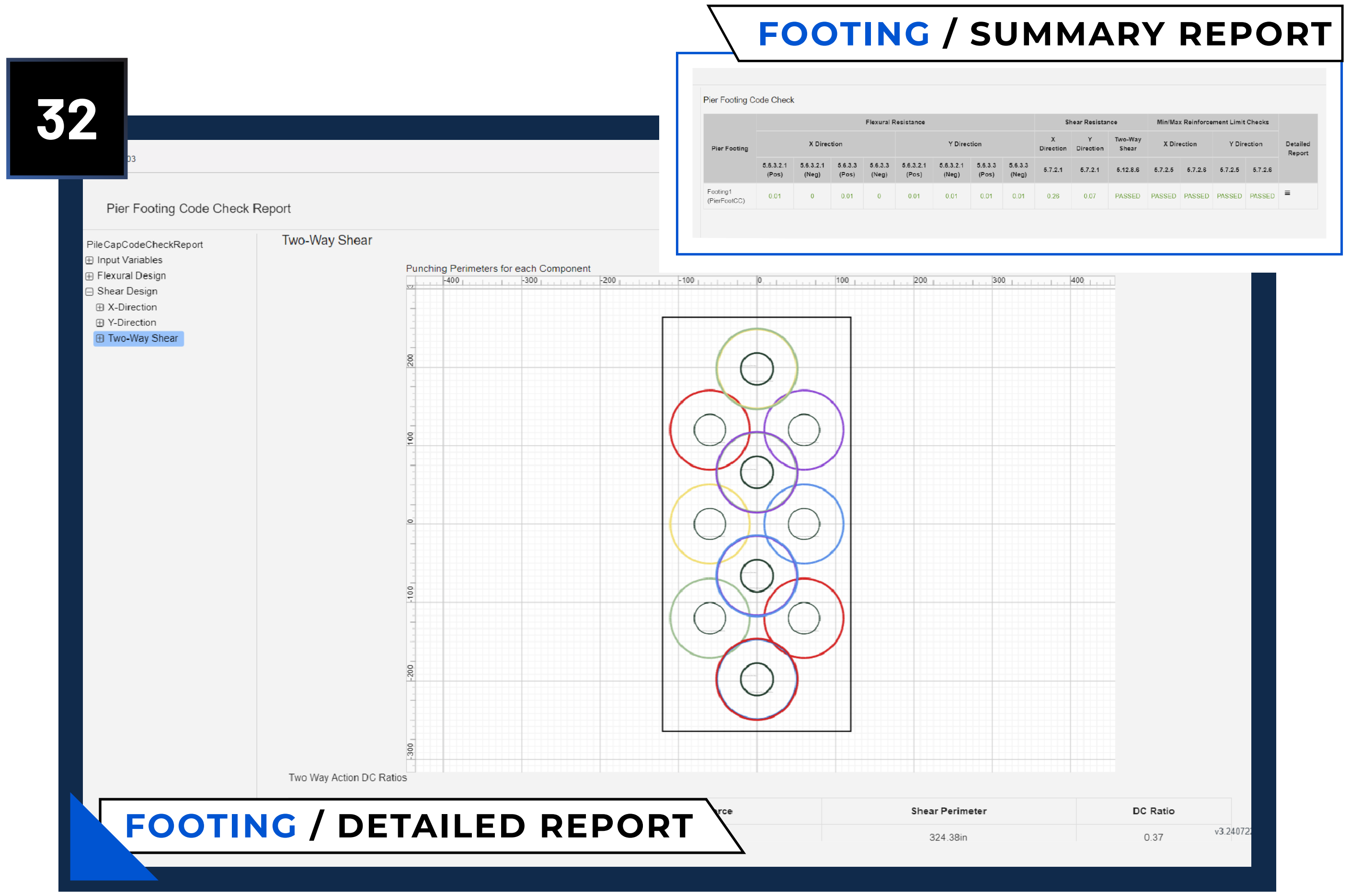

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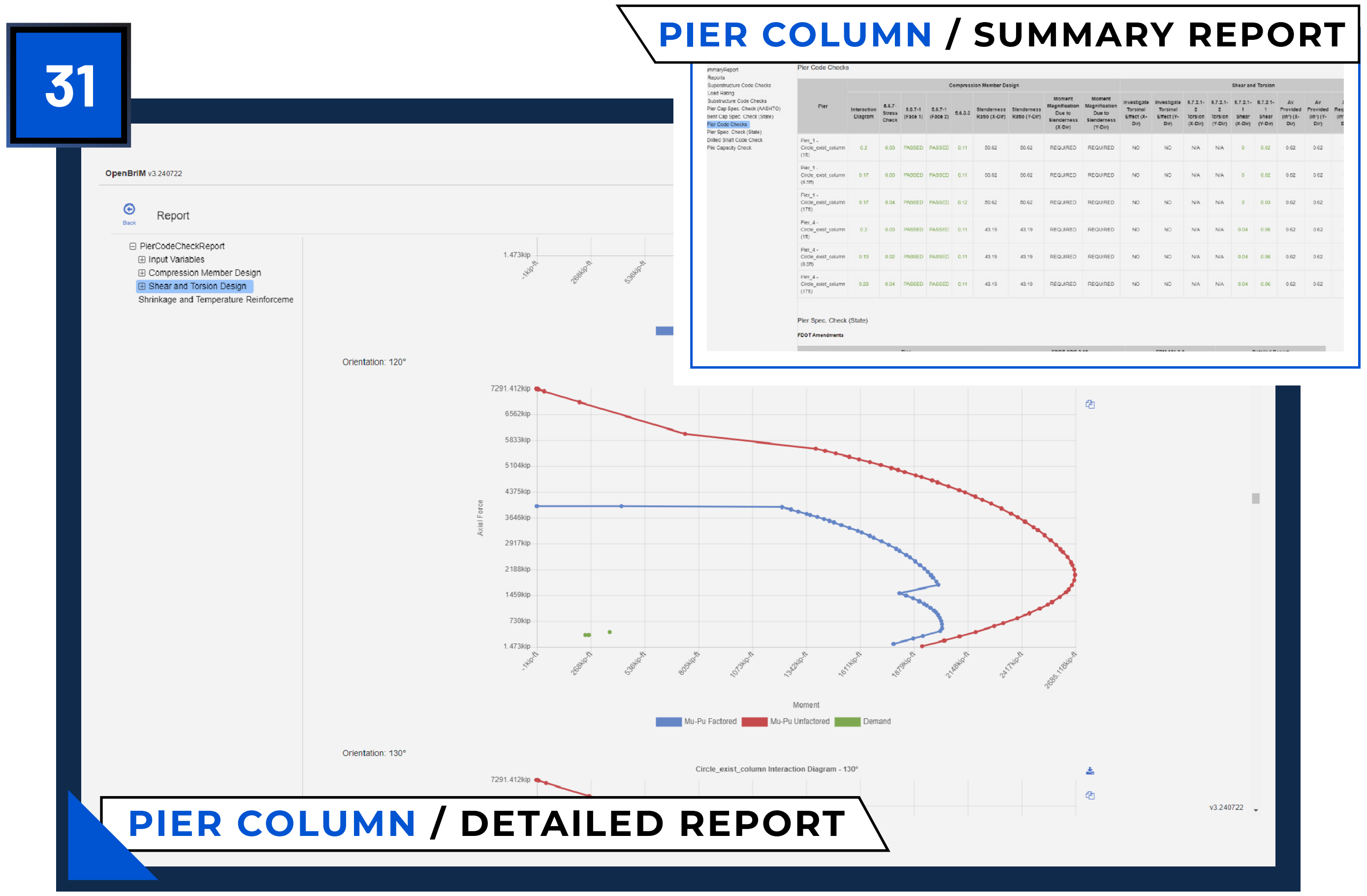

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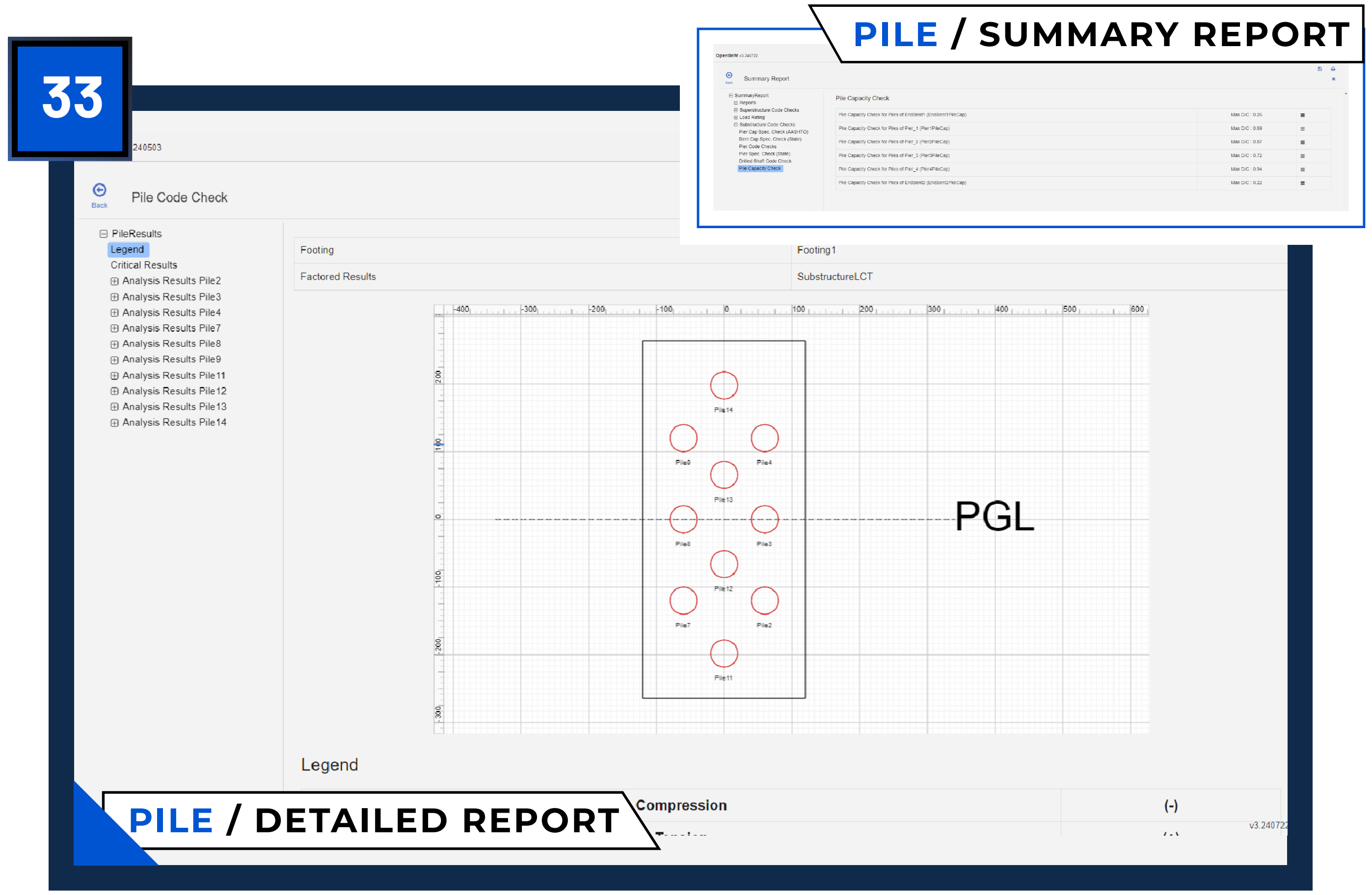
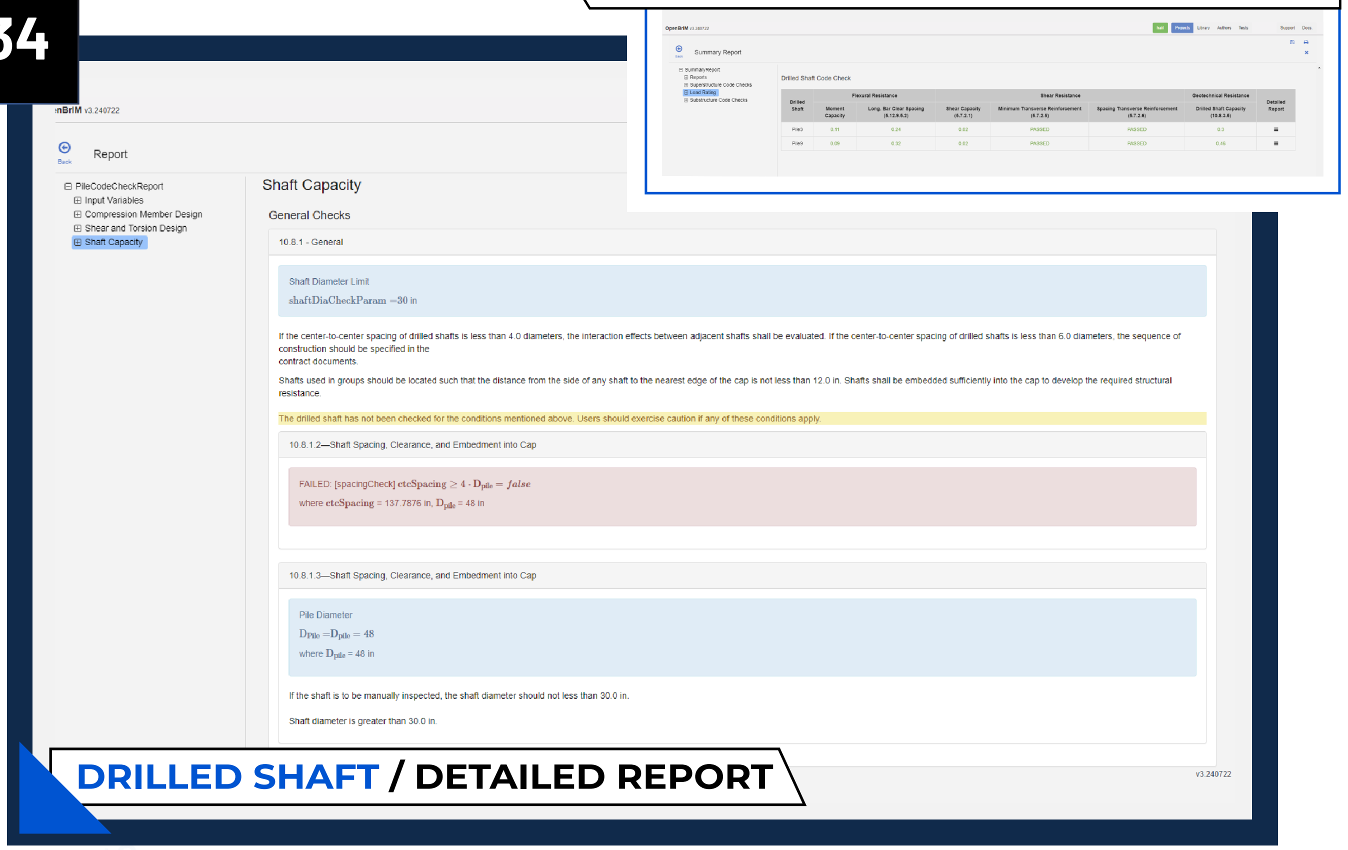


PARAMETRIC WORKFLOW

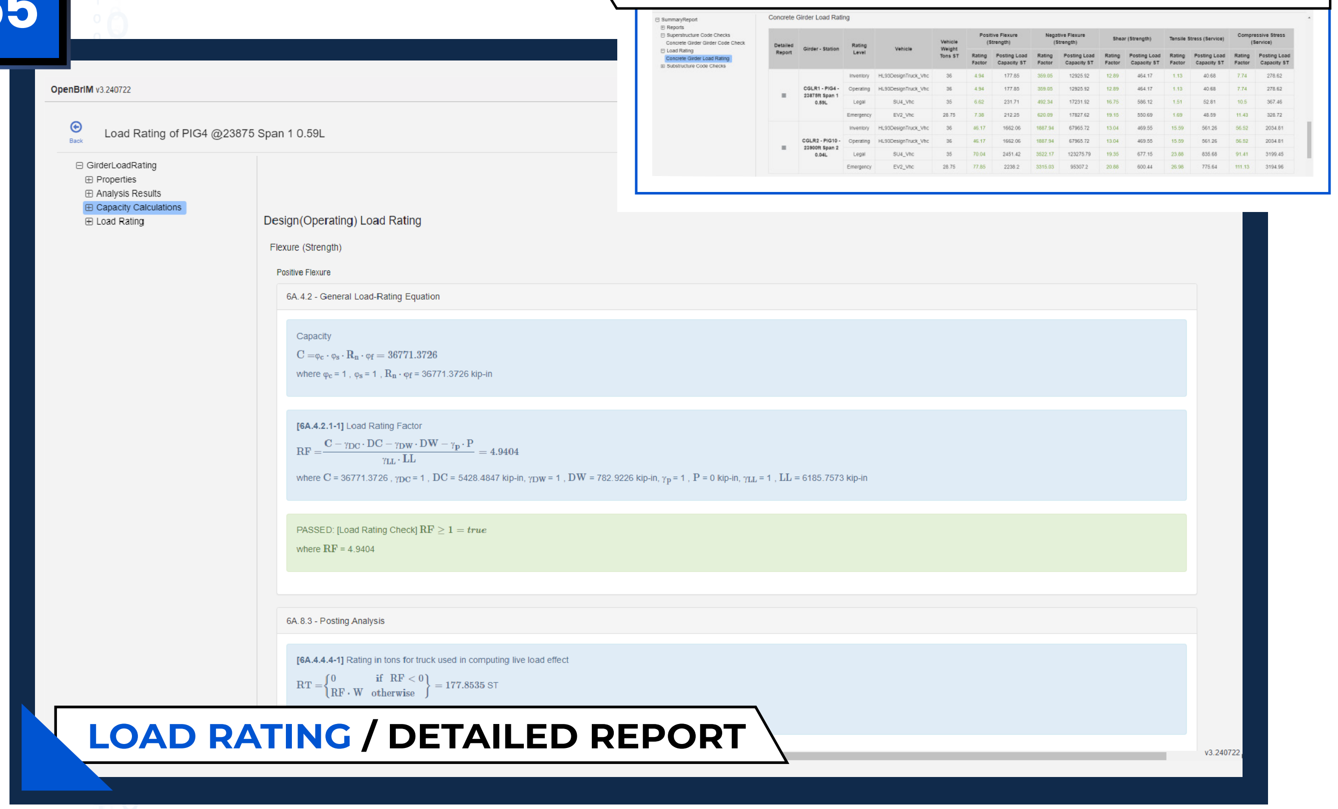
34



DRILLED SHAFT / SUMMARY REPORT

DRILLED SHAFT / DETAILED REPORT

35



LOAD RATING / SUMMARY REPORT

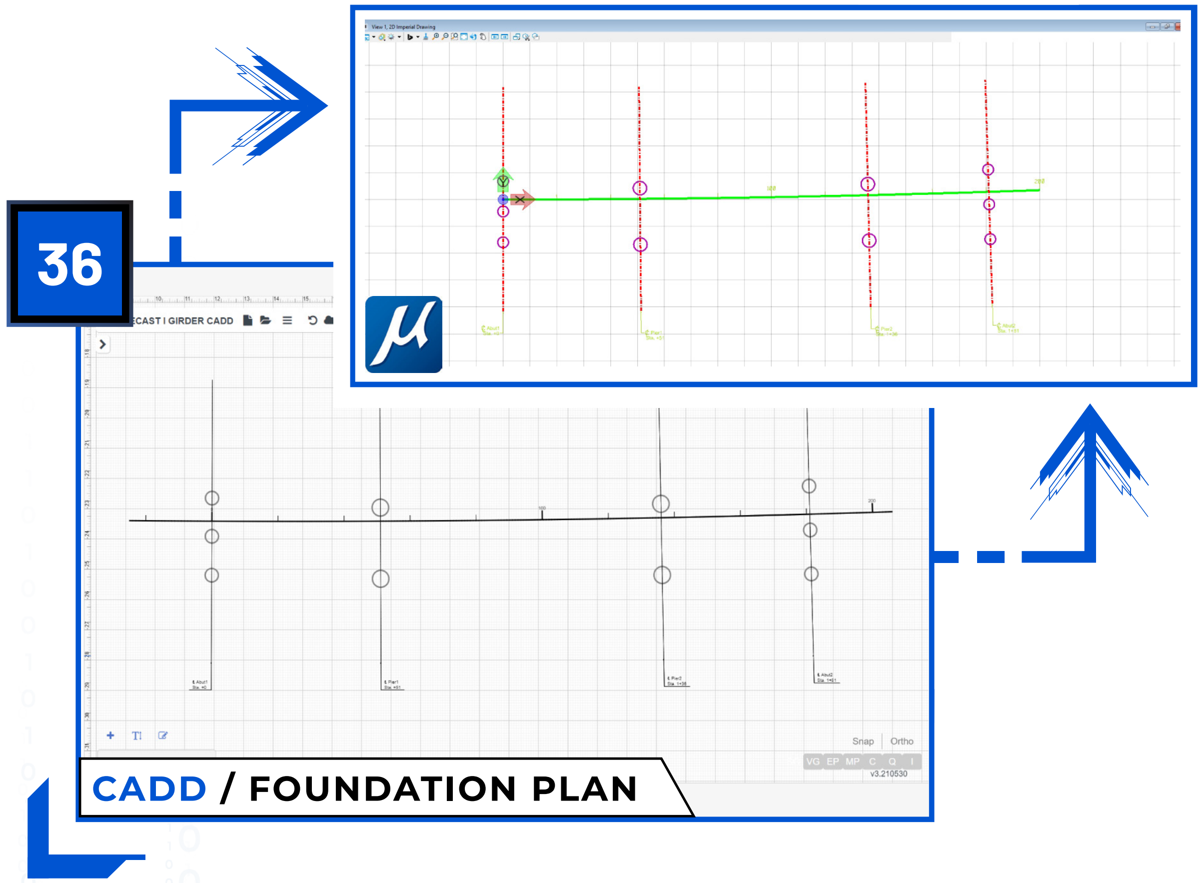
LOAD RATING / DETAILED REPORT

2D CADD

Experience the innovative approach of our 2D CAD library, which stands apart from conventional 3D modeling software. Unlike traditional tools that merely slice through 3D models to create sections, our advanced parametric method leverages metadata to generate 2D drawings with annotations. These drawings are meticulously crafted based on bridge parameters, seamlessly integrating both 2D sheets and 3D geometry. This unique approach empowers you to deliver 2D drawings precisely as they are, adhering to state standards, without the need to alter any standard for digital delivery or modify your 3D model.

With OpenBrIM, you gain diverse ways to visualize your data through 3D/2D drawings, reports, tables, graphs, and analytical models. At OpenBrIM, we believe in the enduring value of 2D drawings, which have been the standard and most effective method for visualizing information for the past 30 years. Our approach seamlessly blends the best of 2D and 3D technologies, allowing you to enhance your workflows while preserving proven practices.

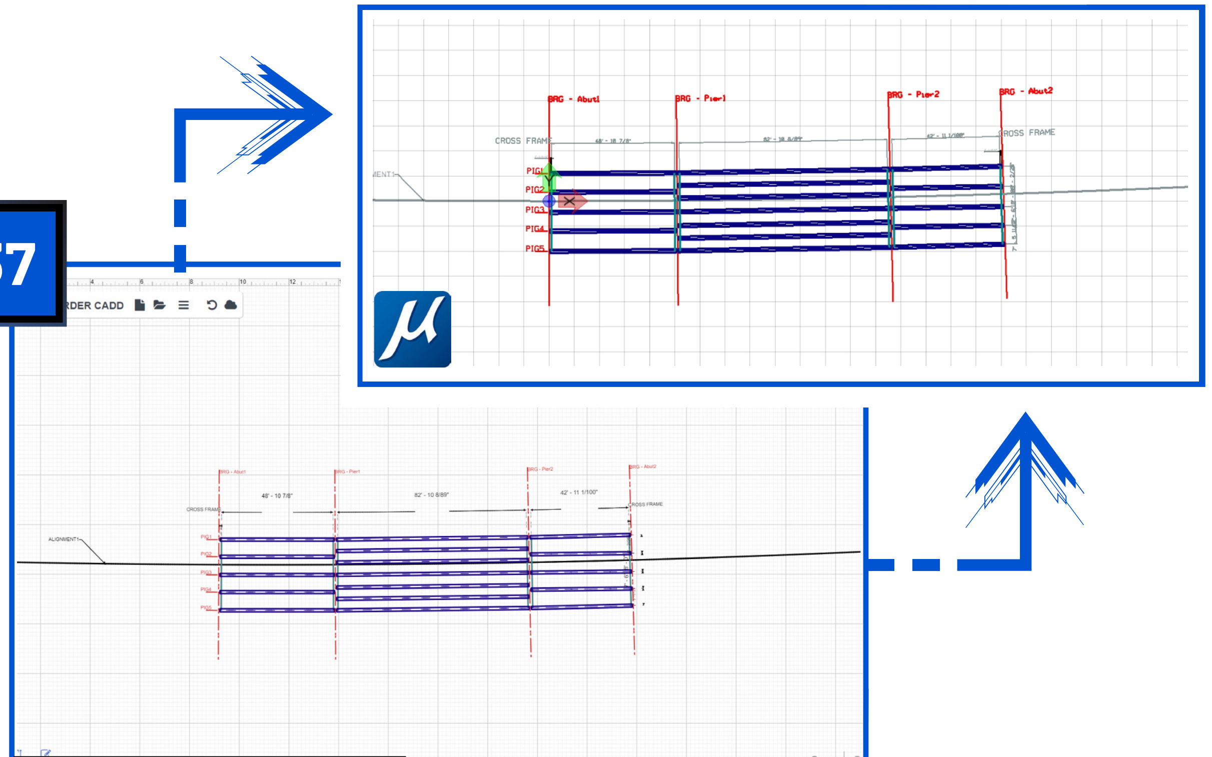
36



CADD / FOUNDATION PLAN

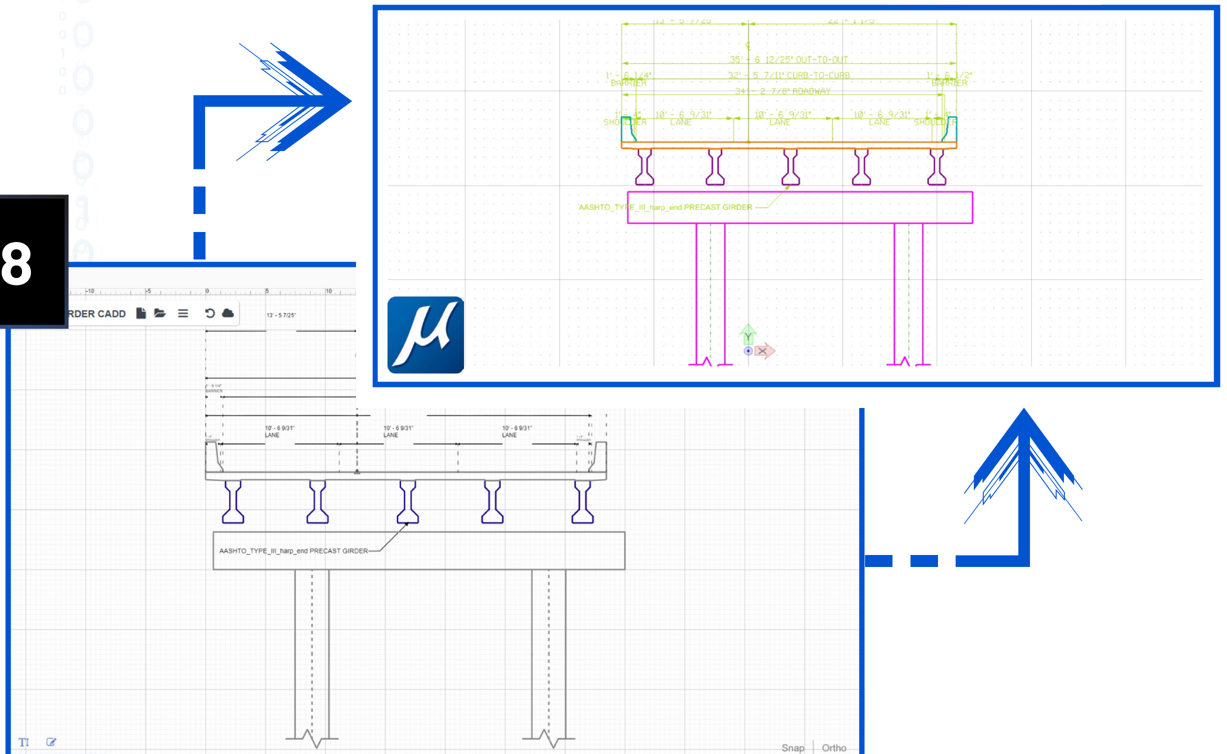
PARAMETRIC WORKFLOW

37



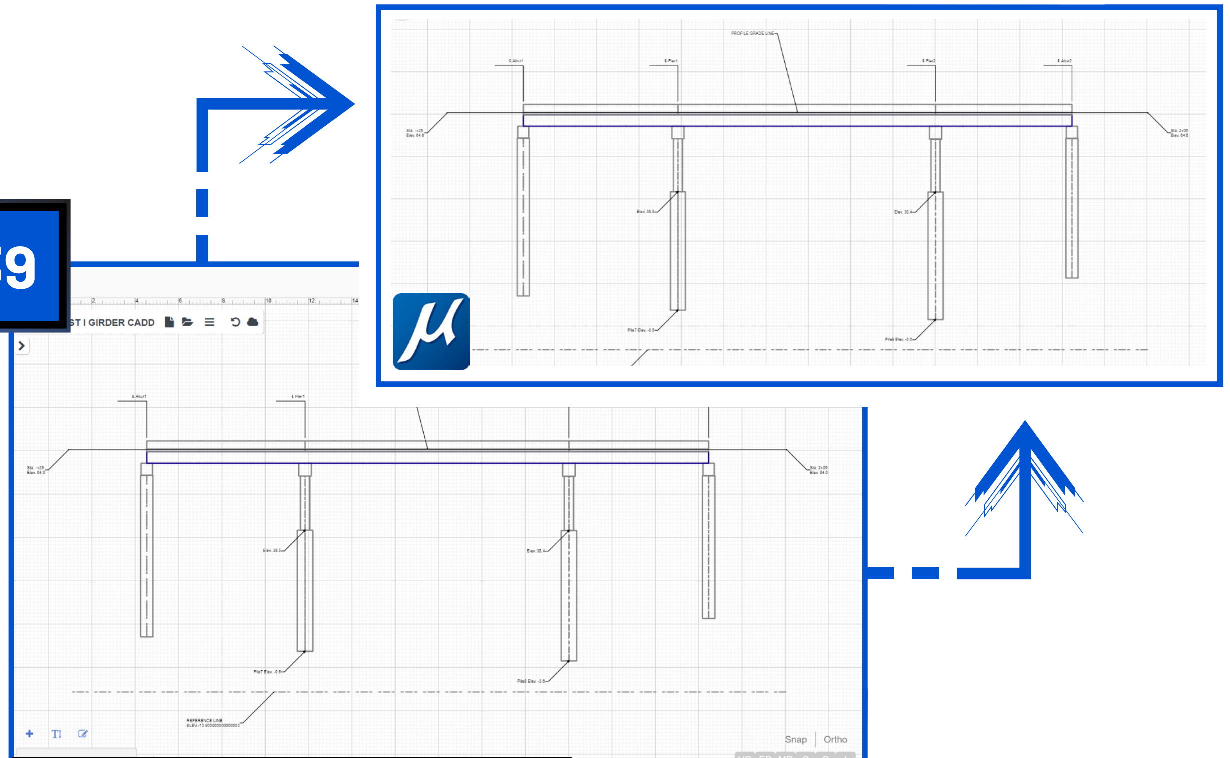
CADD / FRAMING

38



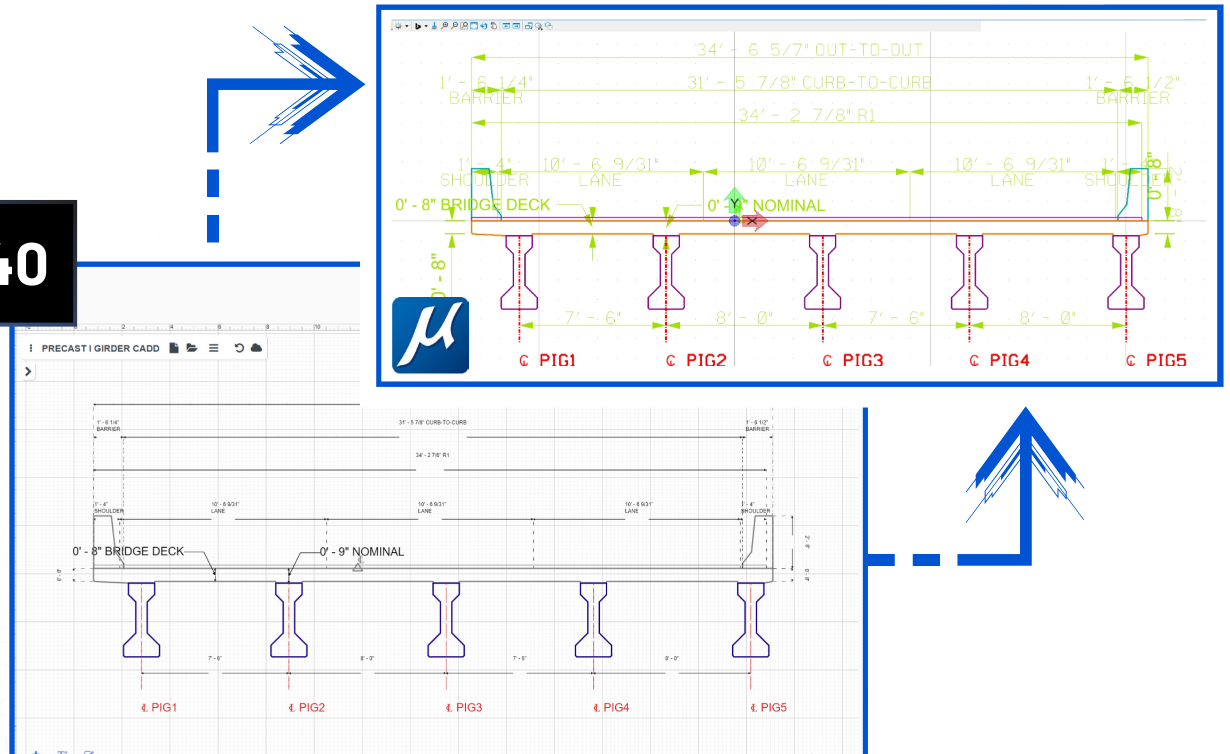
CADD / SUBSTRUCTURE

39



CADD / GIRDER ELEVATION

40



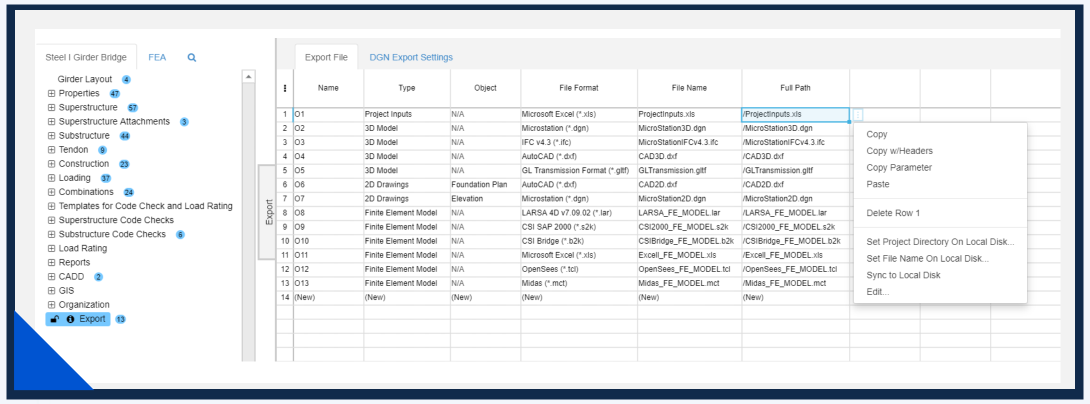
CADD / BRIDGE CROSS SECTION

45 INTEROPERABILITY / EXPORT

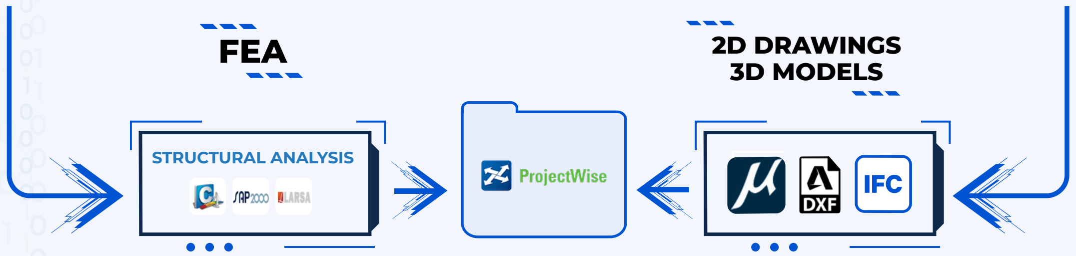
01 **Finite Element Analysis:** Export directly to leading engineering software like Larsa 4D, CSIBridge, and Midas Civil. OpenBrIM.FEA is well-suited for your projects and supports the features you will find in these software packages. Nevertheless, if your state requires one of these specific software packages, or if you simply want to verify that you are getting consistent results with OpenBrIM by comparing these results with your previous software packages, this export functionality can be immensely

02 **2D Drawing:** Convert your drawings into DGN and DXF formats. For DGN export, utilize the seed DGN files that are specifically generated for your project. This ensures the level of quality and standards required by your state.

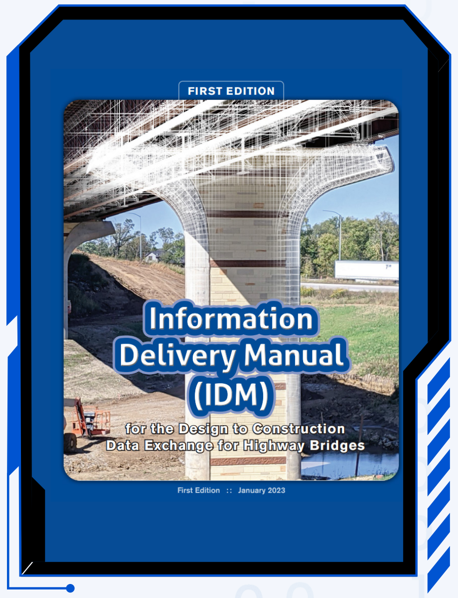
03 **3D Model:** Seamlessly export your 3D models in DGN, DXF and IFC formats. Export to i-Twin while retaining asset information, metadata, bid items, etc.

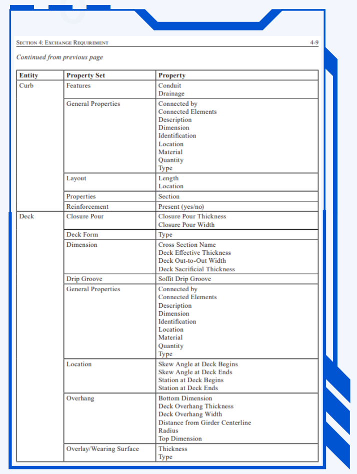


For efficient file management with OpenBrIM, it's recommended to select a dedicated ProjectWise folder for exporting your files. Once this relationship is established, you can easily keep your export files up to date by clicking the sync button after each parameter update, ensuring they are always current in your ProjectWise folder.

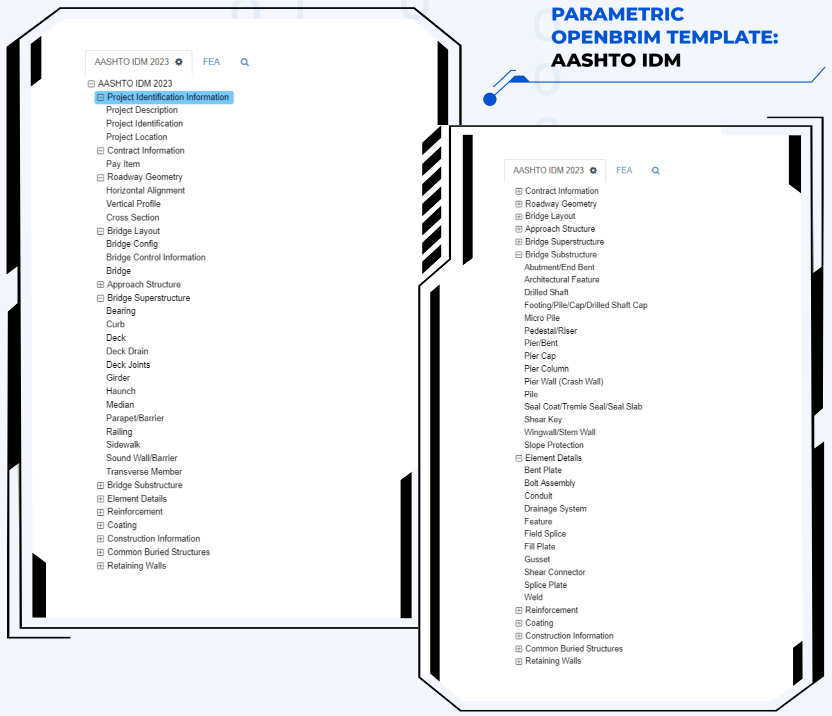


04 **Comply with Digital Delivery Requirements:** OpenBrIM supports IFC 4.3 export, ensuring compliance with all AASHTO IDM data exchange parameters. Once your model is ready in the OpenBrIM environment, simply click export to generate your IFC file seamlessly.





PARAMETRIC OPENBRIM TEMPLATE: AASHTO IDM



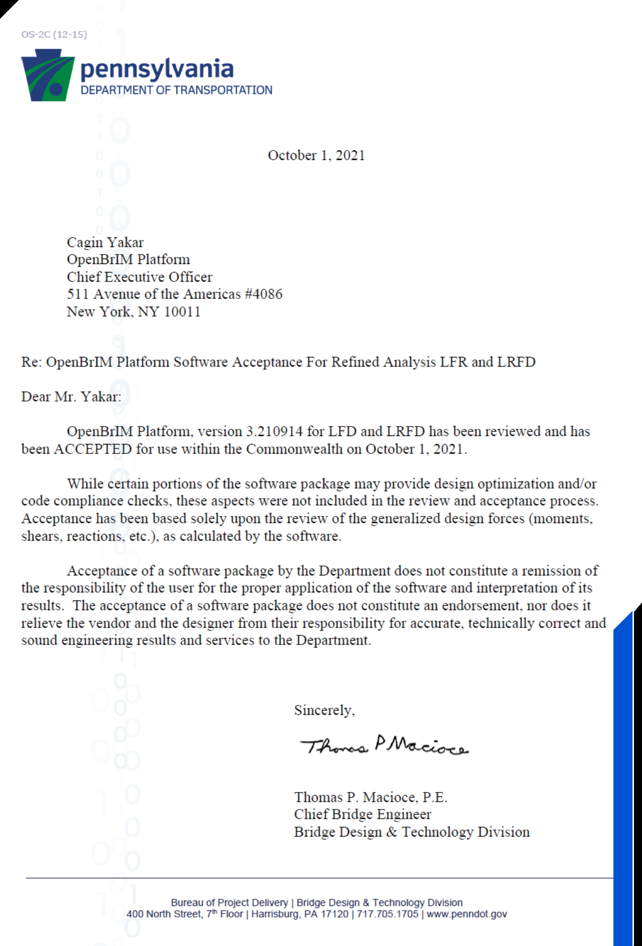
FINITE ELEMENT ANALYSIS

THE WORLD'S FIRST AND ONLY PARAMETRIC FINITE ELEMENT ANALYSIS ENGINE THAT RUNS IN YOUR BROWSER

OpenBrIM.FEA is a 100% cloud-based, cross-platform, high perfomance, 3D finite element simulation software specifically designed for the bridge engineering industry. It enables you to test, validate, and optimize your designs through Finite Element Analysis via a standard web browser.

OPENBRIM.FEA APPROVED BY PENNDOT

OpenBrIM.FEA was reviewed and accepted for use within the Commonwealth of Pennsylvania on October 1, 2021 for refined analysis to determine LFD and LFRD analysis and ratings.



OS-2C (12-15)

pennsylvania
DEPARTMENT OF TRANSPORTATION

October 1, 2021

Cagin Yakar
OpenBrIM Platform
Chief Executive Officer
511 Avenue of the Americas #4086
New York, NY 10011

Re: OpenBrIM Platform Software Acceptance For Refined Analysis LFR and LRFD

Dear Mr. Yakar:

OpenBrIM Platform, version 3.210914 for LFD and LRFD has been reviewed and has been ACCEPTED for use within the Commonwealth on October 1, 2021.

While certain portions of the software package may provide design optimization and/or code compliance checks, these aspects were not included in the review and acceptance process. Acceptance has been based solely upon the review of the generalized design forces (moments, shears, reactions, etc.), as calculated by the software.

Acceptance of a software package by the Department does not constitute a remission of the responsibility of the user for the proper application of the software and interpretation of its results. The acceptance of a software package does not constitute an endorsement, nor does it relieve the vendor and the designer from their responsibility for accurate, technically correct and sound engineering results and services to the Department.

Sincerely,

Thomas P Macioce

Thomas P. Macioce, P.E.
Chief Bridge Engineer
Bridge Design & Technology Division

Bureau of Project Delivery | Bridge Design & Technology Division
400 North Street, 7th Floor | Harrisburg, PA 17120 | 717.705.1705 | www.penndot.gov

OPENBRIM.FEA SUPPORTS WIDE VARIETY OF BRIDGES AND CONSTRUCTION ACTIVITIES

01 Staged Placement of Girders and Slabs for Continuous Structures

02 Span-by-span Erection of Segmental Bridges

03 Cast in-Situ Balanced Cantilever Bridge Construction

04 Balanced Cantilever Construction Precast Segmental Bridges

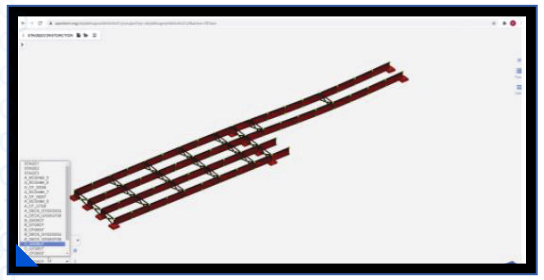
05 Incrementally Launched Bridges

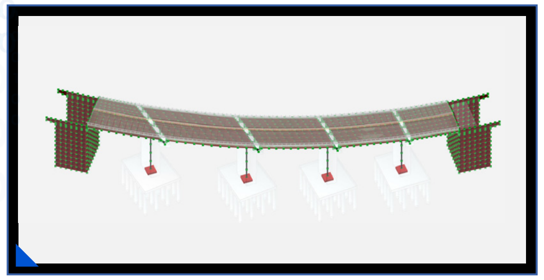
06 Erection of Cable-Stayed Bridges

07 Extradosed Bridges

08 Suspension Bridges

INTELLIGENT MESH NETWORK





Meshing is a challenging aspect of structural finite element modeling. Most meshing applications are either too complex, too slow, low quality, or not specifically suitable for the models commonly encountered in our industry. OpenBrIM.FEA comes with an AI-powered meshing network. You provide a set of mesh surface in your model and specify the desired refinement. OpenBrIM.FEA creates networks of surfaces throught connectivity and intersections. These surfaces then negotiate refinement and contraints. In the blink of an eye, they reach a consensus on the meshing scheme that will optimize the mesh quality of your overall mode.

IMPROVED FINITE ELEMENT FORMULATIONS

OpenBrIM.FEA features a wide range of finite element formulations supporting the lates developments and improvements in finite element research. The platform uses the most suitable finite element formulation based on the element's model utilization. It also provides the option of manually establishing the formulations:

- 1- Node: linear/non-linear stiffness, 6x6 stiffness matrix.
- 2-Node: Euler-Bernoulli, Timoshenko (Beam, Truss, Cable, Hinge)
- 3 or 4-Node: DK, MITC, ANDeS
- 6 or 8-Node: Incompatible Mode, Reduced Integration

FLEXIBLE LOADING CAPABILITIES

Creating complex loading patterns for structural analysis is a complex task. OpenBrIM.FEA provides a range of loading capabilities for efficiently handling a wide variety of scenarios.

01 Nodal and Element Loads
Forces and moments can be applied at each node or element. Element loads can be point, partial, or uniform.

02 Nodal Displacement Loads
Displacements can be applied at nodes, which would induce stress to the structure.

03 Temperature Loads
Uniform temperature, linear and nonlinear temperature variation is supported.

04 Prestressing Loads
Easy modeling through tendon templates, including 3D tendon detailing, support for pre-tension or post-tension, internal or external, and bonded or unbonded configurations.

05 Global Loads
Specify a point, line, or surface load in 3D space that is automatically distributed to the structure.

06 GPU Accelerated Wind Loads
Specify wind pressure and a range of attack angles, and OpenBrIM.FEA automatically distributes the load to elements.

07 Influence Surface Live Loads
Vehicle definitions, design lane definitions, and loading surfaces can all be included in a live load case which handles automatic placement of the design lanesto maximize live load effect on the structure.

For each model load case, active/inactive geometry can be specified separately, properties can be overridden, and project parameters can be changed.

FINITE ELEMENT ANALYSIS

POWERFUL ANALYSIS FEATURES

The OpenBrIM.FEA analysis engine is designed to handle everything from common problems to complex structures with large displacements. The engine has the analytical capabilities to produce the accurate results your project needs. Here is a list of supported analysis types:

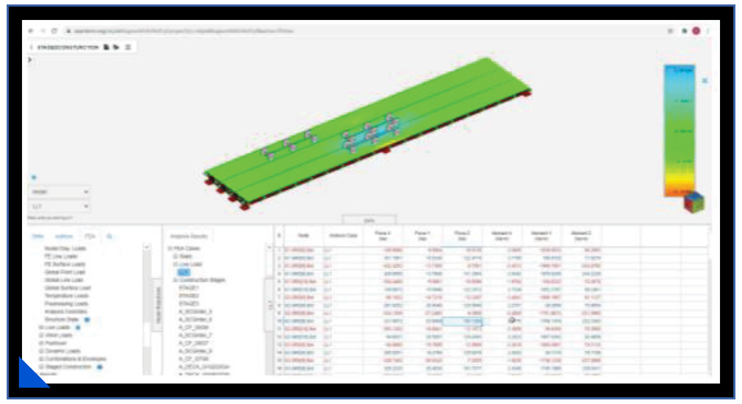
01 Linear/Nonlinear Static

02 Pushover/buckling

03 Full Eigenvalue or Ritz Method (LWYD, QSRV)

04 Response Spectra (CQC, SRSS)

05 Time-Dependent Stage Construction



Staged construction analysis is designed to handle complex construction scenarios. Each step of staged construction allows you to construct/remove geometry, modify properties (material, sectional, or shell thickness), change support conditions, add/remove loads, or customize analysis type (e.g., linear or nonlinear, pushover, or RSA). It even allows for multiple staged construction sequences in your model. You can fork from each step of the construction sequence to create another one to investigate various construction scenarios in one analysis run.

OpenBrIM.FEA reports nodal displacements, nodal reactions, element internal and external forces, and element stresses. In addition, it reports composite forces over structural components that are made up of multiple finite elements.

INTEROPERABILITY

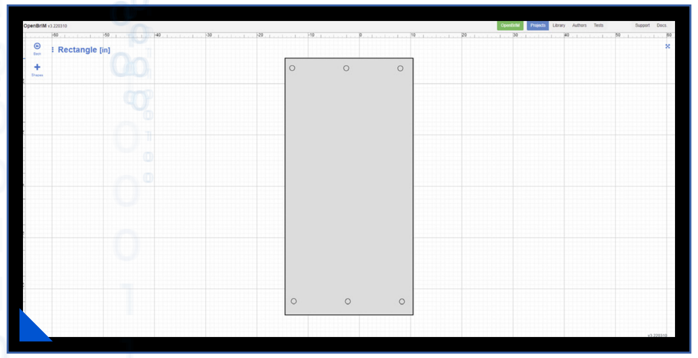
We realize that you have choices when it comes to structural analysis and design. Each application includes its own strengths and weaknesses. OpenBrIM.FEA acts as a hub for your structural model, allowing you to import/export from/to LARSA 4D, SAP 2000, and MIDAS. This means you can take your OpenBrIM model to another software or incorporate your external models into OpenBrIM.FEA with a single click.

OpenBrIM.Connect is a desktop application fully integrated with OpenBrIM.FEA. This allows you to run analysis on the supported applications directly from within OpenBrIM.FEA and compare results on the same screen.

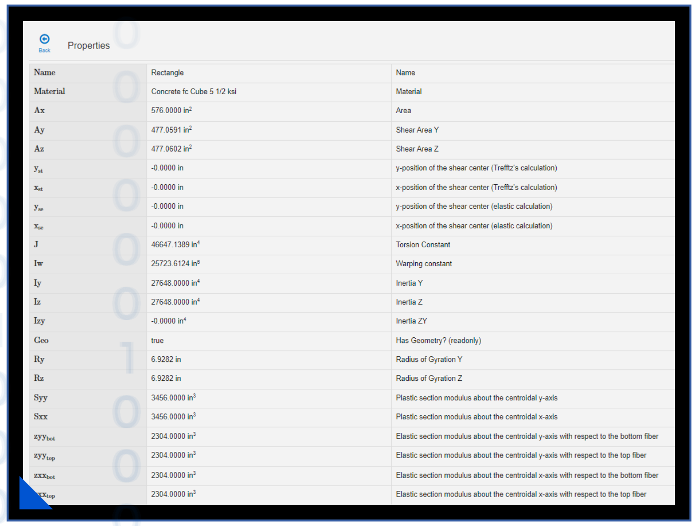
CROSS PLATFORM FEA: DEPLOYMENT AND MAINTENANCE

Built with OpenBrIM platform at its core, OpenBrIM.FEA requires no installation, no maintenance, and no backup. You can use your Windows or Mac machine or your tablet without any platform dependency. All you need is a browser to receive the full OpenBrIM.FEA experience on your mobile.

SECTION ANALYSIS & DESIGN



Not all problems require a full 3D model. Sometimes you may want to perform analysis and design on a single beam or column. You may even need to calculate the properties of a section with arbitrary geometry. OpenBrIM.Section, an integral part of OpenBrIM.FEA, is a powerful tool that handles section property calculations, section analysis, and beam/column analysis and design.



It can calculate shear areas, inertias, torsional constant, and warping constant properties, as well as perform moment capacity checks, create moment curvature curves and interaction diagrams, and support reinforced, prestressed, and composite arbitrary sections.

REAL-TIME VERIFICATION

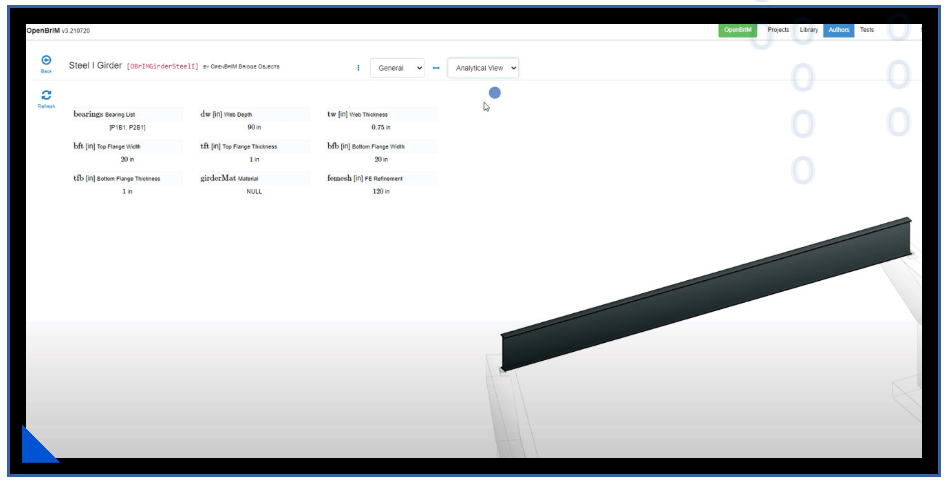
Trust is an important bond between an engineering software and its user. OpenBrIM.FEA includes a state-of-the-art verification system that helps you build this bond quickly and effortlessly. It contains hundreds of verification problems, some of which are contributed by users like you. Using the OpenBrIM Verification system, you can explore verification problems and run them in real time against the current version of OpenBrIM.FEA.

Contributing to the verification system is simple. Take an analyzed model and look at the results on spreadsheets. Find the number for which you have an expected reference value (by hand calculation or a previously designed and verified project). OpenBrIM.FEA allows you to attach that reference value to the reported result. This automatically adds that model to the verification system. At this point, there is a new version of OpenBrIM.FEA. You simply need to press a button on the verification system. OpenBrIM will run all your verification problems and, if detected, report any differences.

If you have OpenBrIM.Connect setup, you can use the verification system to verify new releases of externally connected applications.

PARAMETRIC LIBRARY

OpenBrIM Library provides definitions for all things engineering, such as decks, signs, and barriers, as well as traffic conditions, rules, and regulations. OpenBrIM library is where the new bridge community, the actual users of the information with the most knowledge regarding various bridge components, will develop new Standards.



LIBRARY CONCEPT

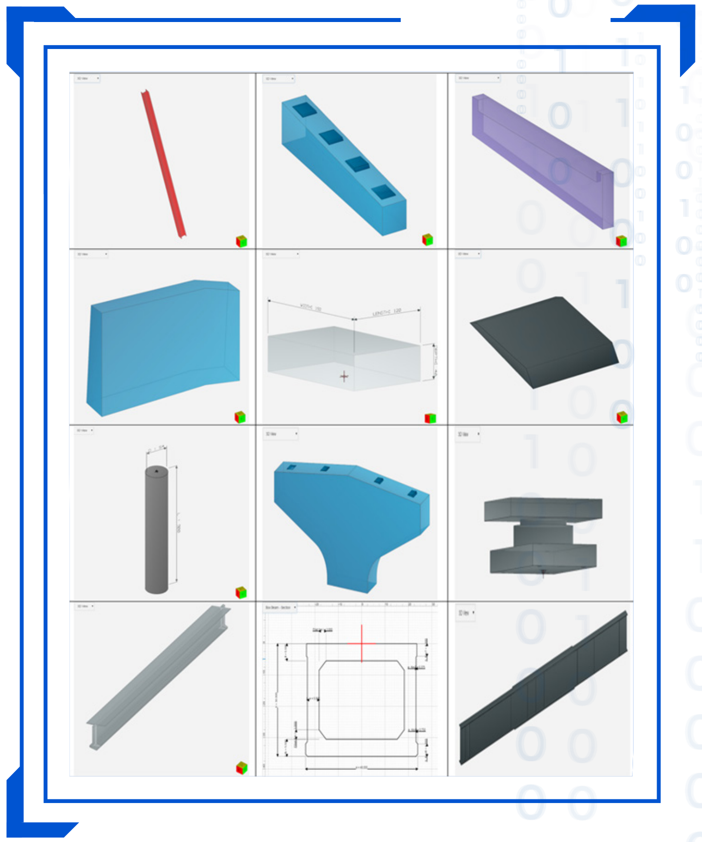
OpenBrIM Platform is built on a community-driven library concept capable of supporting a large community and providing the toolset to encourage collaboration. OpenBrIM.Incubator and OpenBrIM.Library are fully integrated engineering information development platforms.

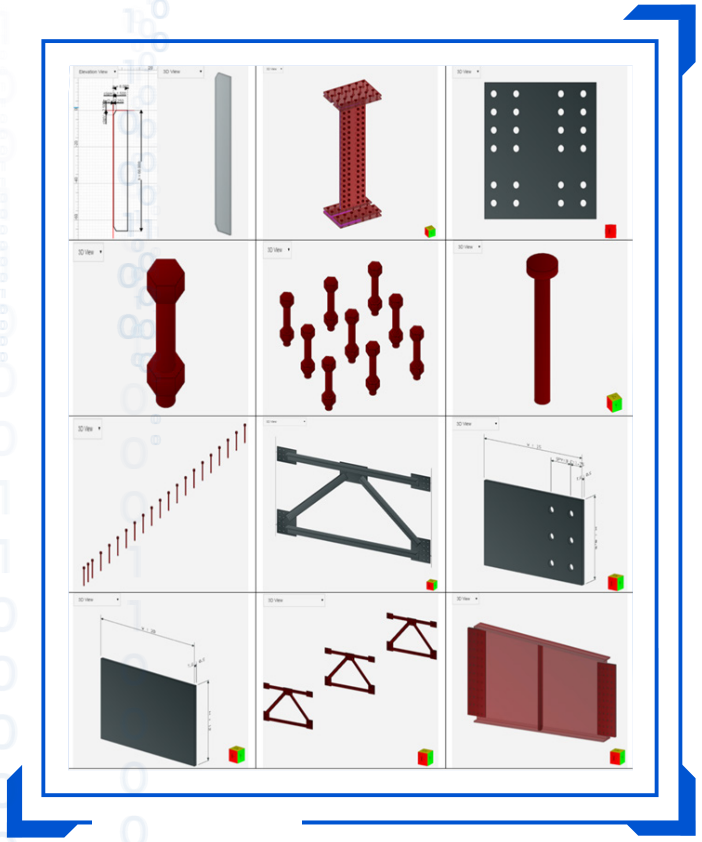
LIBRARY COMPONENTS

Bridge structures can be envisioned as a collection of individual components such as the deck, traffic barriers, girders and cross-frames, bearings, piers, and abutments. Any component or object can be developed into a standard bridge component by identifying the minimum data parameters necessary to completely define it. One simple example is a rectangular concrete footing, where three variables - width, length, and thickness - can be used to define the outline shape. Other non-geometric data can also be associated with the component, such as material type or date constructed. All of these parameters form the standard data required to define the component.

USE LIBRARY COMPONENTS TO CREATE A DIGITAL TWIN OF BRIDGES

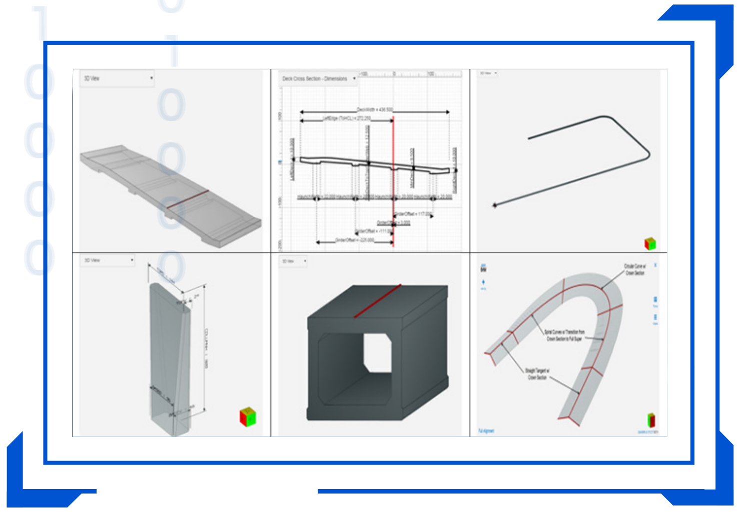
A complete bridge model is developed by integrating each of the individual standard components into an assembly. Hundreds of individual bridge component objects must be developed to properly account for the complexity of bridge models. The OpenBrIM Library application provides a home where these objects can be developed, organized, and hosted in an open and collaborative environment.





OPENBRIM.INCUBATOR

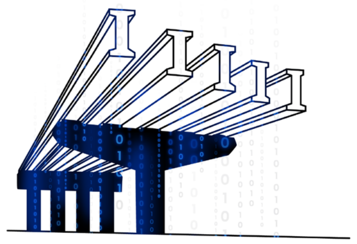
OpenBrIM.Incubator is a free and open environment that requires no licensing. Anyone can create an account and start creating content or using existing content on OpenBrIM Incubator. Any content created on OpenBrIM Incubator is immediately available to all OpenBrIM users under the author's (content owner's) name.



OPENBRIM.LIBRARY

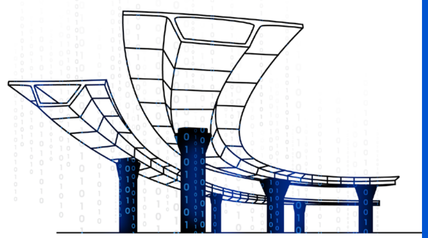
While OpenBrIM Incubator is open to everyone, OpenBrIM.Library is monitored and selected from incubator objects that have been verified and/or used extensively by the community.

PARAMETRIC **WORKFLOWS**



PRECAST I GIRDER CONCRETE BRIDGE

CONCRETE U GIRDER BRIDGE

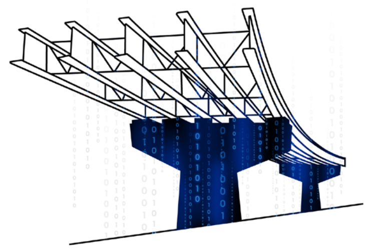


SEGMENTAL BRIDGE

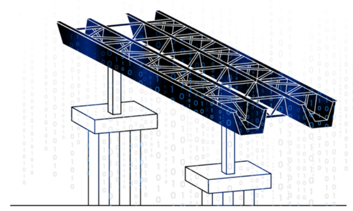
CABLE STAYED BRIDGE

SPLICED GIRDER BRIDGE

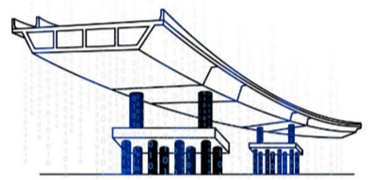
TRUSS BRIDGE



STEEL I GIRDER BRIDGE



STEEL TUB GIRDER BRIDGE



CONCRETE BOX GIRDER BRIDGE

SUSPENSION BRIDGE

INCREMENTALLY LAUNCHED BRIDGE

AND MORE